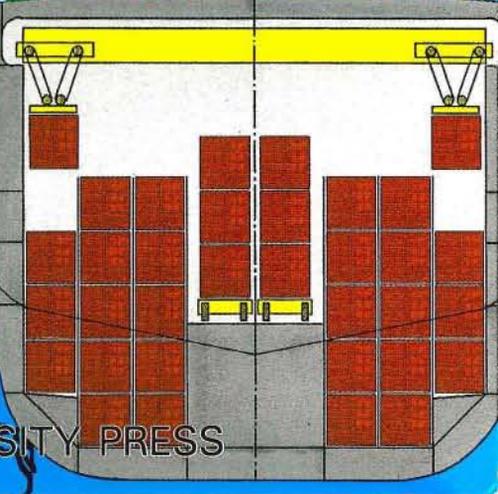
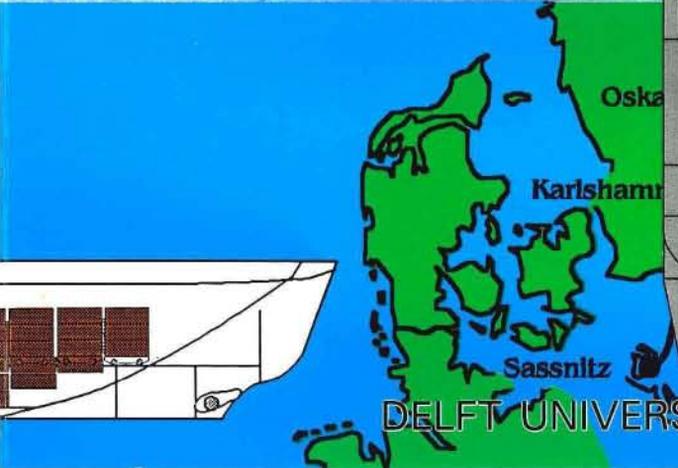


INNOVATION IN SHORTSEA SHIPPING: SELF-LOADING AND -UNLOADING UNITLOAD SHIPSYSTEMS

S-Curve shift in the handling of unitloads

Prof.dr.ir. N. Wijnolst
ir. H.B. van der Hoeven
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INTRODUCTION

Shortsea shipping should and can play a more important role in the logistical chain of unitloads within Europe. This was the rationale behind the 89th Roundtable Conference, organized by the ECMT in Paris, in September 1991. Göran Efraimsson of the Swedish consultancy company MariTerm AB handed out at this meeting a short description of an interesting coastal unitload shipping project, on which he and his team were working in Sweden. The project was financed by the Swedish Transport Research Board and identified as the major focus of future innovation a more efficient ship-terminal interface. I liked the results of this preliminary study and decided to put two engineering students of the Faculty of Marine Technology of the Delft University of Technology on this project in the framework of their master thesis work.

The Dutch Foundation for the Coordination of Maritime Research was willing to cover their out of pocket costs for travel to Sweden and in December 1991 we visited MariTerm in Gothenburg for the first time in order to define our part of the research. The two students, Ben van der Hoeven and Coert Kleijwegt, graduated in May 1993 after extensive work, both in Sweden and in Delft.

Parallel to their work, Anders Sjöbris of MariTerm was deeply involved in the "Automated coastal shipping project" which resulted in a report, titled "Coastal and ShortSea Shipping; Technical Feasibility Study", September 1993. The most relevant part of this report, the conveyor-elevator ship design, is also included in the book.

The results of both studies are quite positive and promising, and therefore we have asked the Swedish Transport Research Board, The Dutch Foundation for the Coordination of Maritime Research and The European Commission, DG-7 Transport to sponsor a follow-up study.

If shipping has to become competitive in comparison to land transport, fundamental innovation in the ship-terminal system of unitloads has to take place. This book draws an indepth picture of all the relevant issues the researchers in this field have to address.

The objective for the present book is not to develop new technological knowledge, but rather the diffusion of the innovative ship-terminal concepts and their rationale.

DIFFUSION OF INNOVATION IN SHIPPING

The acceptance of the container in the maritime industry is an unparalleled example of high speed innovation adoption by hundreds of different players in many segments of transport.

The perceived attributes of the innovation corresponded and coincided with the tremendous increase in cost around the word of liner shipping and stevedoring.

Introduction

There was no alternative for deepsea liner shipping, as is not the case in short-sea shipping. The alternatives of shortsea shipping are foremostly road and railtransport. As the cost increases in these other modes have been very modest over the last decades, there has not been a strong incentive to change all this.

"Selling" the self-loading and unloading ship concepts of unitloads, which is the central theme of the book, does not have the benefit of spiralling costs, which influence major shippers and receivers. Although, this may change in the coming decade. Environmental and social costs will more and more be charged to each mode.

If small ports want to become a part of a coastal/shortsea unitload shipping system, this will not happen by itself. The authors believe that a system can be developed with similar impact as the introduction of the container thirty years ago. The technology can be developed, that is not the issue.

Shortsea shipping can and should compete more effectively against road and rail transport. This can be achieved by looking at the total transport chain and not only the hardware of ships and terminals but also the software of VTS, EDI etcetera.

This book is not about the technology of a selfloading and unloading ship system, but about the constraints and conditions under which shortsea shipping can compete against other modes, on the level of transit time, frequency of departure, quality of service and of course, in price. The environmental benefits will be treated "pro-memorie" in spite of their magnitude.

The authors wish to communicate the transport concept of a competitive short-sea shipping system to their peers around Europe. We wish to inform the shipowners, terminal operators, shippers, transport companies, governments, consultants, universities, politicians on the essence of such a system.

Therefore we have chosen the route of dissimulation of the information through the publication of a book, accompanied by a video presentation. A "roadshow" through countries in north-west Europe will accompany this diffusion-drive.

We intend to raise the awareness of the system with potential decision makers, and ultimately to obtain their support. Not for personal gain, but as the only way to avoid an unparalleled congestion in Europe. So, give it some of your valuable time and give us feedback.

If you wish to comment on this book, please, do not hesitate to do so. You can direct it to either of us:

ir. Anders Sjöbris

MariTerm AB,

Visiting address:

Banehagsgaten 1P

Gothenburg, Sweden

Phone 46-31-122030

Fax. 46-31-245856

Mailing address:

PO. Box 12037

S-402 41 Gothenburg, Sweden

Prof. dr. ir. Niko Wijnolst

Visiting address:

Faculty of Mechanical Engineering and Marine Technology

Mekelweg 2

2628 CD Delft, The Netherlands

Phone 31-15-784682

Fax 31-15-620620

Mailing address:

Borodinlaan 5

3055 KC Rotterdam, The Netherlands

PART I - INNOVATION IN SHIPPING

CHAPTER 1: INNOVATION PROCESS

Shortsea shipping plays a vital role in the international movement of passengers and goods. Especially within Europe its importance in number of passengers and tons of goods is impressive as various studies have shown. Therefore the objective of this book is not to show its importance, but to explain the constraints posed on an even larger role. Changing the modal split in favour of an environmentally friendly sector like shipping is the challenge addressed in this report.

Technological innovation is the key-word to achieve this.

In **Part I** the process of innovation in shipping is described and mechanisms behind it analysed. This excursion in innovation is necessary in order to understand the examples of innovative developments in shortsea shipping as presented in the report.

In order to avoid confusion about the terminology, the following definitions are used:

- * an **invention** is the prospective useful idea of how science and technology can be combined or extended in a new way
- * an **innovation** occurs when the invention is turned into an economically successful use
- * **diffusion** is the spread of the innovation among its potential users

Innovations are subdivided into **basic** or concept innovations and **improvement** innovations.

Examples of basic innovations are container ships, roll-on/roll-off ships, pure care carriers, chemical tankers, reeferships, supertankers, bulk carriers, heavy lift ships, etcetera.

Examples of improvement innovations are: the bulb, reaction fins, SPC antifouling, shaft generator, contra rotating propellers, shipboard cranes, folding hatchcovers, unmanned machine rooms, etcetera.

There are several basic conditions which have to be fulfilled before innovation can occur:

- * market demand for the innovation
- * availability of technology to meet the market demand
- * financial means to combine the above two factors, and an opportunist who hopes to cash in on the commercialisation/diffusion of the innovation
- * a creative, technologically educated entrepreneur who can combine the above three factors into a commercial application

Part I: Innovation in Shipping

In general the shipowner who is close to the market place, is at the conception of basic innovations in shipping, and the shipbuilder or marine equipment manufacturers develop the improvement innovations.

There are of course many other actors who initiate change in the shipping system, such as shipbrokers, consultants, classification societies, shippers, receivers, etcetera.

Innovation is generally triggered by a constraint or limit in the shipping system. A useful conceptual tool to analyse constraints or limits is the S-curve.

S-CURVE THEORY

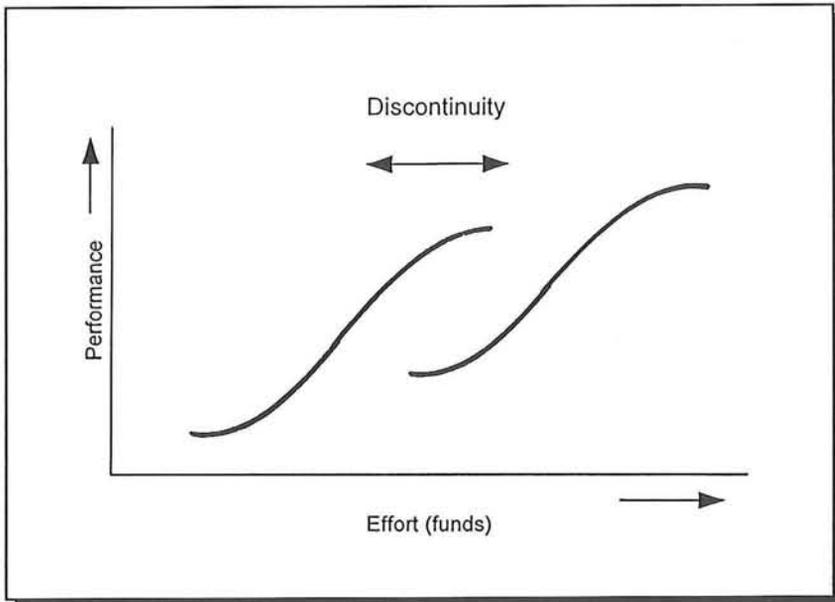


Figure 1

The S-curve is a graph (Figure 1) of the relationship between the effort put into improving a product or process and the results achieved by that investment. Initially, as funds are put into developing a new product or process, progress is very slow. Then, suddenly development goes very fast and gradually it levels off, when the scope for further improvement of the technological process reduces.

Some companies continue to invest heavily in the existing technology, with relatively little return on investment. Others, the innovative ones, look for a radical new technology, though still undeveloped, which might eventually outperform the current one. The original S-curve is replaced by another, which represents a sort of discontinuity.

EXAMPLES FROM THE REAL WORLD

A theory like the S-curve feels intuitively right, as it looks like the product-life-cycle. However, there is an important difference. The product-lifecycle has "time" on the horizontal axis, while the S-curve has "effort". The vertical axis also differs; the product-life cycle has volume and the S-curve performance. If we go beyond the intuition, the real world offers plenty of examples which substantiate the theory. A number of examples will illustrate this.

Figure 2 shows the development of the gasturbines as a function of time and material applied. The sequence of conventional alloys, via super alloys to ceramic materials is logical, as the performance of the gasturbine is linked to the combustion temperature. Ceramic materials allow high temperatures and therefore high performances.

Figure 3 shows similar graphs for jet engines.

Figure 4 shows the S-curve development of fibres, from cotton via rayon, nylon to polyester. **Figure 5** shows an equally dramatic change in cash registers. The market leader NCR lost 80 percent of the market share of electromechanical cash registers in four years to producers of the new electronic cash registers, with a superior performance.

Figure 6 shows the consumption of tires in the USA. The radial tire took a long time to gain market share, as the technology had to be developed. Then in less than 18 months, the bias-ply tire manufacturers lost 50 percent of their market to radials, as a result of the superior performance.

Figure 7 shows the development in lamps. The output of the traditional light bulb did not improve over the last forty years, inspite of research. A significant performance increase required a change of technology as the graph illustrates.

Figure 8 shows a similar development for batteries.

The dramatic change from vacuum tubes via transistors, semi-conductors, integrated circuits and chips is fuelled by new technologies that can harness the atomic world. This quest for the smallest circuit is clearly illustrated in **Figure 9** and is not likely to come to an end soon. These eight examples demonstrate the continuous search for performance-improvements, and the necessity to change techology to achieve this.

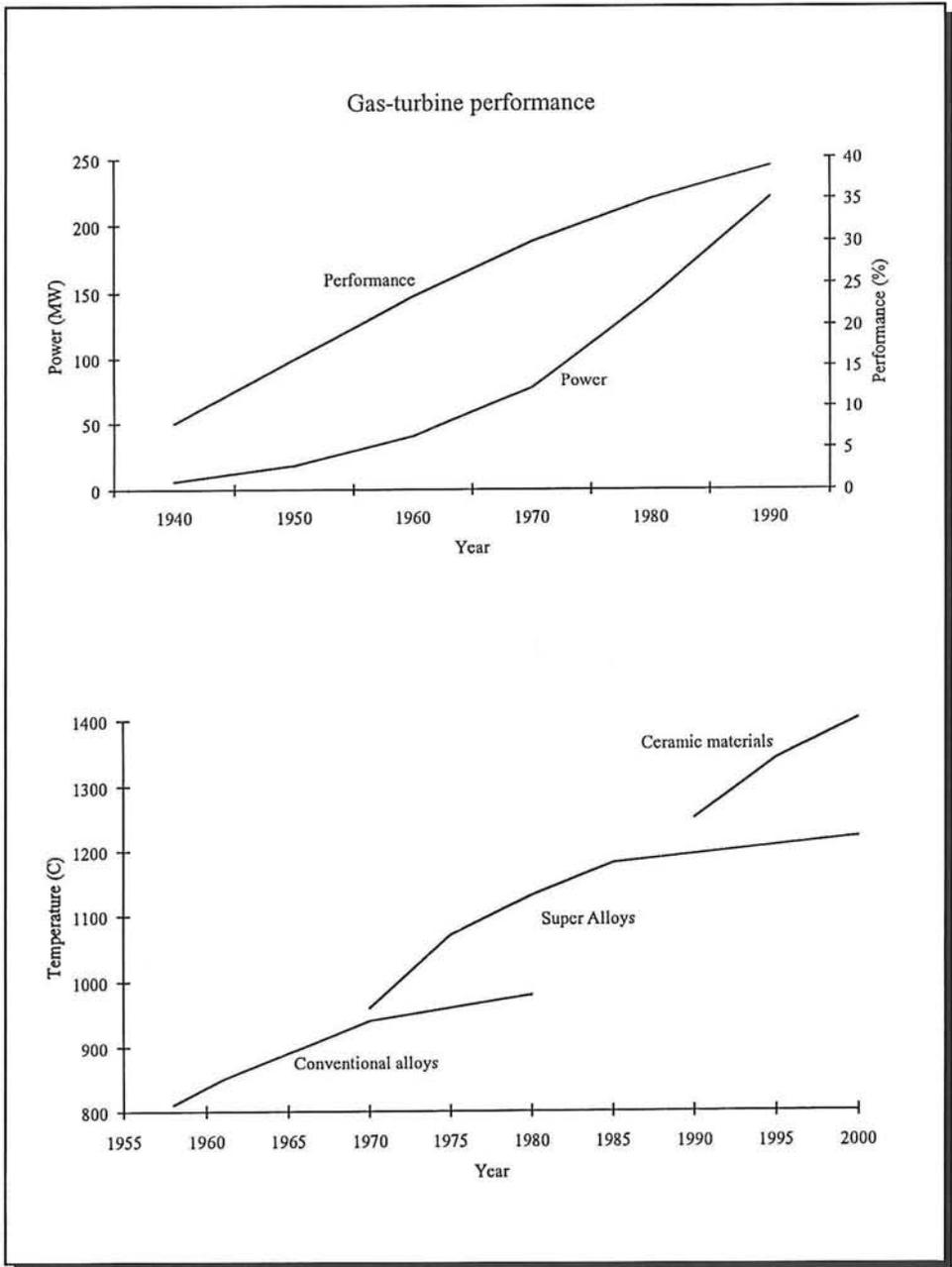


Figure 2

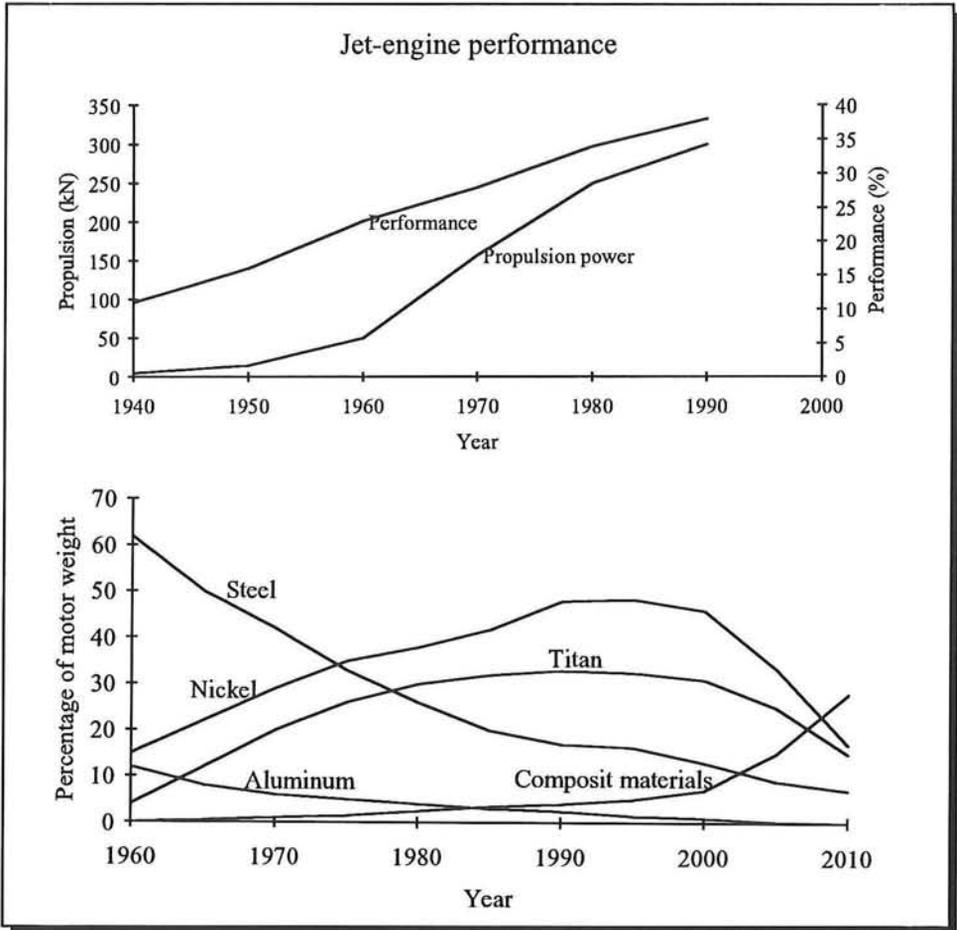


Figure 3

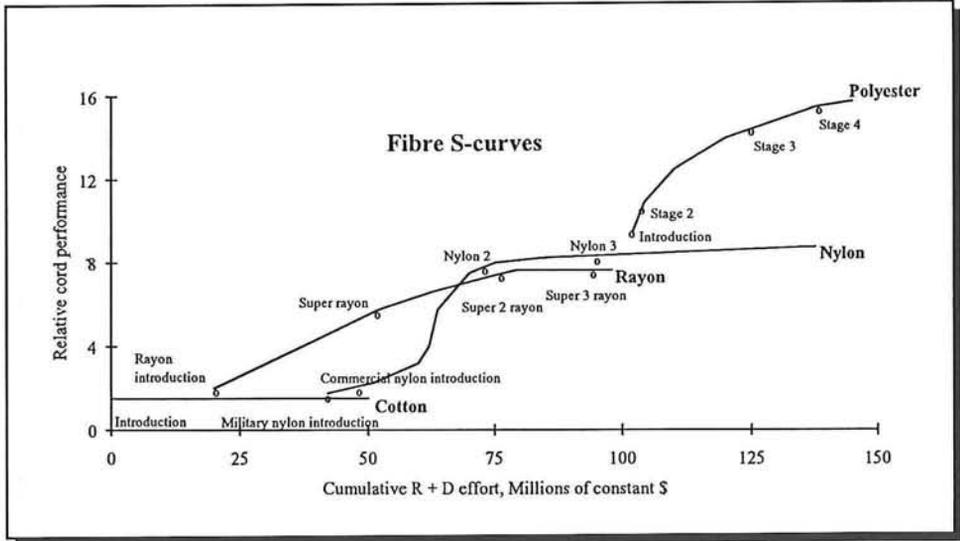


Figure 4

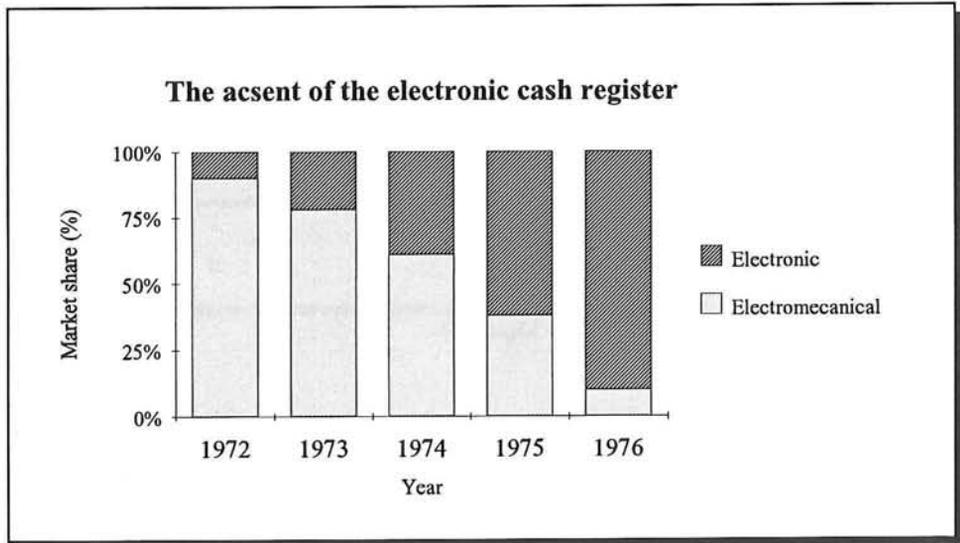


Figure 5

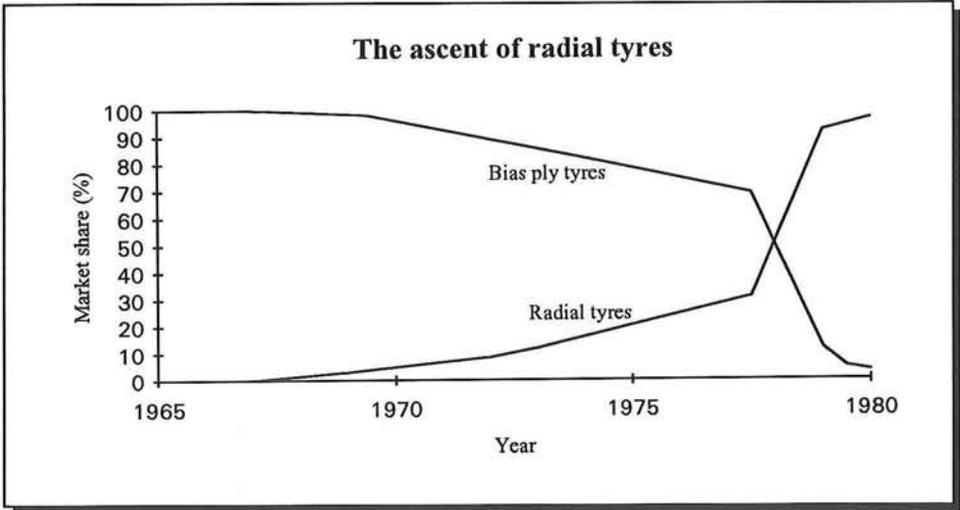


Figure 6

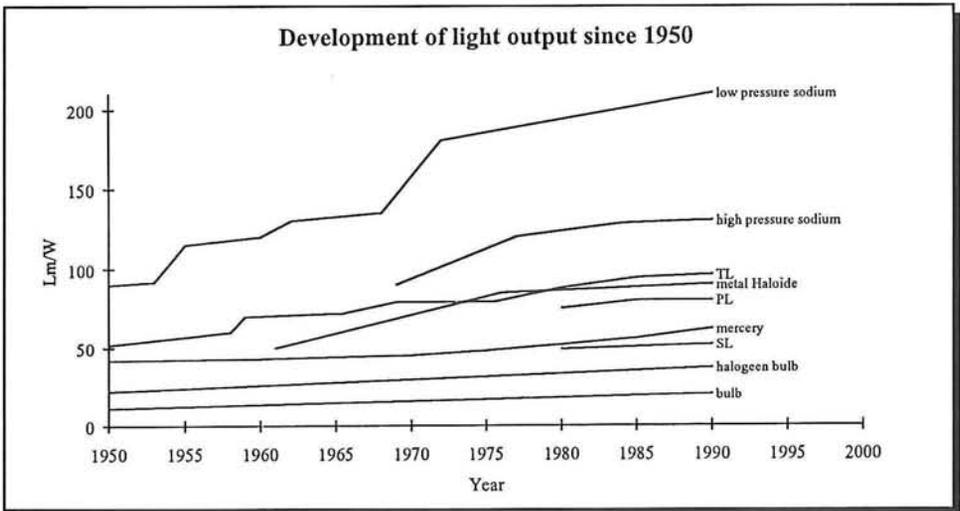


Figure 7

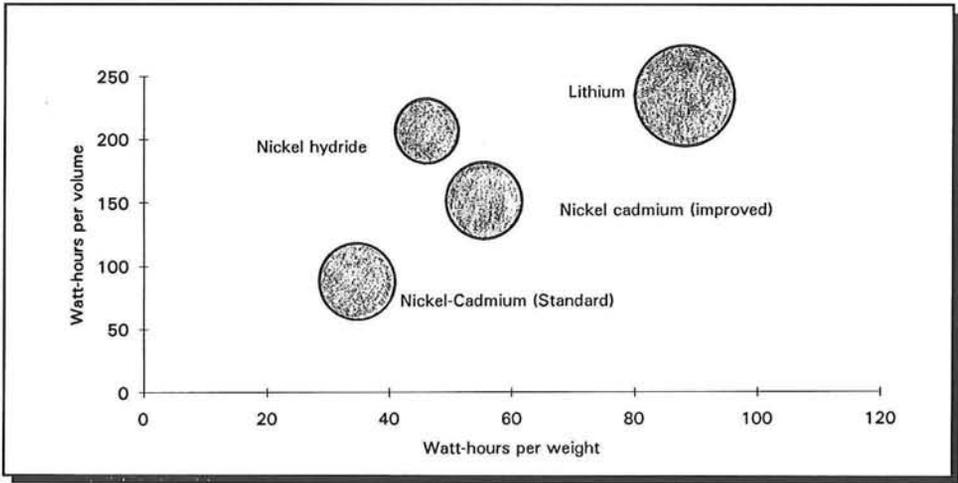


Figure 8

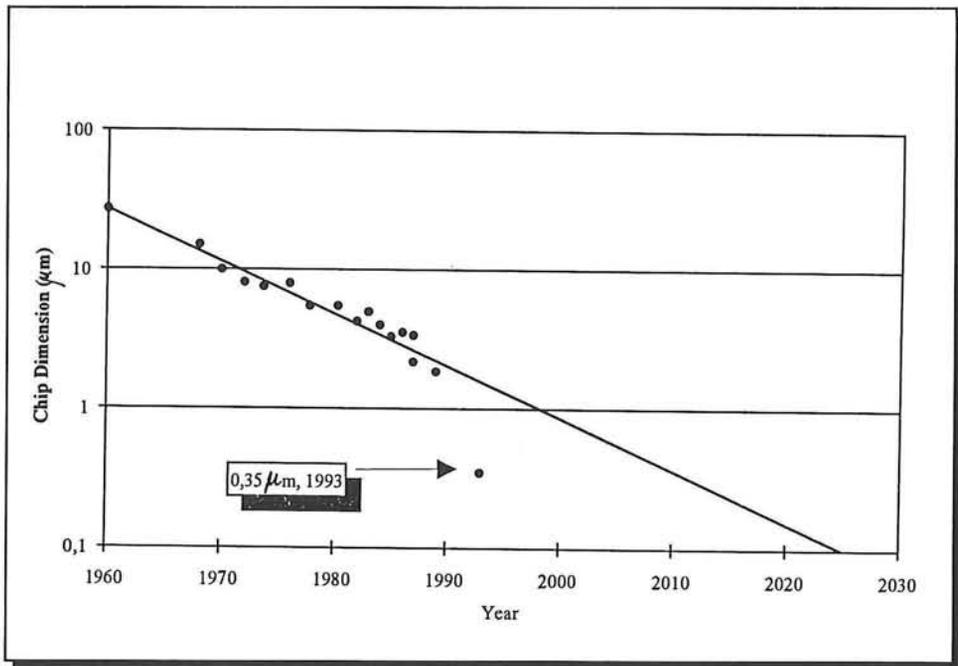


Figure 9

CHAPTER 2: INNOVATION S-CURVE AND SHIPPING

The previous examples are all drawn from the non-shipping sector. This paragraph describes in brief two important periods of S-curve change in shipping. The first period covering one century of fundamental change from the advent of the steamship to the development of the diesel-motorships. The second period of half a century covering the change from general cargo ships up to the hatchless containerships.

This is not a book on the history of shipping, however it is important to understand the reasons behind fundamental change, in order to understand future change. And that is where this introduction will end; with a conceptual model to understand and anticipate change in shipping, in particular shortsea shipping.

SAIL-STEAM-DIESEL CURVES

The first application of steampower to a vessel took place in France, England and the U.S.A. simultaneously at the end of the 18th century. The experimental model was further developed in England, where it resulted around 1820 in the paddle steamer (Figure 10). The ship often used sails and steam for propulsion. The first deepsea liner service between the UK and the USA (1840) shipped mail. As the voluminous coal bunkers allowed for little payload, the diffusion of the paddle steamer in shipping remained limited, with the exception of coastal and river shipping.

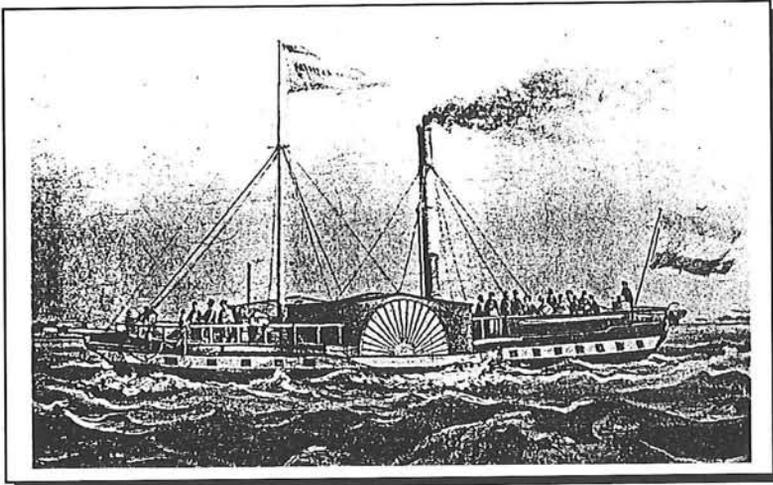


Figure 10

Part I: Innovation in Shipping

Around 1830 F.P. Smith invented the Archimedes propellor (Figure 11) which was linked to a steamengine. However, the wooden ships were too narrow at the stern to accommodate the large powerplant. Therefore steel was introduced in the construction around 1850 in order to be able to build large, wide vessels. Again, coal bunkers took up a lot of deadweight capacity.

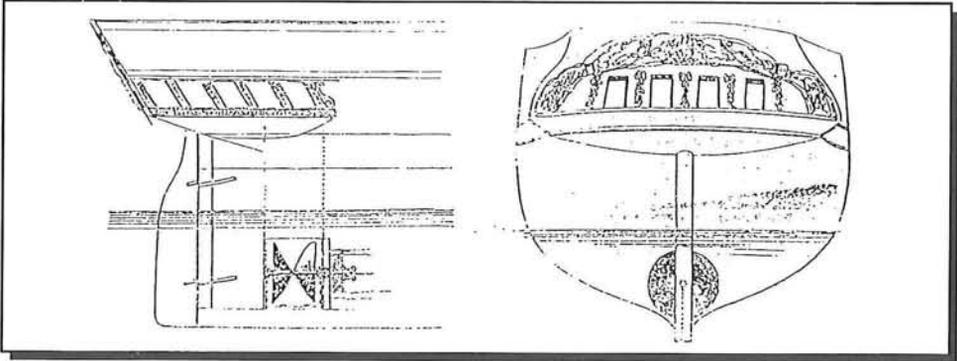


Figure 11

In the meantime the traditional shipowners, who were sceptical about the introduction of steampower, developed fast and efficient sailing ships, like the clipper. The S-curve of speed by sailing vessels (wood and steel) is shown in Figure 12.

Ultimately they developed a ship, called "The Thomas W. Lawson", with seven masts, which capsized while at anchor in 1907 and marked the end of the sailing era (Figure 13).

The process of change from sail to steampower was accelerated by the opening of the Suez-canal in 1869. Sailing ships could not use this long canal and had to make the long journey around South Africa to reach the Far East.

The steamships were perfected in design from 1870-1910 and replaced almost entirely the sailing ships. The last drawback of the steamship, its voluminous need for coalbunkers, was eliminated by the invention of the diesel-engine in 1892. The first marine application took place on the Danish ship, the Selandia in 1912 (Figure 14). It marked the beginning of our modern day oil-powered motorships of today. Figure 15 shows the succession of sail, steam, diesel S-curves over the period 1800-1920.

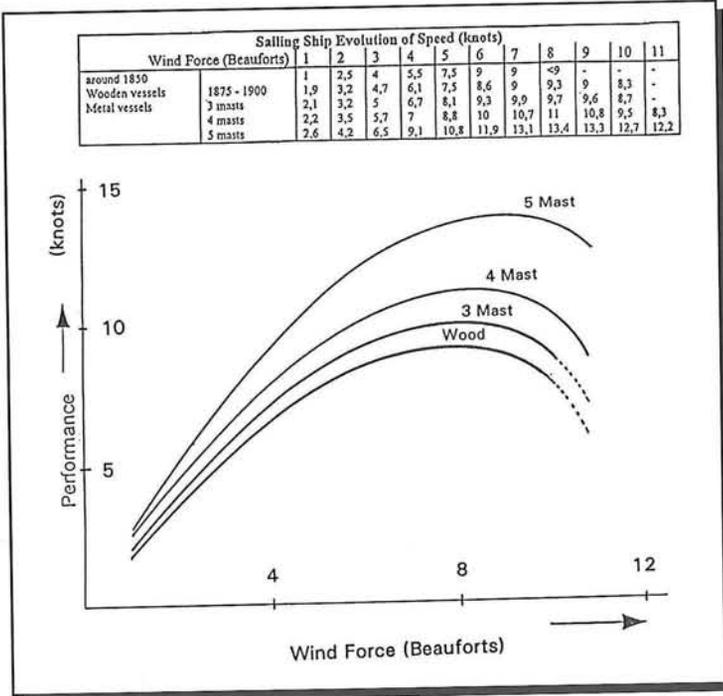


Figure 12

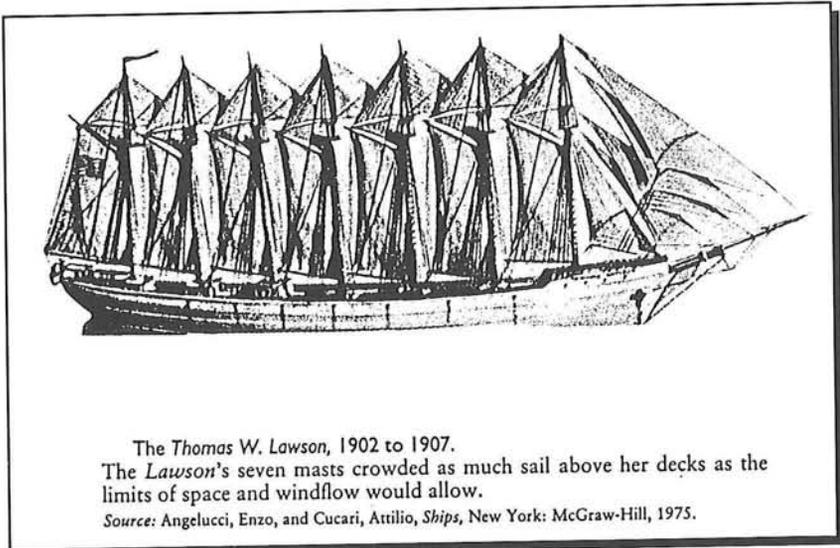


Figure 13

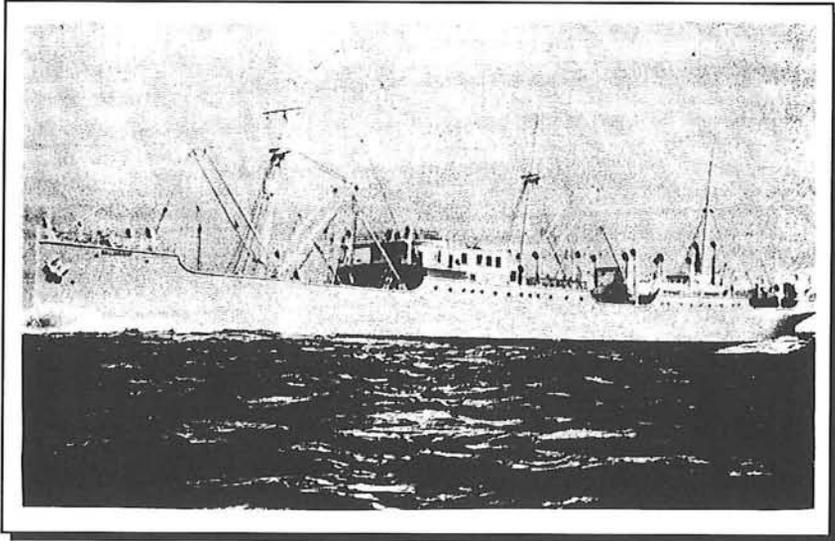


Figure 14

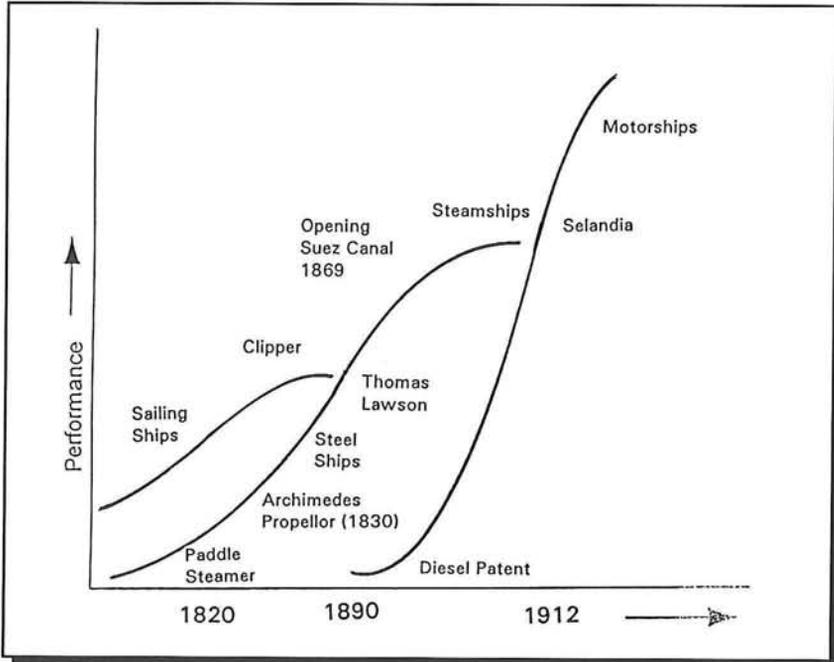


Figure 15

Figure 16 shows the development of the Dutch merchant fleet over the period 1852-1934. In this graph the decline of the sail ships, the growth of the steamships and around 1924 the growth of the diesel motorships is self-evident. It should be noted that although the fleet reduced in number of ships, the resulting transportcapacity was greater than those of the sailing ships as the productivity was larger.

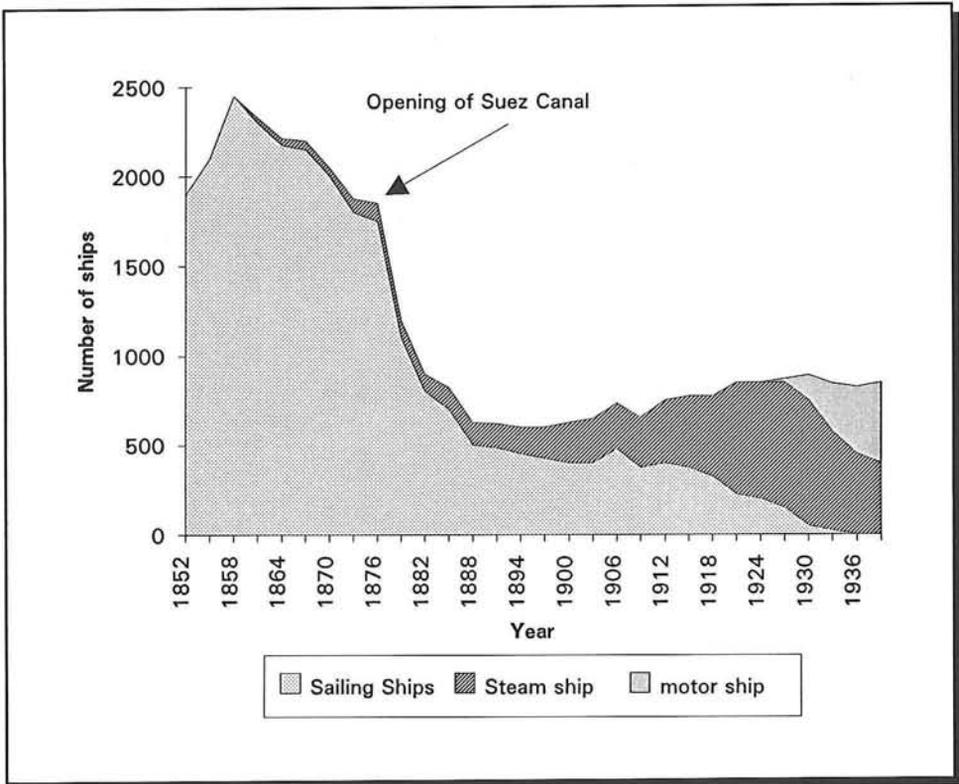


Figure 16

Part I: Innovation in Shipping

This example clearly illustrates the rate of adoption of innovations. It took roughly hundred years before the steam engine was developed and applied to the ship and eventually replaced the sailing ship. One innovation, e.g. the steam-power plant, required parallel innovations before it could come to fruition. The development of screw propellers, seals, lubricants, steelships, navigational aids, bunker stations around the world, etc.

The adoption rate of the diesel engine was much faster, especially among the Nordic shipowners.

The ships continued to increase in speed and Figure 17 shows the S-curve of speed of today (experimental ships).

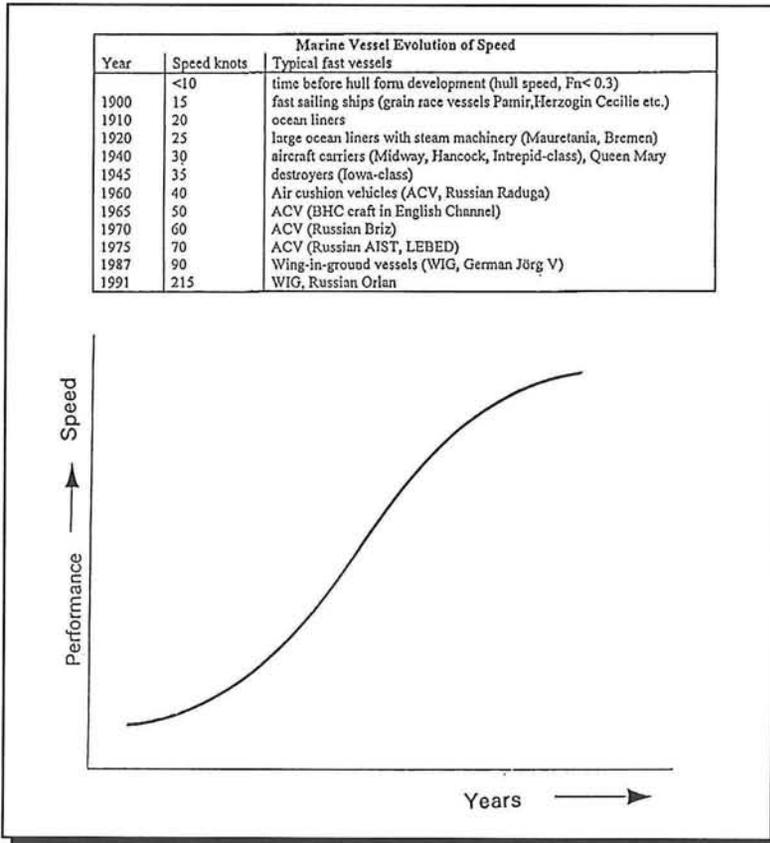


Figure 17

GENERAL CARGO-CONTAINER-HATCHLESS SHIPS CURVES

General cargo ships were gradually improved after WW II, hatches were made wider, tweendecks removable, heavy lifting gear speeded up loading and discharging. However, the cost of crewing and stevedoring rose to staggering heights, as the labour productivity increases achieved were by far not enough to offset the cost increases. The general cargo ship was around 1950 at the end of the S-curve (Figure 18).

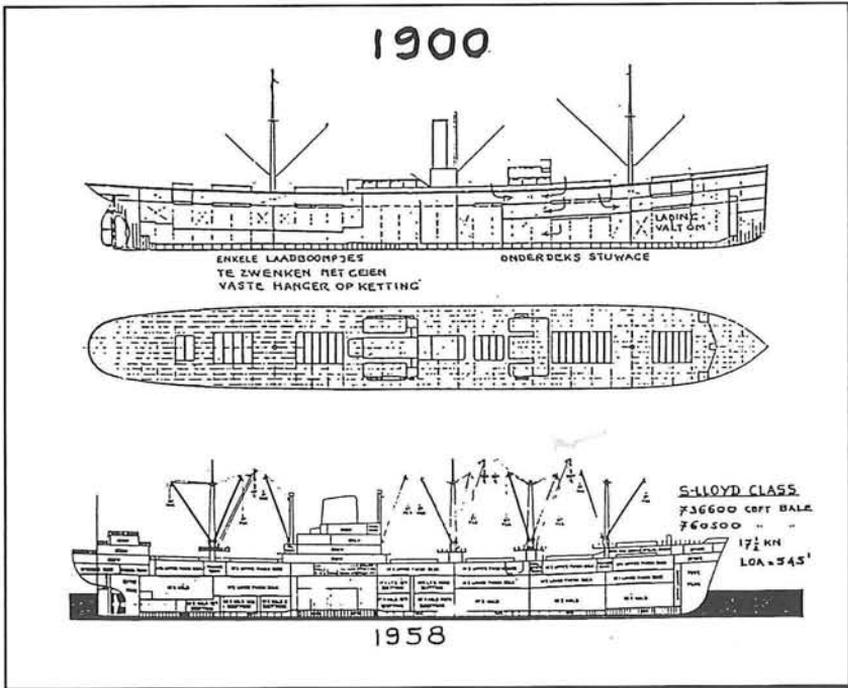


Figure 18

In the meantime an American trucker chartered obsolete WW II shallow draught landing craft and used them for coastal shipping of trucks. This intermodal system soon started using standardized boxes, which lead to the container system as we know it today. The containership innovation started around 1965 to spread worldwide, and contrary to other innovations, its rate of adoption was extremely fast. By 1970 all the major trade routes were covered by container services.

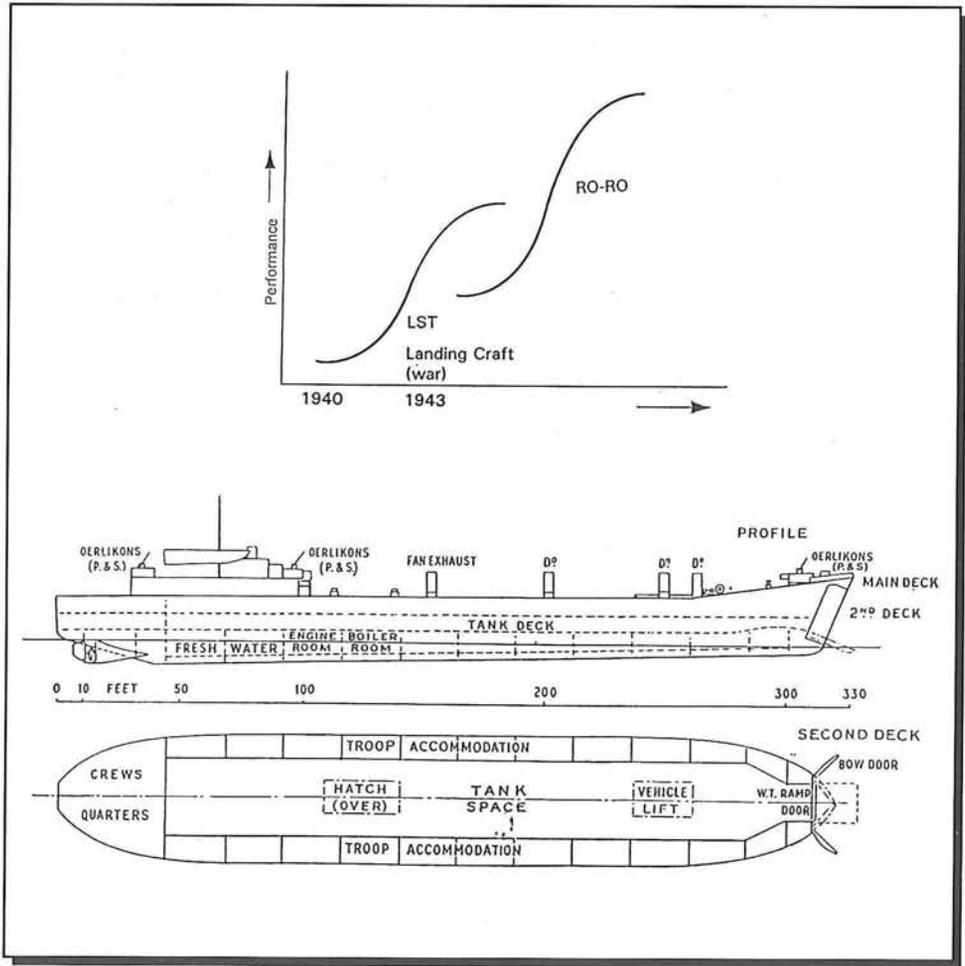


Figure 19

The reason for this fast adoption were the compelling economics of the new system. Studies from that period comparing a 12 conventional cargo ships service with a 2 cellular containership service showed that freight rates were halved by using the container system. The landing craft developed by W. Churchill in 1940 had a short S-curve. By 1943 they were in mass production. Out of this early concept developed later on the roll-on/roll-off vessels as we know it today (Figure 19).

The containership design was perfected during the following decades. A daring new design, 301 TEU without hatch covers, was first built in 1990 (Figure 20) and soon followed by very large Hatchless containerships of NedLloyd (3500 TEU). The objective of the design is to shorten the porttime, which reduces costs and increases the performance.

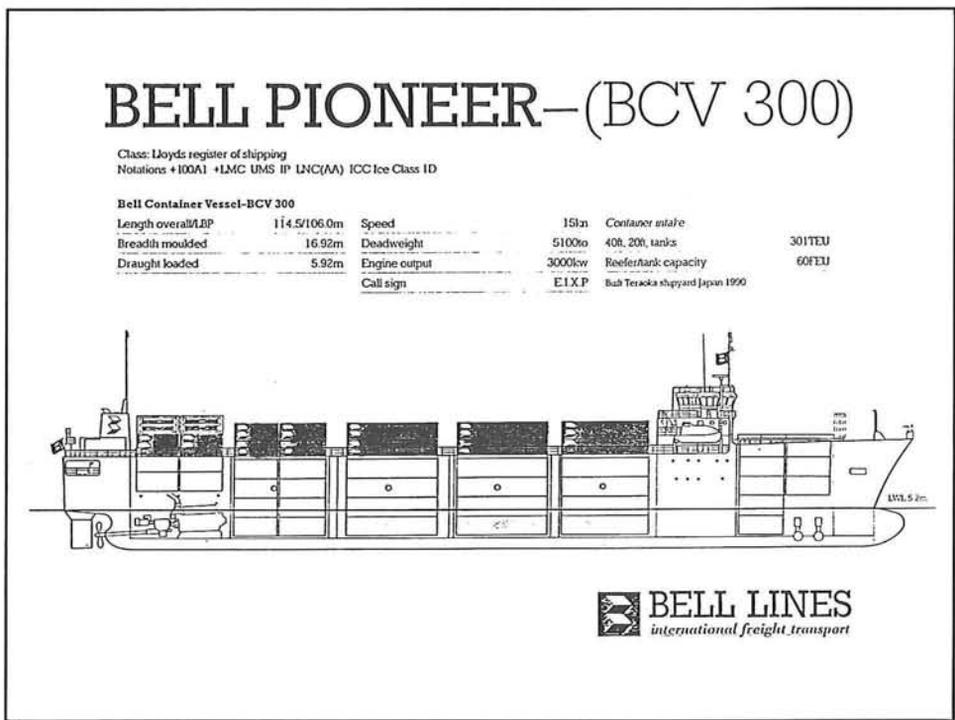


Figure 20

The hatchless concept was developed out of the experience with Dutch semi-submersible dockships for the transport of heavy lifts (Figure 21). This example shows that new concepts often evolve out of a new combination from existing technologies.

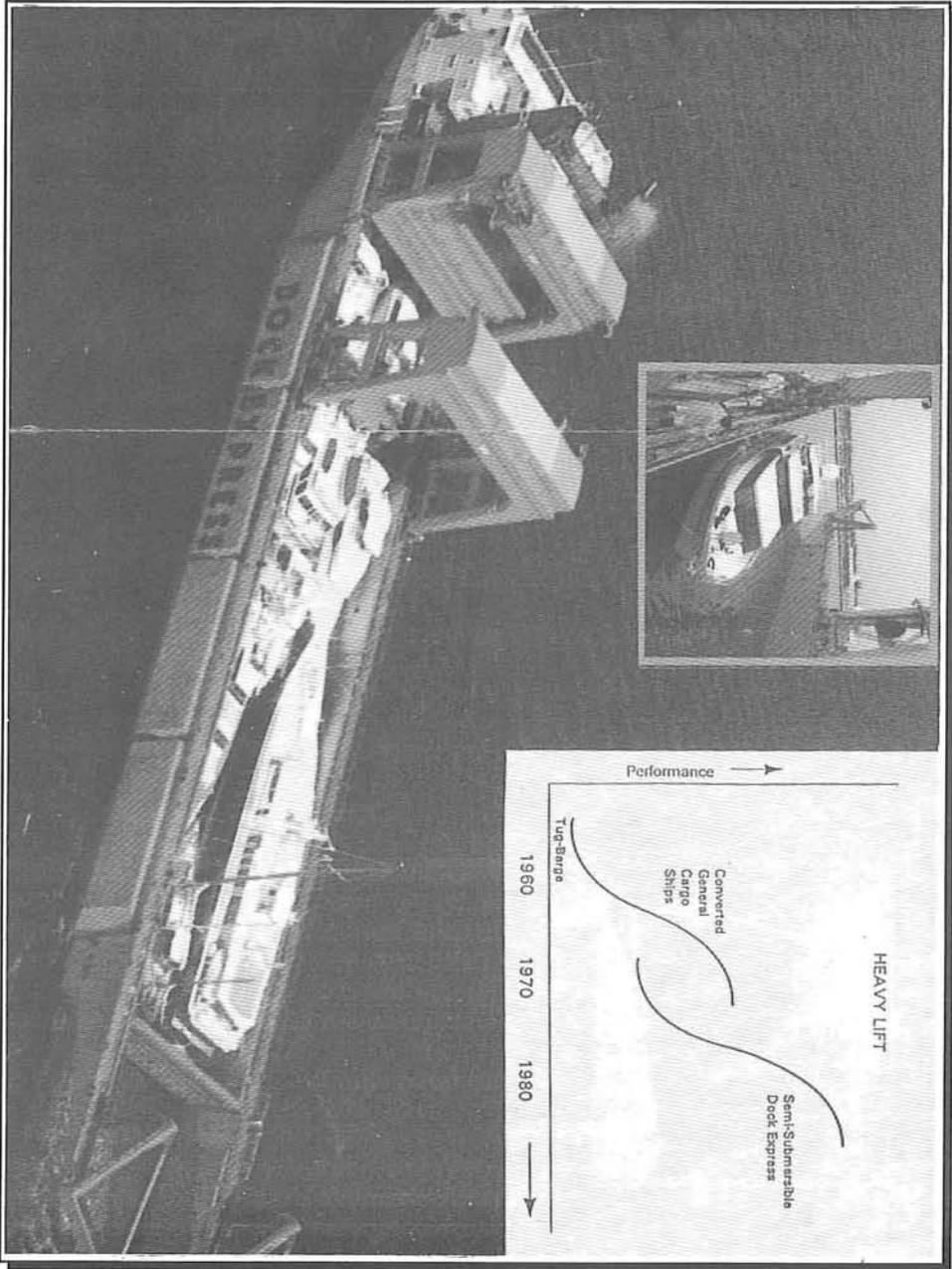


Figure 21

Figure 22 illustrates the S-curves of the general cargo-containership-hatchless containership development.

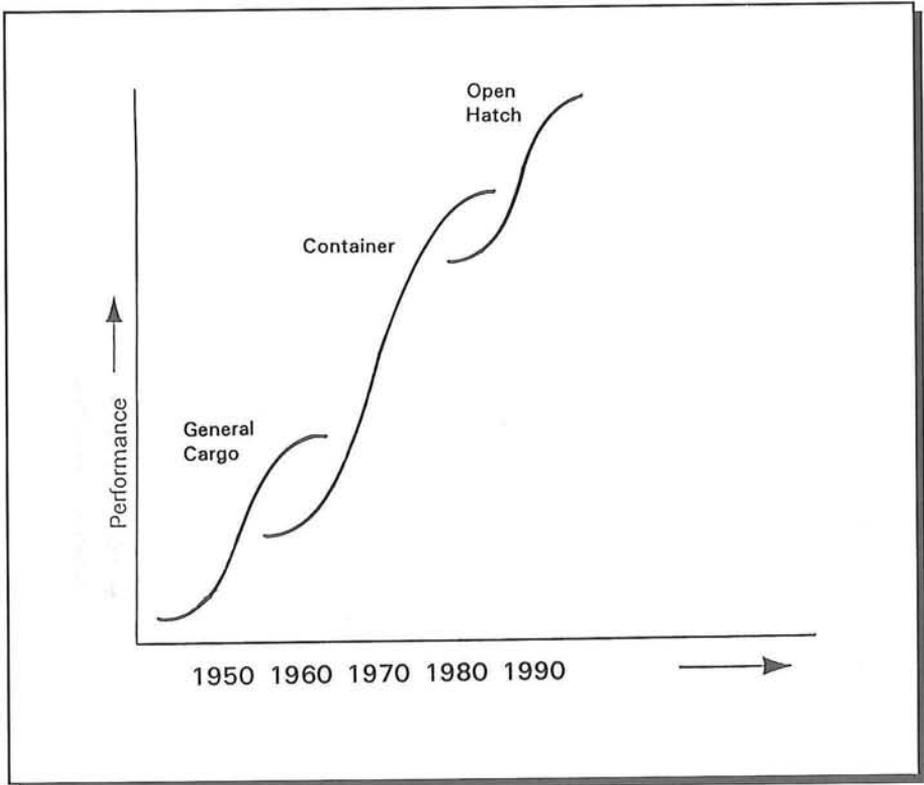


Figure 22

CHAPTER 3: INNOVATION TRIGGERS

S-curves always approach a horizontal line, which forms the natural limit of the performance of the existing technology. Strategic planning seems therefore reduced to assessing the position of a company's technology on the S-curve. However, the establishment of the S-curve itself, defining and measuring the performance indicators is quite difficult. If established, each S-curve provides the limit of the existing technology and implicitly the trigger for innovation. One can define five classes of triggers for innovation in shipping. These are:

1. *Physical laws triggers*
2. *Geographical conditions triggers*
3. *Economic parameters triggers*
4. *International regulations triggers*
5. *(Technological) change in related sector triggers*

These triggers will be briefly discussed.

PHYSICAL LAWS-TRIGGER

A normal passenger airplane cannot go faster than the speed of sound, otherwise the sonic boom will destroy the plane.

It took a decade before the designers could achieve the last 10 percent increase in speed up to the Mach 1 speed limit, and very sophisticated calculation programmes and powerful computers. The S-curve of airplanes is shown in **Figure 23**.

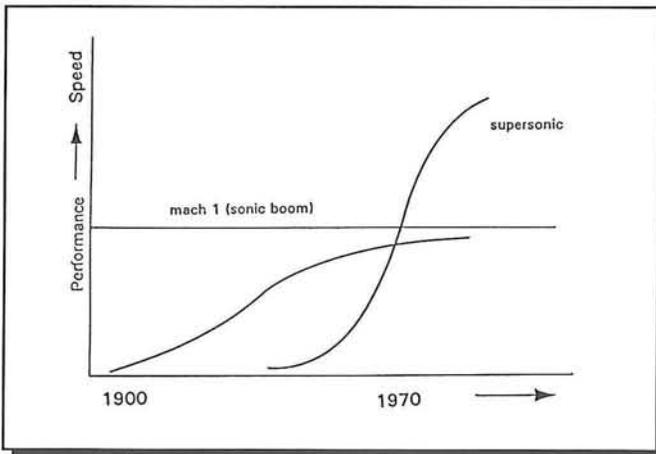


Figure 23

Planes are carried by air on the basis of the principle of dynamic lift; forward motion is converted into vertical, lifting forces. In shipping this principle is also used with fast ships. Normal ships are carried by water, the so-called buoyancy support. The speed in water is limited because of the exponential increase in water resistance when a ship increases its speed. There are two ways to reduce the resistance; dynamic lift and powered lift (helicopter). Both methods achieve a reduction of the wet surface of the ship, which is proportional with its resistance. **Figure 24** shows the lift-triangle of ships, and **Figure 25**, a more detailed graph with performance indicators relating to the effective payload (W_p), the speed V and the poweruse P . This graph shows all the transport modes, based on the three main support characteristics water, air, land.

To transport one ton of oil with a crude tanker, the ratio P/WV is 0.03; the transport with a helicopter results in a ratio of 1, or 300 times more energy use!

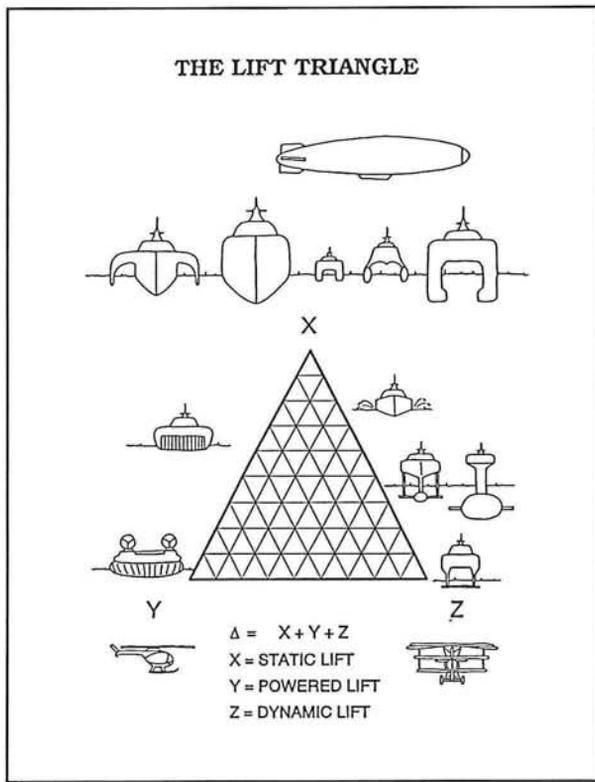


Figure 24

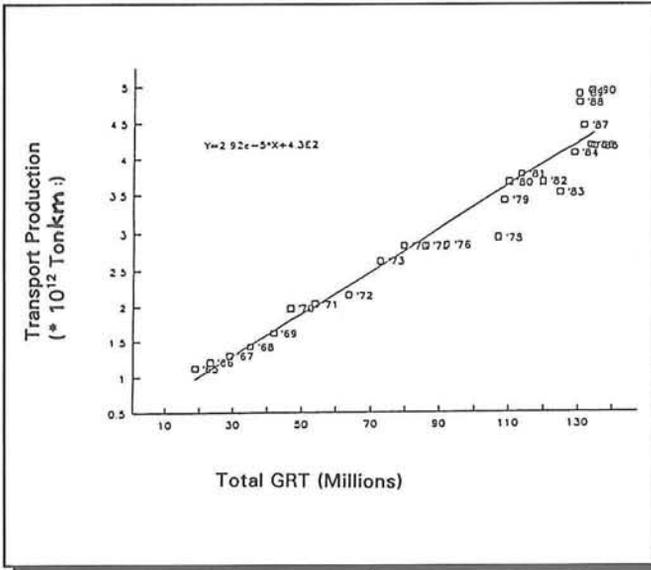


Figure 27: Bulk carrier fleet development 1963-1991

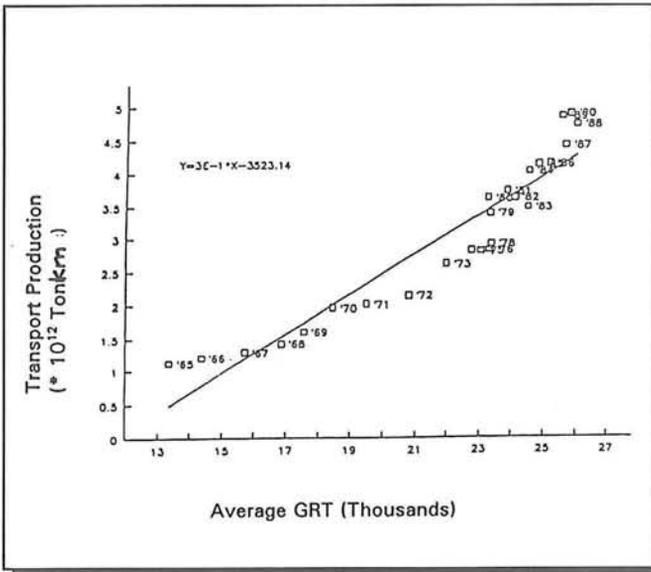


Figure 28: Average bulk carrier size

The optimisation of the design within well defined physical constraints is typically an engineering job and falls under the heading "improvement innovations".

Yet another geographical condition which determines many ship designs is the occurrence of ice in the sea. Building ice-class ships influences heavily the design of a ships hull and machinery.

ECONOMIC-TRIGGERS

The most powerful trigger for innovation in shipping is the drive of shipowners to develop new shiptypes which have maximized earning capacities or minimized costs.

The combination bulk carriers like oil-bulk-ore (OBO), or container-bulk are examples of ships which can operate in different markets and offer flexibility to the owner. A rather innovative shortsea container-oil-bulk ship (COB) (Figure 29) was developed for the Baltic trade on the basis that ballast voyages could be avoided by alternating dry cargo and oil products. This concept proved to be too expensive to built in relation to the general low freight rate level of both these commodities and has therefore not been successful.

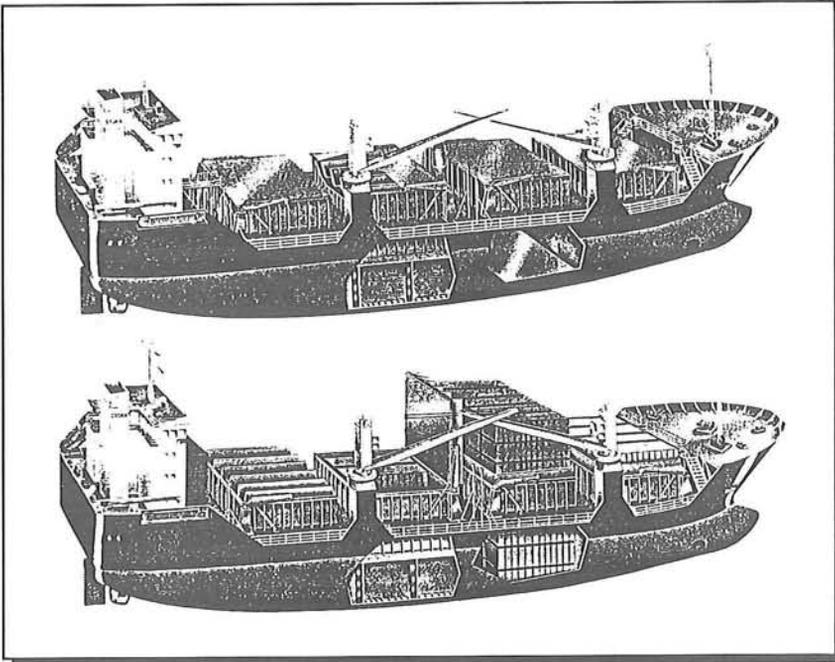


Figure 29

Maximizing revenues as mentioned above is a strong trigger for innovation. The other side of the coin is costminimisation. In general four costcategories are distinguished for a ship: capital cost, running cost, voyage cost and cargo handling costs.

The reduction of capital costs can be looked at from the pure shipbuilders perspective, e.g. making a cheap ship by reducing steelweight and/or reducing the number of construction elements.

It should be kept in mind that different shiptypes, like containerships and oiltankers have completely different cost pictures because of the difference in lightship weight per ton deadweight.

Figure 30, shows the average sale and purchase prices paid during 1992 in dollars per ton deadweight for the major shiptypes.

The traditional way for shipowners to reduce the capital cost per unit deadweight within a certain shipscategory (which represents the earning capacity) is to increase the size of the ship. The drive for economies of scale is clearly visible in all shipping sectors.

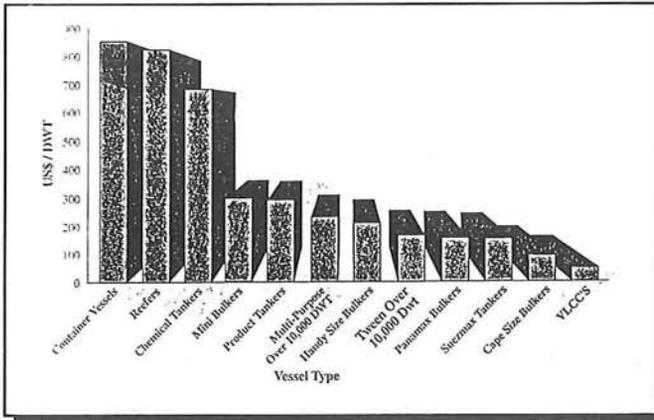


Figure 30

Figure 31, illustrates the relationship between capital cost and daily time charter hire per TEU for containerships in the range from 200-1800 TEU.

It is clear that the present generation of 4000-plus TEU ships create even larger economies. The only condition for the successful increase in size is that the market demand is there to fill the ships.

The reduction of the running costs or operational cost of the ship is achieved through process innovation in the machinerroom and at the bridge, but also in the maintenance system. The use of cheap foreign seamen is not an innovation, but a simple operational solution.

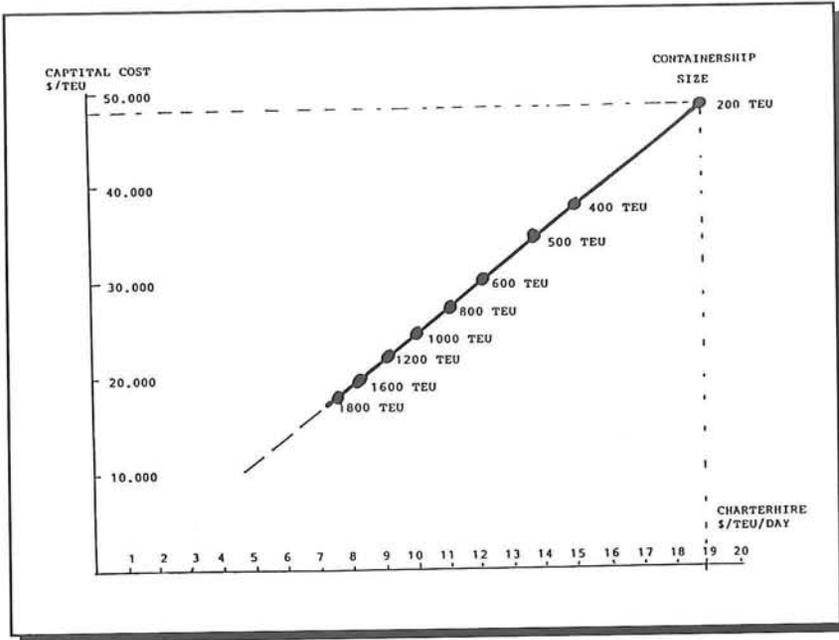


Figure 31

Many improvement innovations have led over the years to a minimal crew and an integration of functions on board. Further major improvements will probably not lead to major changes in the cost structure.

Voyage costs consist of bunkers and port/canal dues. Improvement innovations in hull form, fuel efficient machinery, self polishing paints, efficient engines and auxiliary equipment, etc. have significantly lowered the voyage costs. Major innovations on conventional ships are not to be expected.

Cargo handling cost is a very important area for innovation and the last major frontier for shipowners and shipbuilders, especially in shortsea shipping of unitloads.

The discharge of conventional general cargo will cost a minimum of \$ 30/ton in European ports; if shipped in a unitload, these costs are reduced to say \$ 8/ton. The ultimate example of an efficient, low cost bulk handling system, can be found on board the increasing number of selfunloading bulk carriers. The basic concept of this innovation goes back to 1911 (Figure 32).

The automation of cargo handling on board unitload ships is still in its infancy. In shortsea trades, various studies have shown the need for advanced, automated handling systems in order to make the ship-route competitive with the other modes.

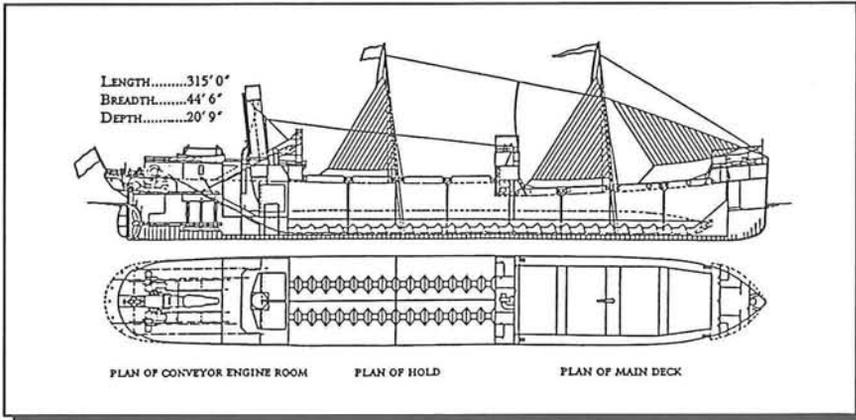


Figure 32: M.s. Herman Sauber 1911

This book contains a case-study from Sweden, where a coastal shipping system is being developed which can provide a serious alternative for road and rail transport.

REGULATIONS-TRIGGERS

The design and operation of ships is regulated by international and national regulations. The IMO is responsible for most of the maritime regulations in the world, but also unilateral action as for example taken by the USA with the Oil Pollution Act 1990 after the Exxon Valdez accident, can heavily influence the design and innovation in ships. World regulation of shipping started by Lloyd's in the previous century, when it introduced the maximum draught mark from Plimsoll on ships. The international community started to create regulations after the dramatic disaster of the Titanic in 1912. The Solas convention (Safety of Life at Sea) defined rules for the damage stability calculations of ships, in particular passenger ships.

Of more recent times is the Marine Pollution (Marpol) convention which defines rules and regulations for the carriage of chemicals and other dangerous goods. These regulations form important triggers for changes.

In this context it is noteworthy that the requirements on the maritime sector are often much more strict than on other sectors such as road transport.

If for example, the road transport of dangerous cargoes is in the future restricted to certain routes and times of the day (not through cities, only at night, nor in weekends), the competitive position of shortsea shipping will improve.

OTHER-TRIGGERS

Innovations in other areas, such as computers and datacommunication, in particular electronic data interchange (EDI) can impact the competitive position of shortsea shipping in a positive way.

Low cost networks between the shippers, receivers, forwarders, truckers, stevedores, customs and shipowners, can create a virtual integration and control of the broken transport chain, and compete therefore with simple point-to-point road/rail transport. Good examples of these EDI networks can be found in the U.K. and other Northwestern European countries. Also Italy's Viamare sea-road intermodal system proves that modern EDI technology can cement all the parts in the communications chain together.

A completely different trigger for innovation comes from the need to reduce the pollution in the world and save scarce resources, while increasing the world standard of living and doubling the world population.

This requires a new design and engineering philosophy, which is based on durability. A longer lifespan of ships, extensive re-use of shipsparts, emission reduction, improved fuel efficiency, reducing road haulage, improving handling efficiency, etc. are all necessary to achieve this.

Technological innovation is more and more directed towards these macro-economic, or better, world-environmental objectives.

This new thinking is already visible within some sectors of IMO (Marpol) and is likely to become the leading design principle of the next decades.

CHAPTER 4: S-CURVE AND SHORTSEA SHIPPING

SEA-RIVER LANES INFRASTRUCTURE

The maritime equivalent of a road or rail, is the sealane. A part of the European sealanes are formed by the seas that surround the countries; another part is formed by the connecting navigable rivers and canals. Figure 33, shows the sea-river lanes infrastructure in Europe. Seagoing vessels are in general not designed for the navigation on rivers, because of air (bridges) and water draught restrictions. The old small coastal ships of 500 gross tons were able to navigate the

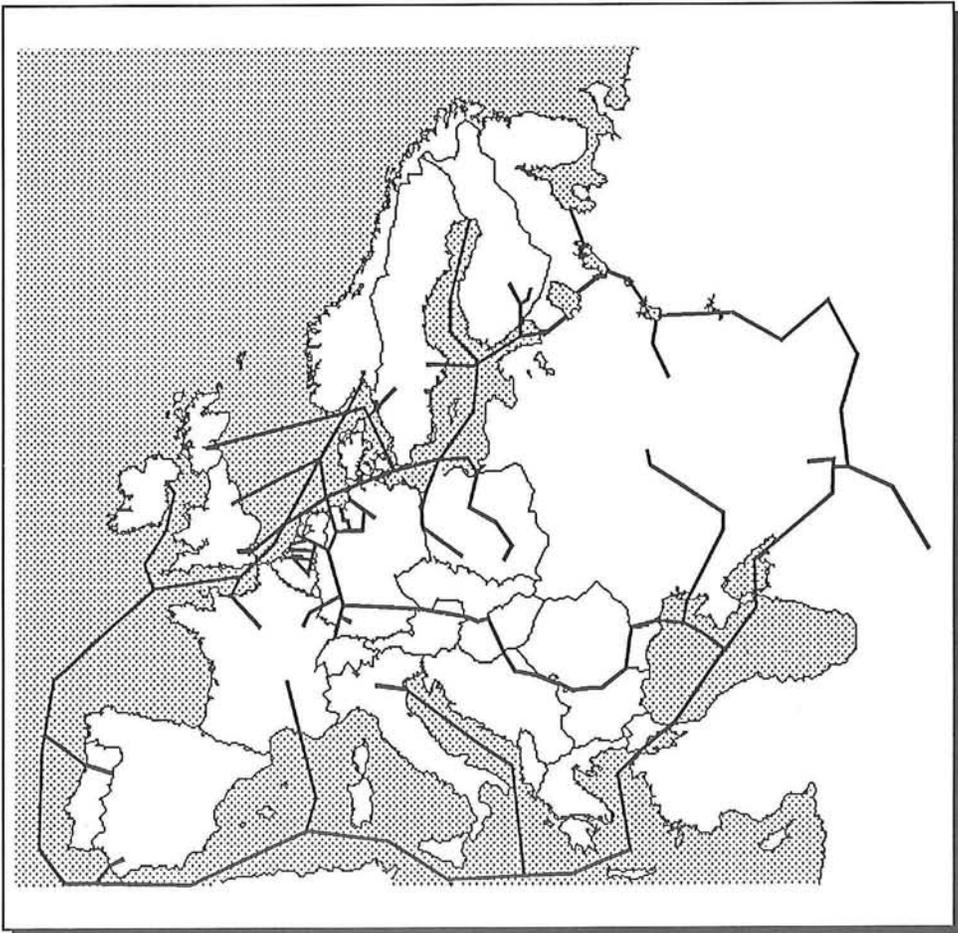


Figure 33

sea as well as on most of the rivers. However, the dis-economy of scale eroded their competitive advantage overtime. For this reason a new class of sea-river vessels was developed around 1970, characterized by a larger carrying capacity (deadweight-dwt) and a very shallow water and air draught.

These vessels are able to transport cargo via the sealanes into the river/canals system, without additional transshipment, which reduces costs substantially and improves the competitive position vis-à-vis other modes, such as road and rail. The development of this shiptype is briefly discussed in the next paragraph.

Within Western Europe, the major sea-river routes are related to the River Rhine system; in Eastern Europe, the Russian riversystem, connecting the Baltic, via the Volga to the Black Sea and Caspian Sea is an even more important domain of sea-river ships and a potential new corridor between the Baltic Sea and the Mediterranean.

The limits posed on the design of sea-river-vessels in Western Europe are determined by the limitations of the major rivers and canals, such as the river Seine (air draught 8.7m), the Albert Canal in Belgium (air draught 6.4m, waterdraught 3.40m), the rives Rhine and Elbe, etcetera.

The sea-river ships concept grew out of the traditional European coastal ships. **Figure 34**, shows in brief the change in design of the coastal ships from 1880-1960.

The 70's and 80's saw a rapid growth in the size of these vessels as **Figure 35** illustrates.

The growth of the sea-river fleet is clearly demonstrated by **Figure 36 and 37**. The fleet consists of an impressive 1100 ships, half owned by West European owners and half owned by former Sowjet Union owners.

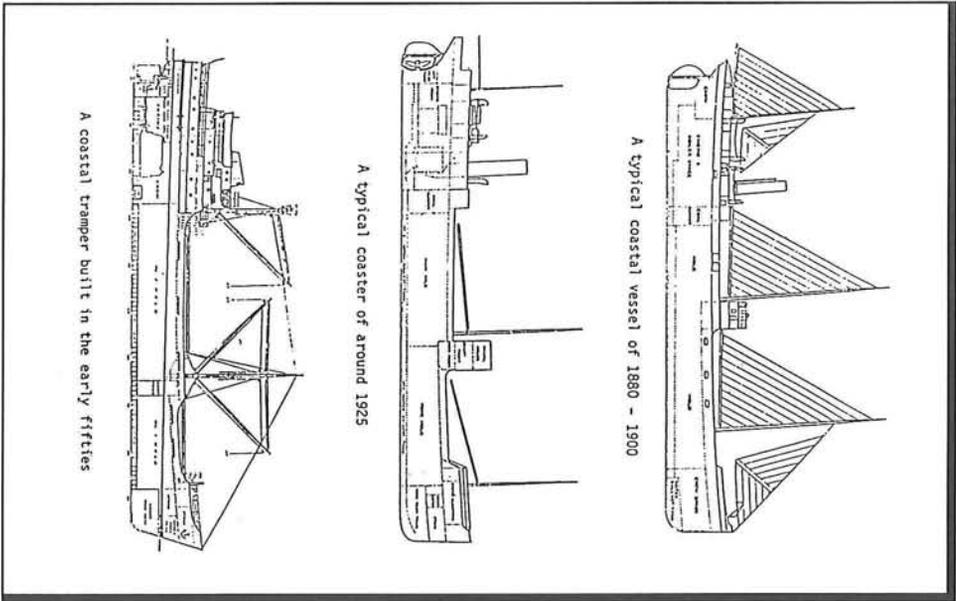


Figure 34

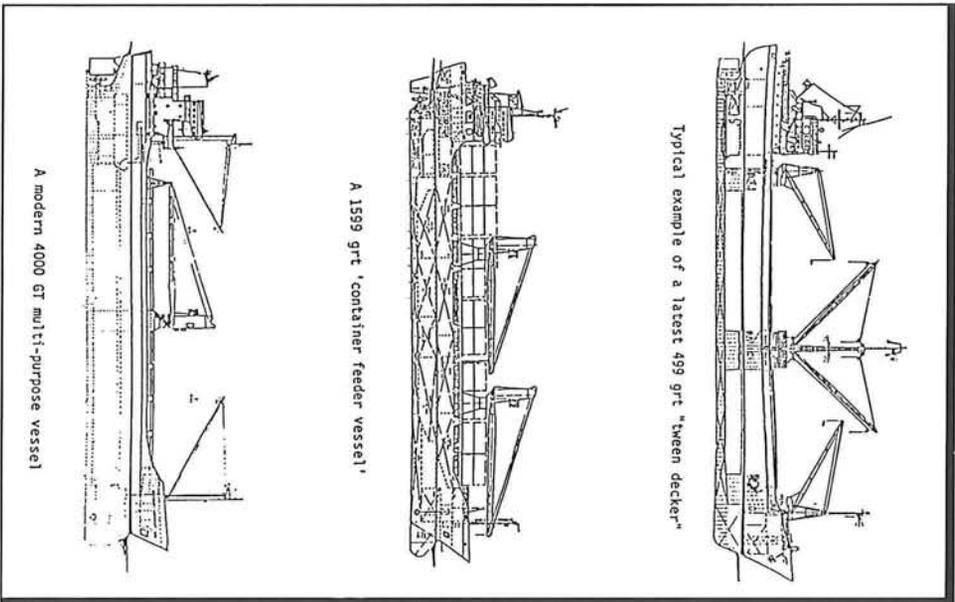


Figure 35

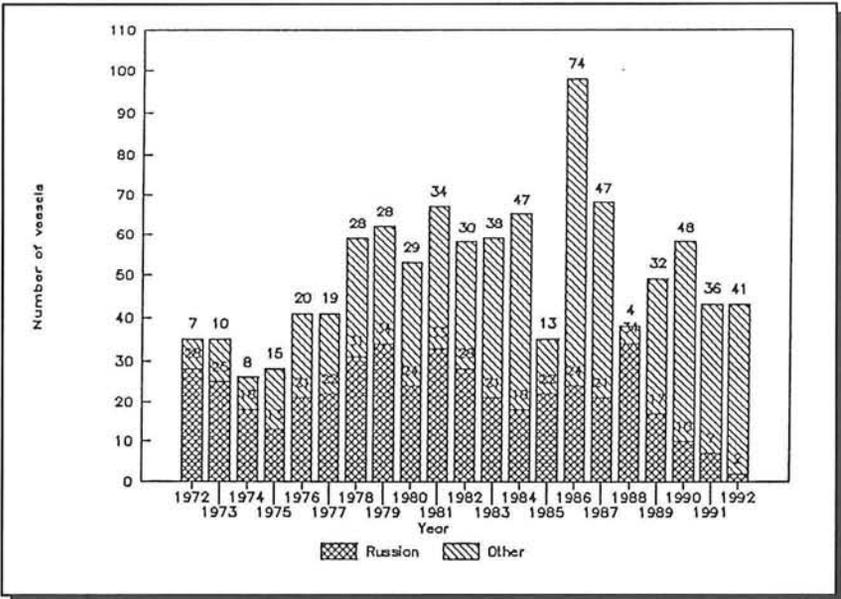


Figure 36: Sea river vessel fleet

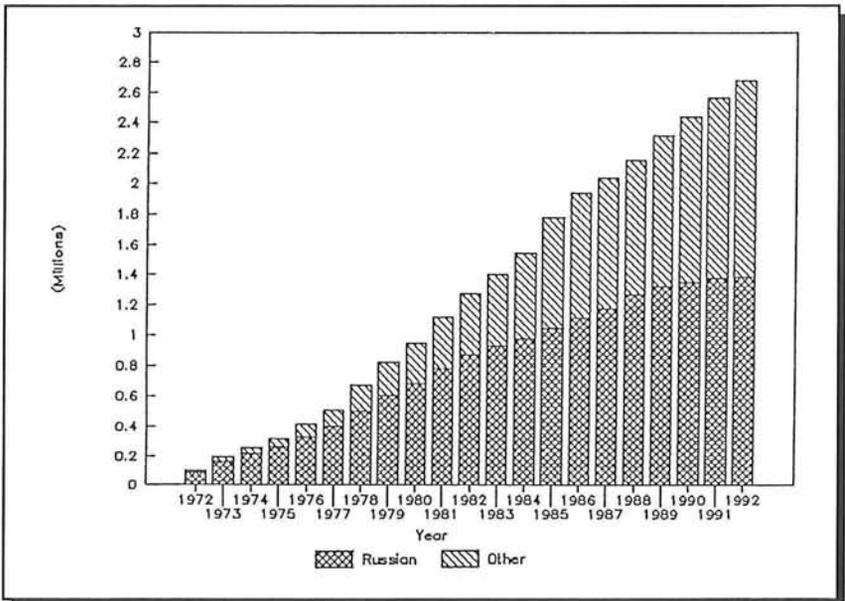


Figure 37: Deadweight

INNOVATION TRIGGERS

The development of the purpose-built shallow draught vessels since the early seventies, illustrates the search for innovation in the sector. This innovation was triggered by geographical constraints, e.g. shallow water and air draught of rivers.

Within the dry cargo segment of the shortsea shipping sector, various other triggers for innovation can be distinguished, A systematic overview of these triggers is presented below.

* **Physical laws trigger**

- **Speed**: Shortsea ships are in general small ships, which speed depends on their length. Surpassing the natural limit of nature has been a trigger for innovation.
- **Stability**: Small ships often have intact and damage stability limitations, which reduce the effective deadweight capacity. Solving the conflict between stability and measurement still is a major trigger for innovation.

* **Geographical conditions trigger**

Shallow waters in ports and on rivers, as well as the limitations of locks have been and still are major triggers for innovations. The development of the sea-river ships is an example. Improving the manoeuvrability by, for example, using waterjet propulsion in shallow waters, as on the Sea Orade Ultra (Figure 38).

* **Economic triggers**

- **Maximization of revenues** can be achieved by design of a flexible, multi-purpose ship, which can carry for example dry bulk and containers. The Dutch in particular have developed these box-shaped ships. But also sto-ro or ro-ro vessels create flexibility. The container-oil-bulk ship, discussed before is yet another example, of ballast voyage minimization, or revenue maximization.
- **Economy of scale** is a major trigger for innovation. Large ships have significant lower investments per ton, as well as lower running and voyage costs. So indirectly, the search for economy of scale is trigger by cost-reduction objectives.
The increase in the average size of the shortsea fleet shows the importance of this trigger

- Cost reduction

Capital investment: The reduction of capital cost can be achieved, not only through economy of scale, but also through standardization. This is for example achieved by several shipyards, which have developed a standard design. They can realize important cost savings through smart engineering and production, as well as the experience gained on the learning curve.

Running costs: The major item is the crew cost, which is determined by manning regulations. These are in turn related to the training level of the crew, the complexity of the machine room and the size of the ship (measurement), besides, the flag of registration and the nationality of the crew.

Important efficiency improvements have been achieved in order to reduce the running cost. The scope for major improvements on shortsea ships seems limited.

Voyage costs: Two major items make up this category: bunkers and port costs. Bunker costs depend on many factors, such as the deadweight of the vessel, blockcoefficient, speed and type of fuel. Major improvements have been achieved to improve the fuel-economy.

Port costs: are not uniformly calculated in ports around the world. Most of the ports relate these costs to the measurement of the vessel (gross tonnage).

Shortsea ships call very frequently in ports and the reduction of port costs through creatively lowering the measurement of shortsea ships has been, and still is, an important trigger for innovation. This has also led to a situation whereby most of the cargo is carried on deck, and to a very low freeboard. A major change in port cost calculation principles would become an important trigger for innovation.

Cargo handling: Stevedoring cost are a major cost item in shortsea trades, as the sealeg is usually limited in length.

There are two aspects which form triggers for innovation: the increase in labour productivity (tons/man/hour) and making the ships independent from the availability of terminal labour. The "goal-function" of any innovation in cargo-handling is to reduce these costs to zero, as "the best port is no port at all".

The first objective, improving labour productivity, is achieved through more efficient cranes, on shore and on the ship, the use of cargo units such as the container, bulk bags and cassettes.

The second objective, making the ship independent of terminal labour, is achieved by equipping the ship with self-loading and self-

unloading equipment. This technique is mostly developed on bulk carriers (self-unloaders, see **figure 39**) and on cement carriers (loading and unloading, closed system).

The advantage of such a system is that the ship can enter the port/terminal any time of the day or week, without being penalized by extremely high stevedoring labour costs during the nightshifts, or weekendshifts. This is especially important for small, coastal ports. The selfloading and unloading of unitload ships is still in its infancy. It is the subject matter of this book, and the last frontier of major innovation.

* **Regulations-trigger**

The abolishment of cabotage-regulations has been an important trigger for change, not so much in ship innovation, but rather market innovation.

The wish to reduce the environmental pollution of transport results in an ever growing list of standards and regulations for emission, etcetera. This leads to innovations which are much easier to implement on ships than for example on trucks, due to its large size.

Besides administrative, political and environmental regulations, there are labour/manning regulations, each with its impact, such as noise level reduction onboard. Although very important, they do not fundamentally affect the competitive position of shortsea ships in the near future, and the modal split, unless the other modes are charged with their real social costs.

* **Other triggers**

EDI has already been mentioned as major trigger for market innovation. Also vessel traffic systems, intermodal units and transfer equipment, such as the stackable swap body or the pallet friendly container (2.5 wide).

The opening of new infrastructural links, such as Channel Tunnel also triggers innovative reactions from the ferry-operators.

Each shipowner is keen to exploit each little development to create a protected niche for himself. It is this continuous search for opportunities which propulses the innovation system.

POTENTIAL FOR INNOVATION

The triggers mentioned above and their potential for innovation are shown in **Table I** Cargo handling is the major trigger for innovation. The means to achieve this, but foremostly the reasons why this problem has to be solved is discussed in **Part II**.

Innovation trigger		Potential for innovation dry cargo/unitload ships	
		High <----->	Low
1	Physical laws trigger		
	Economic triggers:		
2	Revenue maximization		
3	Economy of scale		
4	Capital cost		
5	Running cost		
6	Voyage cost (port cost)		
7	Cargo Handling		
8	Regulations trigger		
9	Other triggers		?

Table I

TOTAL LOGISTICAL CHAIN: HOLISTIC VIEW

Shipping, i.e. the sea leg, is often the largest part in the logistical chain measured in distance but certainly not in cost. Traditionally, each part of the chain tries to improve through innovation of the performance, with only marginal success.

A good example is the forest products logistical chain. Another publication in the "Delft Marine Technology Series", titled "Innovation in Forest Products Shipping", clearly illustrates the case for a holistic view in which the whole chain is involved and not only parts.

CHAPTER 5: DIFFUSION OF INNOVATION IN SHIPPING

Many successful innovations have two things in common: a smart innovator/entrepreneur and an innovation diffusion strategy.

Many books on innovations emphasize the diffusion strategy. Especially Roger's book "Diffusion of Innovation" provides a conceptual framework which is useful.

The diffusion of the innovation can be measured by its rate of adoption. As a function of time, these rates follow S-shaped curves as shown in Figure 38. The objective of each innovation is to create an adoption rate which is steep, (furthest to the left).

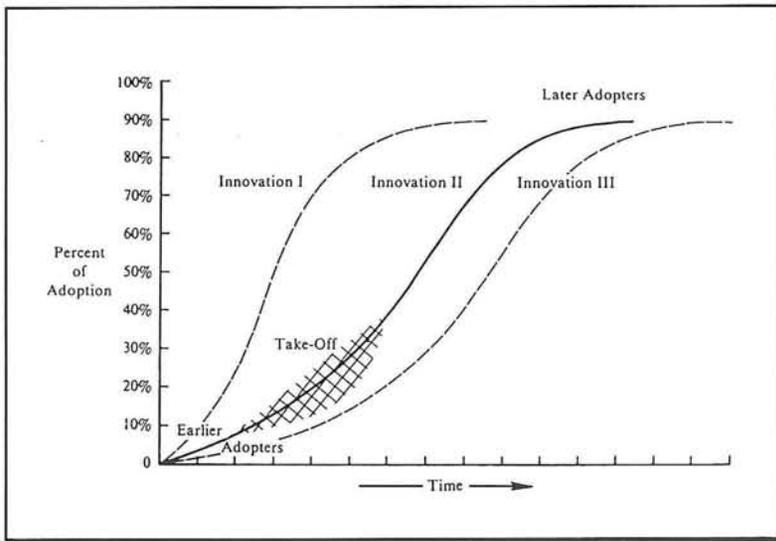


Figure 38: S-shaped curve of innovation diffusion process

In order to understand the mechanics behind the rate of adoption of innovation another model of Roger can be used (Figure 39). He identifies five key-variables.

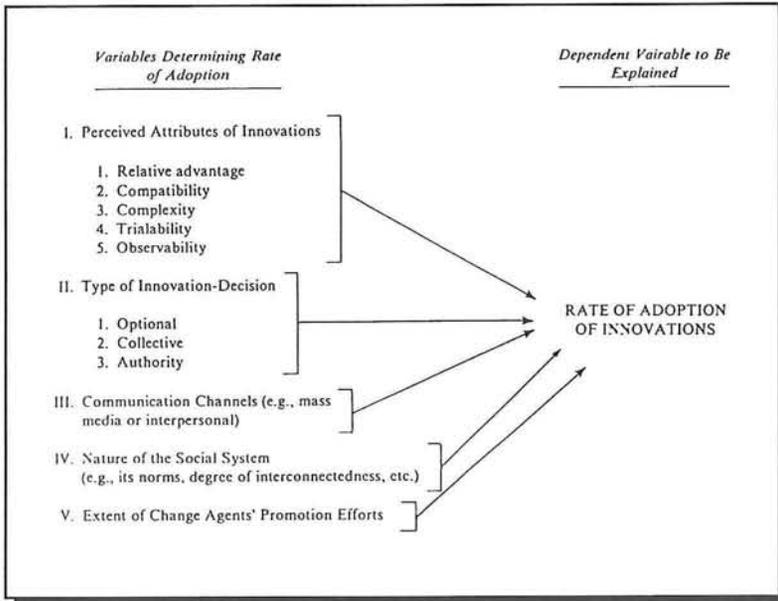


Figure 39

1. **Perceived attributes of innovations:** relative advantage over alternatives, compatibility with values, past experiences and needs, complexity, triability and observability.
2. **Type of innovation.** Innovations requiring an individual optional innovation decision will be adopted more rapidly than when an innovation has to be adopted by an organisation.
3. **Communication channels.** If interpersonal channels must be used, the rate of adoption will be slowed down provided the innovation is not perceived as complex. In this case, interpersonal channels are more effective.
4. **Nature of social system.** In particular the degree of interconnectedness, i.e. how effectively the members of a social system are linked by communication networks, is positively related to the rate of adoption.
5. **Extent of a change agents's promotion efforts,** which is most effective at the early stages of the diffusion process, when opinions are forming.

Prof. L.A van Gunsteren adds one important aspect to this list, which is particularly relevant in shipping: the safety aspect of the innovation. A new technology can entail a risk of physical danger.

PART II: SHORTSEA TRANSPORT SYSTEMS

CHAPTER 6: CRITICAL SUCCESS FACTORS FOR SHIPPING

Competition between seaborne and land transport is presently very limited in volumes and types of commodity. Only high value general or break-bulk cargo packed in unitloads like the maritime container or the swapbody competes in shortsea shipping with road and rail transport.

In order to understand the reasons why this is the situation, the critical success factors will be analysed in this chapter.

The following critical success factors will be examined in more detail:

- * transport (transit) time
- * transport costs
- * frequency and flexibility
- * reliability
- * customer (shipper, receiver) satisfaction
- * environmental impact
- * political acceptability

Although most of these factors are related, they will be discussed separately.

TRANSPORT TIME

Transport time is a crucial element in any discussion about shortsea shipping. An increase in comparison to landtransport is hard to avoid which is unattractive to most shippers. On the other hand, if a considerable cost reduction can be realized in combination with an acceptable and predictable increase in time there could be an opportunity to attract cargo from the transport market. The increasing value of time makes transport time a dominating critical success factor.

Transport time of shortsea shipping can be reduced by:

- * minimizing sailing time
 - * minimizing turnaround time in port
 - * minimizing hinterland lead time
- **Minimization of sailing time can be achieved by:**
- * faster ships (advanced design, unconventional ships and alternative propulsion systems)
 - * availability under all weather conditions
 - * installation of integrated navigation systems (V.T.S.)
 - * support by a traffic control and management system

Part II: Shortsea Transport Systems

- **Reduction of turnaround time in port requires:**
 - * standardization of cargo units
 - * advanced ship- or land-based cargo handling systems
 - * time independence of stevedoring companies
 - * automatic stowing and lashing systems
 - * advanced mooring systems
 - * quick supply (water, provision, bunkers, information...), disposal (waste, waste water, bilge water...) and cleaning, crew changes.

- **Hinterland lead time can be reduced by:**
 - * standardization of cargo units
 - * 24 hours availability of truck docking facilities operated by driver.
 - * advanced truck/terminal interfaces
 - * support by a traffic control and management system
 - * prevent traffic jams by a.o. limiting long distance road transports

TRANSPORT COSTS

A low freight rate has to counter balance the relative increase in transport time. In order to reduce unit costs the variable costs have to be controlled and reduced. In general, reducing the variable-cost part of a total cost figure requires investments which will result in higher fixed costs. An optimal balance between fixed and variable costs should give a lowest unit cost.

The cost structure of a shipping operation, including hinterland transport, will be used as a guideline in this paragraph.

Reduction of transport costs can be achieved by:

- * minimizing capital costs
 - * minimizing running costs
 - * minimizing voyage costs
 - * minimizing cargo handling costs
-
- **Capital costs can be reduced by:**
 - * using the existing maritime infrastructure to its full extend
 - * avoiding complexity in the design of the system components
 - * using existing and proven technology
-
- **Running cost reduction requires:**
 - * a minimum crew
 - * planned maintenance system
 - * cost efficient supplying
 - * rationalized shore organization

- **Voyage costs can be minimized by means of:**
 - * automated mooring systems
 - * good manoeuvring capabilities
 - * good performance in ice
 - * low fuel consumption
 - * formulating cost saving agreements with port authorities for port charges
 - * central booking to avoid brokers commission a.o.

- **Cargo handling costs can be minimized by:**
 - * time independent ship/shore transfer of cargo
 - * reduce number of ship/shore moves
 - * standardized cargo units
 - * automated cargo handling systems in order to:
 - load and discharge the ship
 - transfer cargo on the terminal
 - load and unload trucks or trains
 - * engaging shore labour from 9h/17h only
 - * making the hinterland transport time independent from the ships arrival to allow land transporters to work out their own cost-optimal service schedules
 - * formulating cost saving agreements with stevedoring companies for handling charges

FREQUENCY AND FLEXIBILITY

For a coastal and short sea shipping system it is a major challenge to offer flexibility at the highest possible level. The flexibility a road hauler can offer is very hard to match. Frequency of sailings is a major critical success factor. Offering a weekly sailing only is sure to fail to attract the attention of shippers and receivers. A daily departure is a prerequisite for a competitive shortsea shipping system. The added advantage is that ships are allowed to call on the ports in the weekends, while roadtransport is often prohibited to drive during the weekends.

A high frequency of sailings creates a huge transport capacity. The "catch 22" of the situation is that shortsea shipping needs a high frequency, consequently a large volume of cargo to compete with roadtransport. The start-up of a huge system will be difficult, but not impossible.

Frequency increases the flexibility of the system, other factors are:

- * 24 hour availability of truck docking facilities on the terminal
- * standardized cargo units in respect to handling activities
- * advanced E.D.I. systems providing cargo location, condition and E.T.A.
- * minimum engagement and dependency of personnel

RELIABILITY

From a shippers point of view today's sea transport is sometimes the less reliable form of goods transport when compared to transports by road or railway. A shipping organization is faced with a bigger number of potential delay factors than the other two modes causing a low reliability image.

There are, however, effective means to get in control of some of the delay factors while others can be prepared for in the best possible way.

The following measures are to be taken to increase reliability:

- * availability of the ship under all weather conditions
- * highest ice class (for the Baltic Sea and Botnic Gulf)
- * good performance in ice
- * special agreements with Ice Management of S.A.S.N. to acquire optimal assistance when operating in the ice
- * agreements with road hauliers to offer substitute transport in case problems arise.
- * avoid excessive lay time by being time independent of any activity involving the engagement of non-shipping personnel (shifts, strikes, unavailability, etc.)
- * weather independent terminal operations.
- * avoid complex technology.

CUSTOMER SATISFACTION

In the present situation it is rather complicated to organize a sea transport. Many parties are involved in the shipping industry and most shippers have agents taking care of the organization of their transports. From a customers point of view it is much easier to buy land transport, especially road transport, for transporting goods which do not necessarily have a sea-leg.

Shortsea shipping should offer the same attraction to customers as land transport has. This can be achieved by offering a comparable level of convenience, which means taking care of the complete transport from the first moment a customer calls for a transport until the final delivery at the receiver's end.

Customer satisfaction should comprise:

- * central booking and invoicing system
- * full door to door transport, including:
 - positioning/repositioning of cargo units
 - trucking
 - cargo handling
 - sea transport
 - insurance
 - customs clearance
 - administration
 - information
- * shortsea shipping should be a neutral party available to any shipper
- * shortsea shipping should be able to carry a wide variety of standardized cargo units
- * shortsea shipping should have a high compatibility with the existing transport systems at the customer's

SAFETY

From a shippers point of view safety of transport means the arrival of the goods in proper condition and the avoidance of liability problems.

Society interpretes the safety of transport in terms of accidents and damage to nature.

Safety is a subject with many conflicting interests. For example, in respect to the accident rate, shipping has a good safety reputation. On the other hand, the number of handling activities increases, which results in more possible damages to the cargo. Reduction of damage to cargo, which is very well feasible in technical terms, has however a direct influence on time and costs which makes combined transport less attractive.

Aspects of safety from a point of view of society are:

- * reduced long distance road traffic has a significant influence on the number of traffic accidents
- * less dangerous cargo on the roads
- * less social security expenses with respect to disability of long distance truck drivers
- * shipping accidents can be avoided by effective use of traffic control and management systems
- * avoid accidents on terminals by increased safety of handling and reduction of the number of personnel involved

Part II: Shortsea Transport Systems

Aspects of safety from a shippers point of view:

- * the damage to cargo must be reduced by improving the quality of handling
- * become less dependant of human failure
- * condition monitoring
- * simplify the liability issues and reduce premiums and deductibles

ENVIRONMENTAL IMPACT

Expanding land transport in order to cover the demand for additional transport capacity would result in a negative impact on the environment in terms of pollution and direct loss of nature. The energy consumption of a truck (kWh/tonkm) is considerably higher than a ship's energy consumption. The consumption figure of a railway transport lies in between the figures for road and sea transport. Important to notice is that the railways use electrical power which has been generated from primary energy suppliers like oil, gas or coal or in some countries from hydropower. When the consumption of primary energy is concerned the railways perform even worse than road transporters.

White electricity from water power plants is cheap and it is clean in terms of pollution. It has one major disadvantage which is the ruining influence on the original landscape and its flora and fauna.

From an energy consumption point of view, ships perform better than truck and trains while, especially onboard ships, modern technology can be utilized effectively for the purification of exhaust emissions. Sea transport already is the most environmental friendly form of transport today and it also has a good potential for further improvement.

Advantages of shipping with regard to environmental impact:

- * low energy consumption
- * less pollution through low energy consumption
- * less pollution through effective application of purification technology of fuel and exhaust
- * less increase of infrastructure, which means saving of the natural environment
- * less noise
- * less accidents

POLITICAL ACCEPTABILITY

Increasing transport capacity by expanding roads and railways requires heavy state investments and it is not an environmental friendly solution and often requires a leadtime of decades rather than years.

The capital recovery period for investments in roads or railways is very long and the interest payments alone could cover a large part of the annual costs of a complete sea transport system.

If shipping can prove to be a competitive alternative in terms of time, costs, reliability, flexibility, reliability and customer friendliness it would be of great interest to both society and the manufacturing industries to have the politically expressed will to develop a competitive shortsea shipping system.

If economical and commercially viable, shortsea shipping is a safe and environmental friendly solution which offers increased transport capacity in a simple way and a positive contribution to the national economy of a country.

EVALUATION OF CRITICAL SUCCESS FACTORS

Selection criteria

In the previous paragraphs many measures for optimization of the critical success factors are discussed. In potential, each of them represents a positive contribution to the establishment of shortsea shipping as the transport alternative of the future.

Some of these measures, however, improve only marginally the competitive power of shipping while others result in more significant improvements and it appears that some measures have positive effects on more than just one of the critical success factors.

The matrix presentation in Table II shows these relations.

This evaluation of the critical success factors results in a selection of variables to which the successful development of a shortsea shipping system is most sensitive. Criteria for the selection of variables are:

- * the level of impact
- * the order of priority or hierarchy

The order of priority is best explained as the domino effect of satisfying one measure which enlarges the potential reach of the successive measure.

Discussion

When selecting a variable from the left column of the matrix table, it soon becomes clear that some measures have an effect on almost any critical success factor.

In particular the combined measures of providing a traffic control and management system, the formulation of special agreements with third parties and E.D.I. technology are very promising. The special agreements should include new regulations in terms of port and handling charges, special treatment by Ice Management and contract negotiations with land transporters about substitute transport.

	Critical success factors												
	Sailing time	Turnaround time	Hinterland lead time	Capital costs	Running costs	Voyage costs	Handling costs	Flexibility	Reliability	Customer satisfaction	Safety	Environmental impact	Political acceptability
Fast Ship	●							●					
Minimum Crew					●								
Integrated Navigation Systems	●				●				●		●		
Ship Available All Weather Conditions	●	●	●			●	●		●		●	●	
Good Manoeuvring Characteristics	●					●		●			●		
Good Performance in Ice	●					●		●			●	●	
Time Independent Operations		●	●			●	●	●					
Minimum Engagement Shore Personnel		●	●			●	●		●				
Standardized Compatible Cargo Unit		●	●	●			●	●		●			●
Automated Cargo Handling		●	●				●	●	●		●		
Automated Stowing and Lashing		●					●	●	●		●		
Automated Mooring		●				●		●	●		●		
24 hours Truck Docking Facilities			●				●	●	●	●			
Quick Supply, Disposal and Cleaning		●	●		●		●	●			●		
Weather Independent Terminal Operations		●	●			●	●	●	●	●	●		
Avoid Damage b.m.o. Quality Handling		●	●					●		●		●	
Traffic Control and Management Sys	●		●		●		●	●	●		●		
Tight Sailing Schedules for Optimal HTP ¹		●	●										
Special Agreements Third Parties	●			●	●	●	●	●			●		
Central Booking & Invoicing System					●	●	●			●			
On Line Information Supply by EDI			●		●	●	●	●	●	●	●		
Full Door To Door Service								●	●	●			
Neutral Party available to all Shippers				●					●	●	●		●
Minimum Shore Organization		●	●		●			●		●			
Planned Maintenance Systems		●	●		●				●		●		
Avoid Complexity of Design				●	●				●				
Use Existing and Proven Technology				●	●				●				
Low Fuel Consumption						●						●	●
Exhaust Purification					●							●	●
Use Existing Maritime Infrastructure	●			●	●						●	●	●
Reduced Long Distance Transport			●					●	●		●	●	●
Less Dangerous Cargo on the Roads											●	●	●
Less Social Security Expenses													●

¹) HTP = Hinterland Transport Planning

Table II: Matrix presentation of Critical Success Factors

Turnaround time and hinterland leadtime are affected by many measures and the matrix table shows that they also affect voyage costs and cargo handling costs. In fact all measures which eliminate shore labour show good potential of making shipping attractive in terms of time and costs.

When part of the mission is to reduce unit costs, the design, construction and use of the vessel itself should also be considered. This, however, basically relates to the capital and running costs and with today's technology only marginal improvement can be achieved.

CONCLUSIONS

The foregoing evaluation of the critical success factors leads to the conclusion that measures which minimize shore labour (stevedoring) have the largest potential for improving the competitiveness of short sea shipping.

Port authorities and stevedoring companies are willing to co-operate because port activities will increase through a competitive shipping system as it attracts cargo, which otherwise would not be transported by sea. This will compensate to some extent the loss of jobs through increased productivity of the stevedoring operation.

Time independent methods for the ship/shore transfer of cargo are expected to lead to the most significant time and cost saving improvements. Automation of the respective on-shore and the on-board cargo handling processes will contribute to further reduction of time and costs.

New applications of existing technology in combination with innovative developments are necessary to realize such time and cost saving cargo handling systems.

Once a time independent and automated cargo handling system has been developed the design of an advanced vessel can be initiated, incorporating all other cost, time and environment saving features it should offer.

The technical feasibility of such a system is dominating although the total competitive strength very much depends on the re-structuring of the goods transport industry as a whole.

Part II: Shortsea Transport Systems

In conclusion; the key-critical success factors of a competitive shortsea shipping system are:

- Time independent cargo handling
- Employ shore labour from 9h/17h only
- Automated cargo handling on board, at the terminal
- New agreements with third parties
- Develop E.D.I. and central booking
- Develop traffic control and management
- Environmental en social costs increases of other modes

CHAPTER 7: STANDARDIZED CARGO UNITS

REASONS FOR STANDARDIZATION

Man has been experimenting with standardized cargo units since the dawn of commercial history. The merchants who first sought to improve cargo handling and protection by placing two parcels in the same crate or using sealed amphorae took the earliest steps towards cargo standardization as known today.

Over the centuries other attempts have been made to simplify cargo movement and consolidate shipments into larger, standardized parcels. However these efforts usually were defeated by limitations in the technology of cargo-handling and movement.

The use of standardized cargo units (especially containers) meant that 'intermodalism', the movement of goods from point to point by more than one mode of carrier, became commercially feasible.

Another aspect of intermodalism is increasing competition among modes.

AVAILABLE STANDARD CARGO UNITS

Shortsea shipping must reach out all the way to the shippers and the receivers. In order to obtain total flexibility in the system, it should be possible to carry out their transports by means of the different modes of transport like road, rail and sea. The loading and discharging system, between the different transport modes, must feature a fully mechanized and automated handling system for cargo units.

The system should be designed according to the conditions for road transport and based on readily available road transport units.

For a competitive shortsea shipping system it is not desirable to introduce a new type of standard unit, because it would:

- * demand a higher degree/level of acceptance of the system by the customers
- * demand transformation of the customer's transport system
- * introduce extra costs for purchasing new units

Part II: Shortsea Transport Systems

The cargo unit, which will be used in the system, should at least meet the following requirements:

- * it must be standardized
- * it must allow on-going intermodal transport
- * flexible in accepting different kinds of cargo
- * the handling of the unit should not require manpower which means that automated loading and discharging of the unit must be possible.

Following the above the options left are:

- containers
- swapbodies

Trailers, which are designed for land transport, are not suitable for shortsea shipping, as trailers cannot be loaded and discharged automatically, not even partly.

Terminal equipment, like mafi's and cassettes, don't fulfill the requirement of being intermodal. This type of equipment is designed for sto-ro operations and as such, they cannot be considered as suitable standardized cargo units.

On the other hand, this kind of equipment could be very useful as part of the cargo handling system itself, which will be discussed in the following chapter.

DESCRIPTION OF THE STANDARD CARGO UNITS: CONTAINERS

Acceptation

Soon after its introduction in 1955, it became clear that the container was the solution for a great deal of the problems the transport world was facing.

Lower unit-costs were achieved and the total transport time was reduced. These are the success factors of the container which caused worldwide acceptation and utilization of the unit, resulting in a quick increase in the number of containers. At present the total volume has reached more than 7 million TEU world wide (figure published by Japan Container Association).

Standardization

The international operation of the container makes it essential that standardization and certification is internationally accepted. The adoption of ISO requirements for construction dimensions and safety testing is in operation internationally and containers manufactured to ISO requirements are universally accepted. The standard ISO 20 or 40 ft container is a compromise between the ocean carrier, for whom it is too small, and the shipper and inland carrier for whom it is sometimes too big. This is the reason why modifications of the standard containers are coming on the market, offering non-standard heights and lengths.

Some transport companies in the USA have begun to buy containers bigger than the present ISO containers.

A new working group has been established within ISO Technical Committee 104 to deal with new container dimensions. In this working group container lengths of 45 ft, 48 ft and even 53 ft have been discussed and are presently built. All these containers have a width of 2.6 m and a height of 2.9 m.

However, calculations to find an optimum outer length of a future container with regard to unit loads (pallets) widely used in Europe, i.e. unit loads of the basic dimensions 800 x 1200 mm and 1000 x 1200 mm, result in a length of 14.8 m, nearly 49 ft.

Dimensions and payload

If the ISO code is taken as a standard, table III gives sizes and ratings.

ISO Designation	Length		Width		Height		Rating MGW* ton
	ft	m	ft	m	ft	m	
1A	40'	12.19	8'	2.44	8'	2.44	30
1AA	40'	12.19	8'	2.44	8'6"	2.60	30
1B	30'	9.13	8'	2.44	8'	2.44	25
1BB	30'	9.13	8'	2.44	8'6"	2.60	25
1C	20'	6.06	8'	2.44	8'	2.44	24
1CC	20'	6.06	8'	2.44	8'6"	2.60	24
1D	10'	3.00	8'	2.44	8'	2.44	10

*) MGW stands for maximum gross weight

Table III

Different types

Containers appear not only in different sizes but also in different types which make them suitable for a great number of cargo varieties. Within the ISO framework containers of the following types can be distinguished:

- **General cargo**
 - * closed
 - * open-top
 - * open-side
 - * open-top, open-side
 - * open-top, open-side, open-end

- **Thermal containers**
 - * refrigerated
 - * insulated
 - * heated

- **Tank containers**
 - * bulk liquids
 - * compressed gases

- **Bulk containers for the carriage of powders**

- **Platform containers**

- **Platform-based containers with:**
 - * incomplete superstructure and fixed ends
 - * incomplete superstructure and folding ends
 - * complete superstructure and open sides

Handling

All the different types of containers, have all the same spacing of the cornerfittings. The cornerfittings on top of the container allow very easy top-lifting of the unit. Another feature of the container is that it is stackable. This enables vertical cellular stow aboard the ship and multiple layer stacking at the terminal. With the lo-lo method containers can be handled very efficiently and reduction of storage place can be achieved.

The features as mentioned above make automation of container handling possible. The ECT in the Netherlands has a completely automatic container handling terminal which is in operation now and works very well (Figure 40).

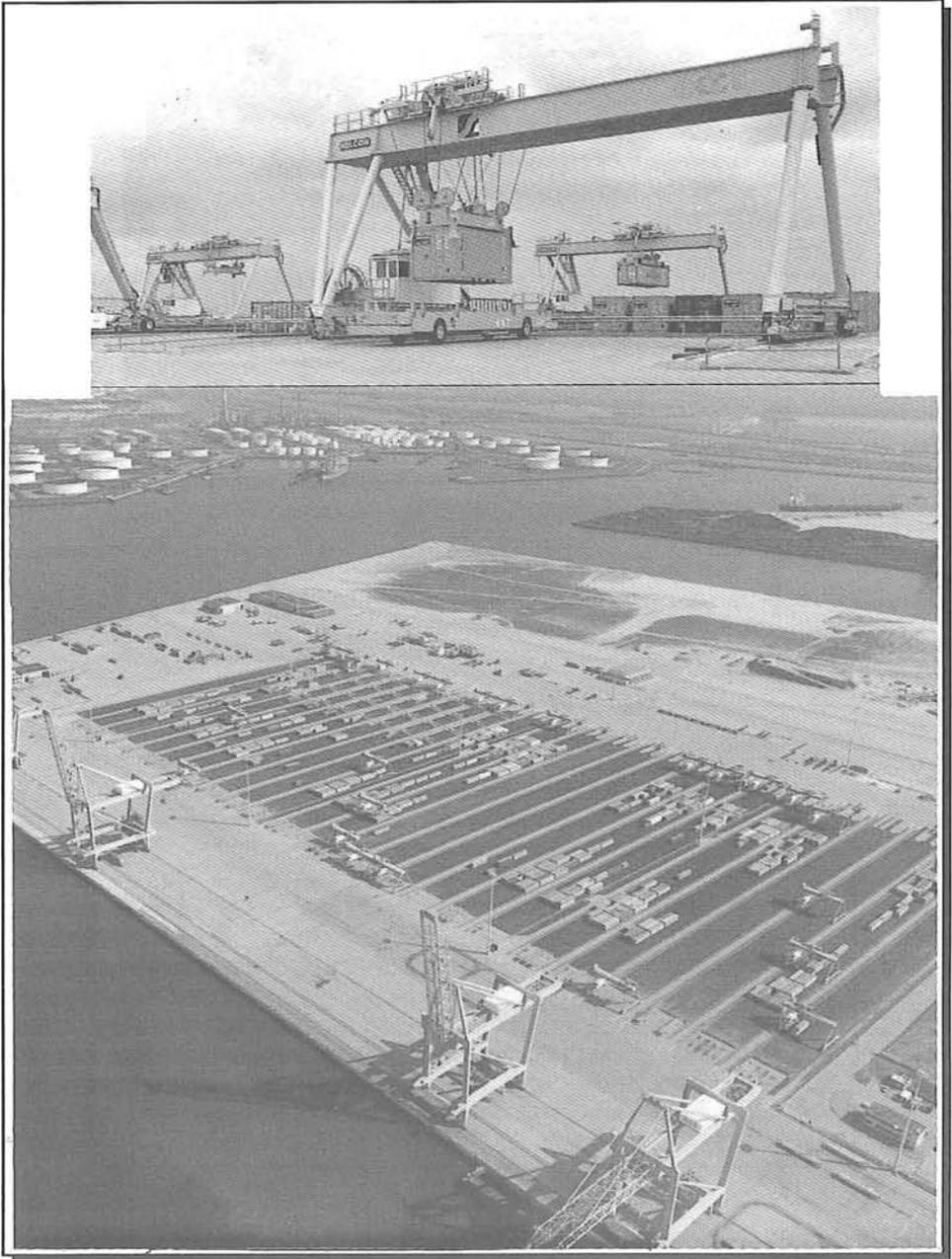


Figure 40

DESCRIPTION OF THE STANDARD CARGO UNITS: SWAPBODY

Acceptation

In the late 1960's, a common swapbody standard had been developed in Germany. The swapbody standard adopted as many features of the ISO container as possible. So the railway terminals could transfer this swapbody from road vehicles to railcar by the use of the same lifting equipment which was already installed for container transport.

When in the beginning of the 1970's the swapbody and other means of piggy-back transport were introduced in international traffic in Europe, the main means of cargo movement was the semi-trailer. This type of road transport equipment was readily available throughout in Europe, so that piggyback services could be introduced without major additional investments. Until then swapbody systems had been limited to, at least with regard to intermodal traffic, West Germany, the Netherlands and Austria.

The swapbody system had been of minor importance in the beginning, but today it caters for more than half of all intermodal road/rail movements in Europe.

At present the swapbody is only very modestly transported by sea. Not the different outer dimensions are the reason that the swapbody is not utilized by shipping yet, but the poor handling characteristics.

If used by sea transport, it is used like a trailer in ro-ro operation, as a semi-trailer swapbody combination. The advantages of a swapbody compared to a trailer, less space requirement and easy lashing, have by then disappeared (Figure 41).



Figure 41

Standardization

The European authorities in Brussels have taken the first steps towards standardization of swapbodies to ensure European compatibility of the unit. As a result of these endeavours, a technical committee on the standardization of swapbodies has been established within the framework of the European Standardization Committee, CEN TC 119.

CEN TC 119 has been working towards a technical compromise between the different features of road and rail throughout the countries of the European Community and the European Free Trade Association. The maximum outer dimensions however differ between various European countries. Because swapbodies evolved in continental Europe and the road and rail regulations comply reasonably well with one another, these form the settings for the swapbody standardization.

The width of the European unit has been fixed at 2.5 m without any additional tolerance. This is a result of the current European regulation on maximum road vehicle width in international movement. For the height, a value of 2.67 m (C 22 standard) has been taken as the present maximum for carriage on certain rail lines with loading gauge restrictions. Higher swapbodies may be used if rail transport can be ensured without difficulties. The task to find a technical compromise has also been complicated by recent technical developments. One of these developments originates in the road vehicle manufacturing industry. In this industry, technical research has been carried out with a view to enlarge the carrying capability of a road train within the given legal framework which prescribes its maximum outer dimensions.

This research resulted in systems of short coupling devices where the distance between the truck and the trailer has been reduced from 1.50 m to some 0.80 m. Some 70 cm could be gained and added to the length of the loading compartment. Further technical alterations led to a shorter driver's cabin with a length of some 1.50 m (Figure 42).

The short driver's cabin and short coupling device led to:

□	1.50	cabin
□	0.80	coupling
□	7.82	truck loading length
□	7.82	trailer length

□	17.94	total length

Such a vehicle can carry 19 pallet loads of 800*1200 mm in the truck and an additional 19 in the trailer.

Of course, the piggyback people try to gain the same transport features to be competitive against road transport. This has led to the decision to standardize,

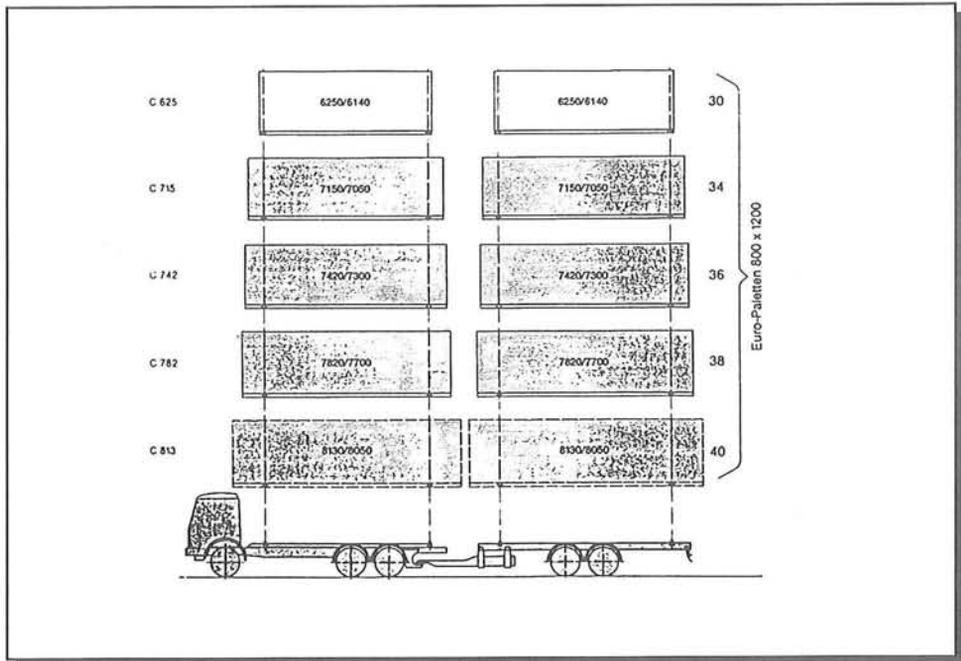


Figure 42

in addition to the most frequently used swapbody of 7.15 m length, a larger swapbody of 7.82 m length.

For those operators who wish to continue to use conventional coupling systems or longer driver's cabins, a compromise size of 7.42 m length has been included in the standards.

For the articulated vehicle, the European length regulation gives an overall length, including the truck, of 15.5 m. This results in a swapbody length of 12.5 m for that road vehicle. Additional to that, a length of 12.2 m, this equals 40 ft, has been suggested to be included in the standard on swapbodies.

CEN TC 119 has to look ahead of these developments, even so far as the legal framework of road sizes in Europe is concerned. It has at least the duty to do its best to try to keep the container standards and swapbody standards as close to each other as possible to enable the transport industry to use the same type of transport and handling equipment for both transport systems.

The 49 ft long container adds another interesting point of discussion for a long term concept of swapbody development, taking into account the following factors:

- * this length divided in two equal modules is exactly the size of the proposed European standard swapbody of 7.42 m length.

- * Two 7.42 m swapbodies can be placed on a road train without further technical difficulties on a road train. The outer dimensions of this road train keep perfectly within the continental European road regulations

In Sweden the regulations (bear in mind the generous road regulations in Sweden at the moment: 2.6 m width, 24 m length and 60 tons gross weight) still differ from those which are adopted by the European Standardization Committee.

At present it is standard practice to operate a 12.5 m trailer with a 7.15 m drawbar unit in Sweden. The road train takes this one step further, allowing the operation of three 7.15 m units, two on the trailer and one on the dolly. Obviously it would be a simple matter to use the equipment for container operation, either one 40 ft plus one 20 ft or three 20 ft units (Figure 43).

This makes the swapbody with a length of 7.15 m the most rational swapbody to be used in Sweden. Furthermore it should be recognized that 98 % of all swapbodies are of the C715-type.

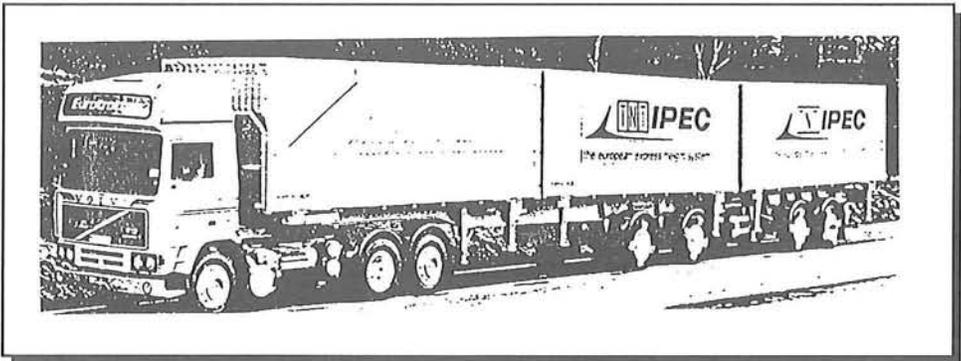


Figure 43: Swedish roadtrain

Dimensions and payload

In July 1991 the CEN standard, EN 283, for testing swapbodies was published followed by EN 284 in February 1992.

These standards concern swapbodies of class C (bottom fittings positioned according to the specification for 1C, 20 ft, ISO-containers).

The standard for swapbodies of class A, bottom fitting spacing 40 ft, is still in design by CEN TC 119. (The proposed standard, is prEN 452) Sweden as a CEN member is bound in accordance with the common CEN rules to implement these European standards (Figure 44).

The EN 284 gives the sizes and ratings as given in Table IV.

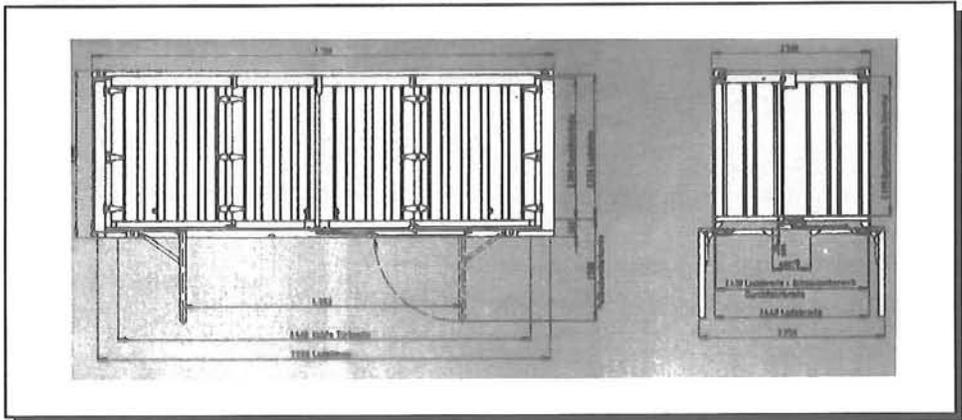


Figure 44

Swapbody designation	Length m	Width ¹ m	Height ² m	Rating MGW ³ ton
C 715	7.15	2.50	2.67	16
C 742	7.42	2.50	2.67	16
C 782	7.82	2.50	2.67	16
Class A	12.19	2.50	2.67	34

- 1) A maximum width of 2.60 m is permitted for thermal bodies
- 2) A height of 2.67 m complies with the international railprofile except for England and Ireland where 2.55 m is maximal
- 3) MGW stands for maximum gross weight

Table IV

Different types

Just like containers swapbodies come in many types and appearances. The EN 284 standardizes the following swapbodies:

- * General cargo
 - closed
 - open sided
 - curtainsider
 - drop sided
- * Platforms

Available swapbodies but not yet internationally standardized:

- * Thermal, maximal width 2.6 m
- * Tanks, may have different ratings
- * Collapsible swapbody, normal height 2.67 m and collapsed 42.5 cm
- * Stackable (max 3 high) and top-lifted swapbody

Handling

Because Swapbodies evolved in continental Europe, where there are only one-high stacking trains, swapbodies tend to be soft topped and thus non-stackable, needing bottom-lift transfer throughout. However like all containers in common circulation around the world, the European swapbody is secured to its rail wagon or road chassis by bottom cornerfittings spaced according the nearest ISO dimensions.

Swapbodies can be handled by trucks, trailers etc with hydraulic- or air-suspension, see Figure 45. The swapbody stands on its legs and the truck can drive beneath the unit. When the twistlocks are in position with the bottom-cornerfittings, the semi-trailer can lift the swapbody of the ground. The twistlocks can be fastened, the legs fold in and the swapbody transported. At the customer's premise this can be done the other way around. The major advantage of the system is that this procedure can be done by the truck driver alone. This makes it possible to pick up the swapbody and to deliver it without being dependant on the terminal cranes and/or stevedores.

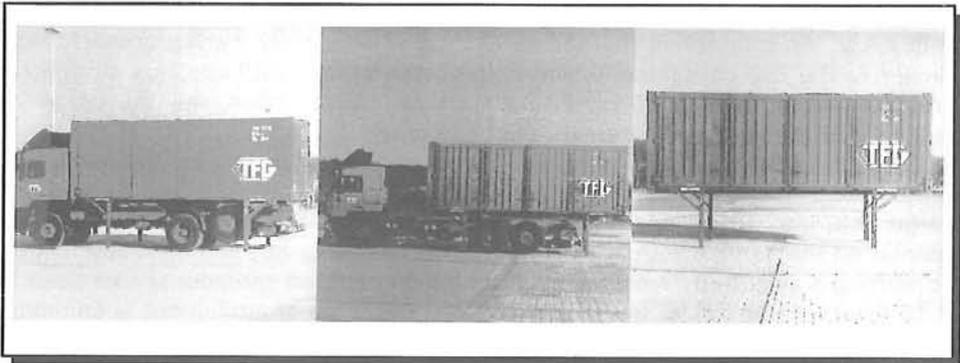


Figure 45

The swapbody is also transported by rail and for this matter the lifting system as described above is not very convenient. So another possibility to lift the swapbody had to be adopted. The solution is found in the piggy-back system where the swapbody is lifted by means of grabber arms, see Figure 46. To make this

Part II: Shortsea Transport Systems

kind of lifting possible the swapbody is equipped with four grabber arm lifting areas.

Problems occurring with grabber-arm lifting are:

- * safety; failures of the locking system result in accidents and/or-damage
- * automation; detection of the grabber-arm lifting areas is very hard to perform automatically



Figure 46

Due to these problems other ways for loading and discharging the swapbody are necessary. An alternative method is lifting the swapbody by top-cornerfittings similar to the ISO containers which is the most logical solution. This alternative provides the possibility of top-lifting, vertical cellular stow and the usage of standard or adapted container handling equipment.

In order to make top-lifting possible, the swapbody needs to be equipped with top-corner fittings. This changes the swapbody from a soft-topped land-borne cargo unit, into a rigid and stackable cargo unit. The top-corner fittings are not spaced on the same distance as an ISO 20 ft container but at swapbody length. Top-lifting a swapbody would simply require an adapted spreader with a span of 7.15 m or an adjustable, telescopic version. This type of equipment is commonly available.

The possibility of top-lifting a swapbody has the following results:

- * safer loading and discharging of the swapbody by land and rail-transport operators

- * the swapbody requires structural strengthening for top-lifting operations. Simultaneously, this added strength allows stacking of the swapbodies (max 3 high, presently).
- * the combination of top-lifting and stackability provides possibilities for vertical cellular stow
- * the swapbody becomes more suitable for seartransport
- * improved cargo protection

Pro's and con's of the standardized cargo units

Designation	ISO 1C	ISO 1A	C715 STL ³	C715	C742	C782	class A
acceptation:							
availability	++	++	++	++	+	+	
types	++	++	++	++	+	+	
price	+	+					
capacities:							
MGW ¹	24	30	16	16	16	16	34
MNP ²	14	25	17	17	18	19	30
handling:							
top-lifting	++	++	++				
grabber			++	++	++	++	++
stackable	++	++	++				
legs			++	++	++	++	++
total score	/+	/+	++	+	/+	/+	

¹) MGW stands for maximum gross weight

²) MNP stands for maximum number pallets (800 x 1200 mm)

³) STL stands for stackable, top-liftable C715-type

Table V

CONCLUSIONS

In Table V it can be seen that the acceptation and capacities of C-class swapbodies are good. The handling characteristics however are primarily based on road and rail transport.

The class A swapbodies are not commonly used today because the standard is still in design, but it is reasonable to expect that the utilization of these units will grow in the near future.

The price of swapbodies is approximately three times the price of a ISO container, mostly because of the larger production series of containers and the harsh competition between their manufacturers. Projected is that the prices of the swapbodies will come down for the same reasons in the future.

The handling characteristics of the container are not better, though different from the swapbody. For transportation by deepsea, containers are the solution. However short-sea transport is closely related to land transport, where the swapbodies are an attractive alternative. A swapbody can easily be placed at the customer's loading platform, where it can serve as an extension of their warehouses or production floors.

The disadvantages of today's swapbodies are commonly acknowledged which has triggered the development of the stackable and top-liftable swapbody. It is expected that this type of swapbody will develop favourably in the years to come and it is worth noticing that the railtransport operators in Germany already use these units intensively.

As far as shortsea shipping is concerned the C715 STL swapbody is doubtless the most suitable swapbody as it allows rational handling methods similar to container operations.

The C715 STL does not have an ISO standardization but the fact that this easy-handling unit originates from operators who run standard ISO 'compatible' equipment makes this disadvantage less important.

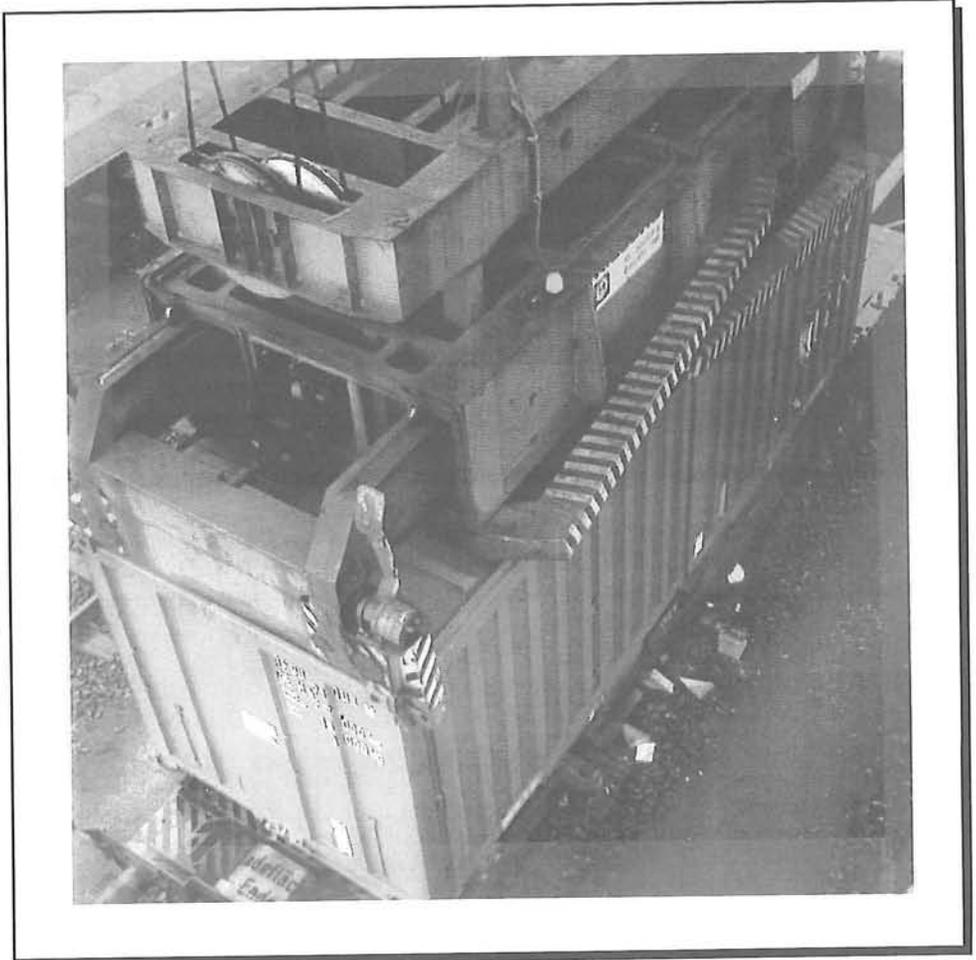


Figure 47: Top-lifted C715 STL

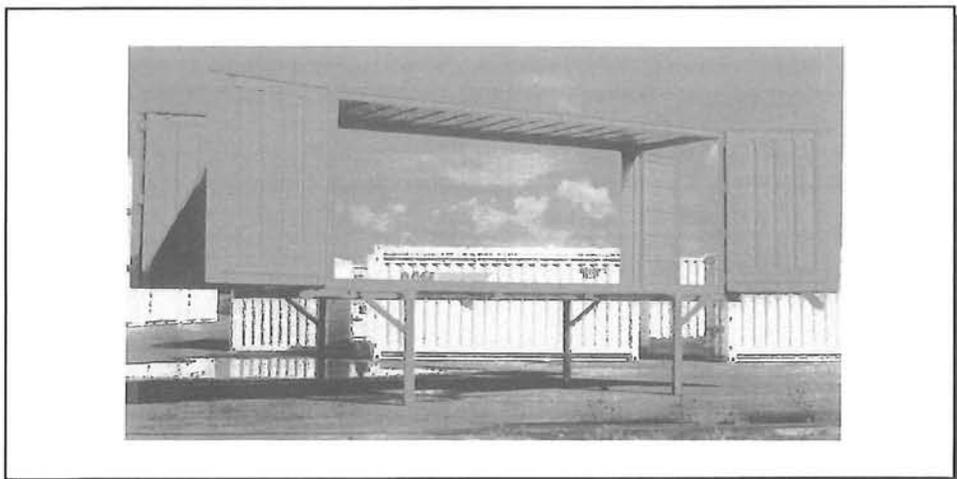


Figure 48

CHAPTER 8: SHIP-TERMINAL CONCEPTS

Reduction of ship-shore moves, economies of scale, time independence and preparation are the key elements of the concepts which are presented in this chapter.

Automation itself is not a critical necessity although it will contribute to reduction of costs. A method for time independent ship/shore transfer of cargo units is the main goal to achieve.

TRANSFER OPERATIONS

Reduction of ship-shore moves, economies of scale

With hindsight, the introduction of the sea going container appears a logical result of a search for rationalization and man power reduction in the days when each individual box, bale, drum, parcel, pallet or any other small quantity of general cargo required separate handling and attention.

The typical bulk commodities were already shipped in dedicated ship types and the introduction of the container allowed the design of special container vessels, dedicated to the carriage of standardized boxes. From a technical point of view the shipment of general cargo in containers became a bulk-alike operation.

History tends to repeat itself and with today's increasing flows of containers and swapbodies there is a growing demand for another rationalization step.

Similar to bringing goods together in a large steel box, the container, it might just well be possible to create large packages of containers.

In that situation each individual ship-shore move represents the simultaneous loading or discharging of a large number of box units in one single operation cycle.

Under the condition that the "scaled-up" loading operation does not require additional labour, a reduction of the average labour costs per box can be achieved due to economies of scale.

Time independence, preparation time

Time dependence of ship and shore is typical for the present container handling methods and requires a high input of labour and fast equipment during a short period of time. Besides the high costs for equipment, it is expensive in terms of man-hour costs, especially during "off-hours" (night, weekend and public holidays). The costs in small ports may easily triple in the weekends.

In contrast to the present handling methods, like LoLo, RoRo, StoRo etc. the time span for preparing the cargo for the loading operation should not be limited to just the ships turnaround time in port.

Part II: Shortsea Transport Systems

The continuity of the terminal operations should be independent of the presence of a ship, which means that loading and discharging should incorporate an intermediate phase which widens the time window.

The physical interpretation of the intermediate phase is the introduction of a new unit which can contain multiple boxes.

The terminal handling methods and equipment do no longer need to focus on the shortest possible turnaround time of the ship but can be optimized for low labour input and slow speed processes for loading or discharging the "Multiple-Box-Unit". This MBU is available at the terminal independent of the presence of a specialised ship.

The time window, originally as wide or as narrow as the ships turnaround time, is split into two half-open windows which provides more time for preparing the cargo for the ship/shore move.

The loading window has a latest time of completion (ships time of arrival) and an open start, while the discharging operation has an earliest start (ships departure) and an open end, depending on the call-frequency.

The result of creating two half-open windows and reducing the time pressure is that less labour is required and that the performance parameters of the equipment become less critical.

The advantages of introducing an intermediate phase reaches its full effect if, and only if, the ship can perform the loading and discharging of an MBU **without assistance** from shore. Consequently, the ship should be of the *self-loading and self-discharging type with the ships crew controlling the operations*.

On-board transfers

Two basic principles can be distinguished once the MBU is on-board the ship, after a self-loading operation performed by the ships crew.

The distinction concerns the question what is done with the individual boxes on that MBU:

- * unpack and re-load the MBU
- * do not unpack and leave the package of boxes on the MBU as it is

Unpacking, on-board distribution and re-loading creates the possibility of sorting out a package which contains boxes with different destinations and subsequently creating a discharging package containing boxes destined for the next port of call.

This type of operation uses the MBU for the one-move-loading method only. The ship will feature vertical cellular stow facilities for containers and swapbodies.

Concepts which are based on the unpacking/re-loading principal are :

- * Super Pallet Loader
- * Unit Loader
- * Train Loader
- * Conveyor/elevator loader

Not unpacking the MBU requires the loading of packages of a homogeneous destination. Either the number of ports has to be reduced or the MBU themselves will be smaller and contain less boxes.

Concepts which are based on carrying destination-bonded packages are:

- * Super Pallet Carrier
- * Six Pack Cradle Carrier
- * Train Carrier

On-shore transfers

The method of loading onto or discharging from an MBU's provides good possibilities for automation because the handling of the individual boxes is entirely carried out on shore. Automatically operating overhead cranes will easily find the boxes on the terminal area because a super pallet, a six-pack cradle, a train and a single unit can be positioned very accurate when the time factor is less critical. The ordinary reach stacker or fork lift truck will be able to do the job in the less advanced terminals. If circumstances allow to do so, the involvement of shore labour (stevedores) should be limited to just the day hours between 09.00 am and 17.00 pm, in order to keep the costs down.

CONCEPTS

We present seven new concepts which incorporate the MBU philosophy. Each of these concepts will be explained and discussed separately.

The concepts which enter the selection process are:

- **SUPER PALLET CARRIER**
- **SUPER PALLET LOADER**
- **SIX PACK CRADLE CARRIER**
- **CONVEYOR/ELEVATOR LOADER**
- **UNIT LOADER**
- **TRAIN CARRIER**
- **TRAIN LOADER**

The super pallet carrier is developed by P.O. Andersson of "SEALIFT Shipping" in Iggesund, Sweden, while the six pack cradle carrier is to a certain extent comparable with CASH-carriers (cassette-aboard-ship), a concept originally drawn by Ahlmark although in its appearance it looks more like the Dock Express heavy lift ships, which feature outriggers and heavy lift gantry cranes.

■ **SUPER PALLET CARRIER**

Containers and swapbodies are packed onto a large "pontoon-hatch-cover" alike pallet which rests on a support structure. This support structure forms a loading platform which reaches out into sea.

All boxes on a pallet necessarily have the same port of destination due to the fact that all boxes on a pallet are loaded or discharged simultaneously.

When half submerged, a vessel with special ballast facilities can manoeuvre underneath the super pallet, a Multiple-Box-Unit, which in that situation still rests on its supports. Discharging ballast will cause the ship to raise. The ship will lift the pallet off the loading platform.

Figure 49 shows a semi-submersible vessel with the wheelhouse amidships. Both fore and aft of the wheelhouse there are two MBU positions.

The discharge of the most forward MBU requires manoeuvring in between the support structure, taking in ballast to lower the ship and positioning of the MBU on the supports.

Discharging a second super pallet requires pulling back of the vessel, discharging ballast to raise the ship until it is clearing the support structure height, manoeuvring in between the second, non-occupied pair of supports, taking in ballast again and positioning of the second MBU.

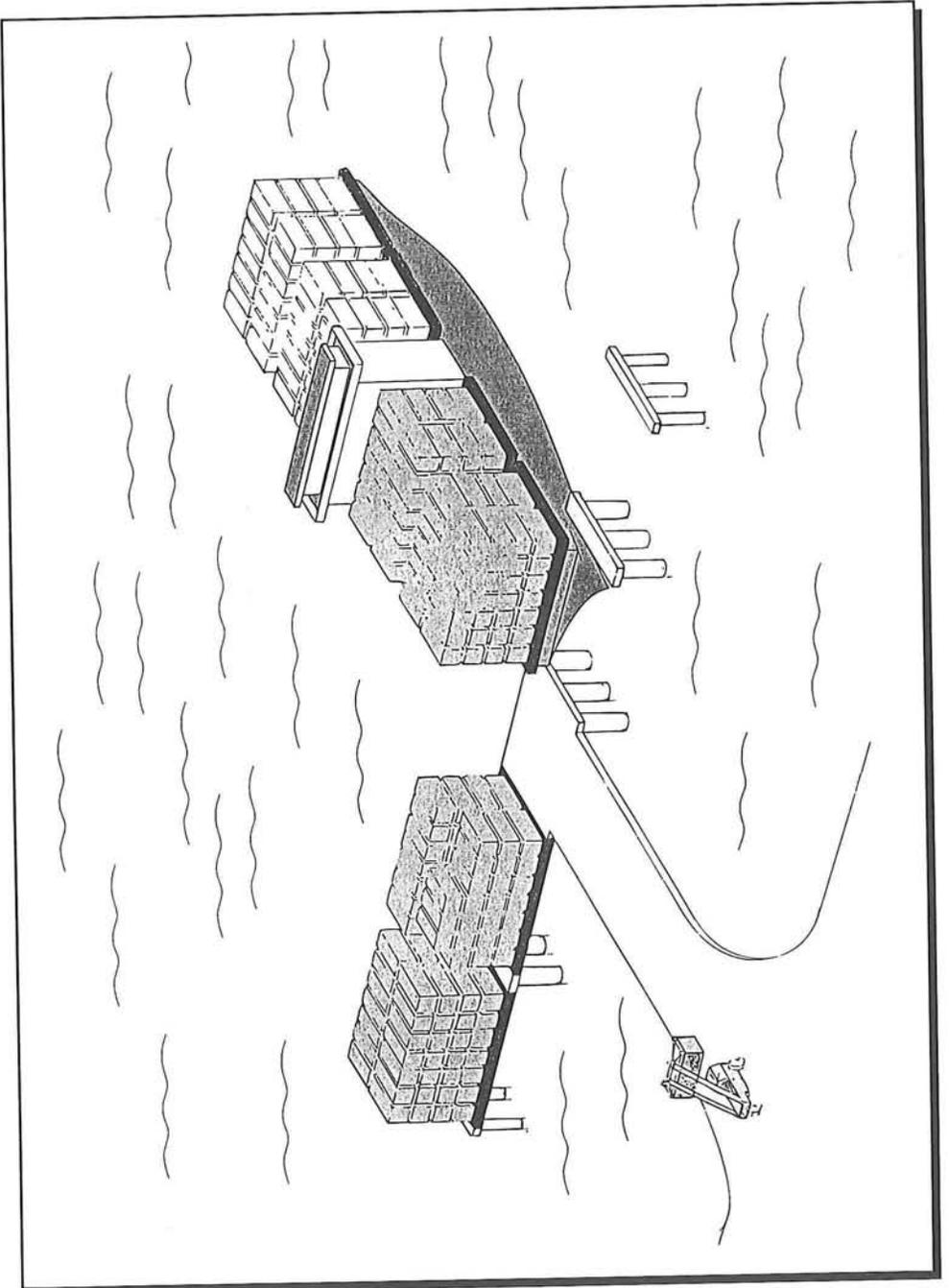


Figure 49: Super pallet carrier

Part II: Shortsea Transport Systems

This same Figure shows a reach stacker finishing the loading of a super pallet. First the outer MBU, far left on the drawing, was loaded. In that situation the other pallet is still empty and acts simply as a part of the loading platform with reach stackers and fork lift trucks driving over it.

Once the loading of the outer MBU has been completed, the loading of the inner super pallet will start.

Figure 50 shows a super pallet terminal with overhead cranes instead of reach stackers and fork lift trucks.

This concept would require as many super pallet positions as there are ports of call in the system. The system would work very well if only a limited number of ports are involved.

■ SUPER PALLET LOADER

Containers and swapbodies are packed onto a large "pontoon-hatch-cover" alike pallet which rests on a support structure. This support structure forms a loading platform which reaches out into sea.

In contrast to the SUPER PALLET CARRIER the boxes on the pallet do not necessarily have the same port of destination.

All the boxes on a MBU are loaded or discharged simultaneously, but once the super pallet is on-board the individual boxes are distributed over the ships vertical cellular stowage area.

When half submerged, a vessel with special ballast facilities can manoeuvre underneath the super pallet, a Multiple-Box-Unit, which in that situation still rests on its supports. Discharging ballast will cause the ship to raise. The ship will lift the pallet out of the loading platform of which the pallet used to be part of.

Figure 51 shows a semi-submersible vessel with a super pallet loadingzone at the aft end of the ship.

Discharging of the MBU requires manoeuvring in between the support structure, taking in ballast to lower the ship and positioning of the MBU on the supports.

This same Figure shows the on-board distribution system. A frame can be lowered above the MBU. This frame contains the extension tracks of the ships internal overhead crane system.

Once the MBU is loaded onto the aft ship, the frame can be lowered and the overhead crane can start the unpacking of the MBU and the distribution of the boxes over the stowage area.

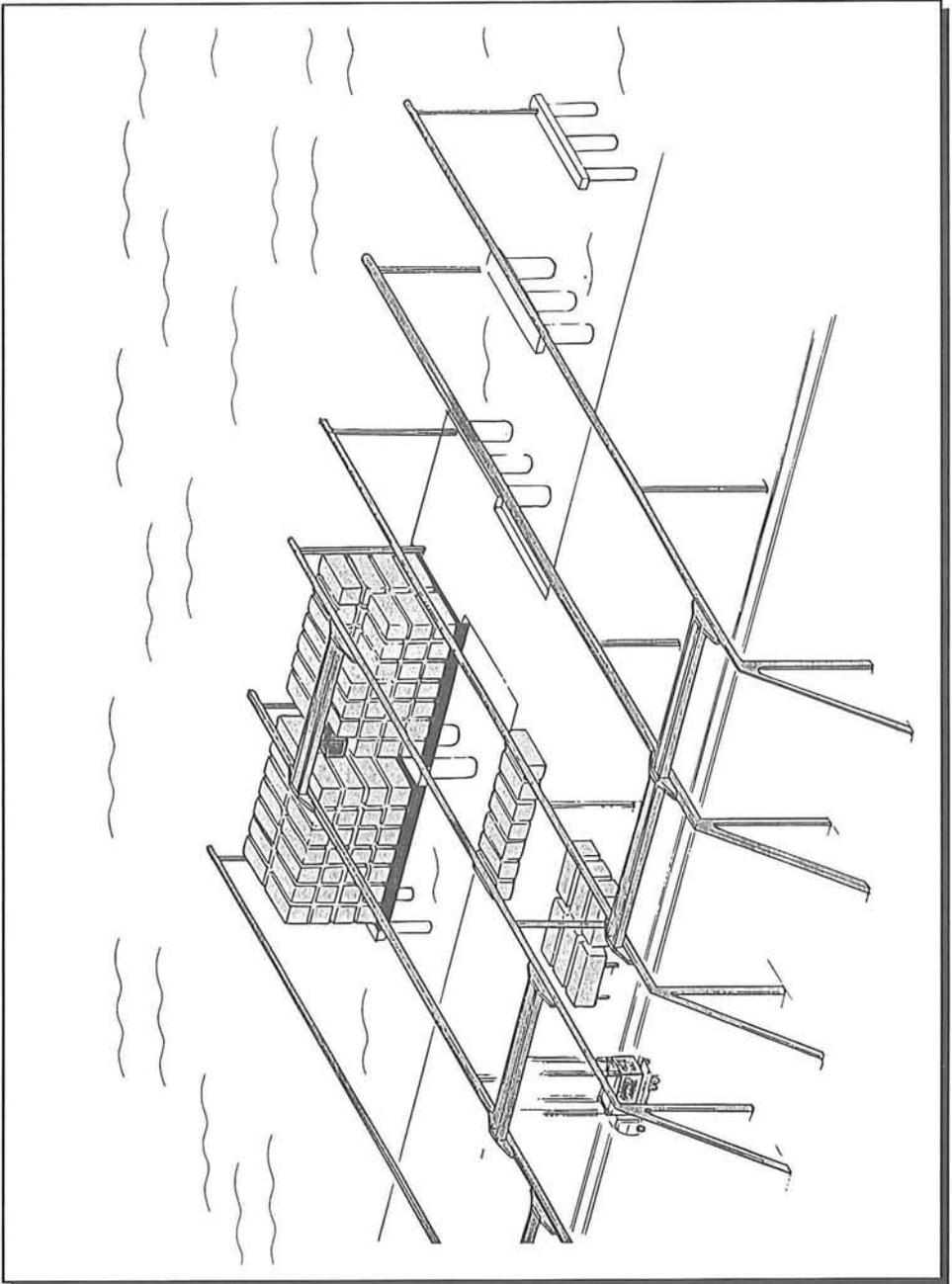


Figure 50: Super pallet terminar

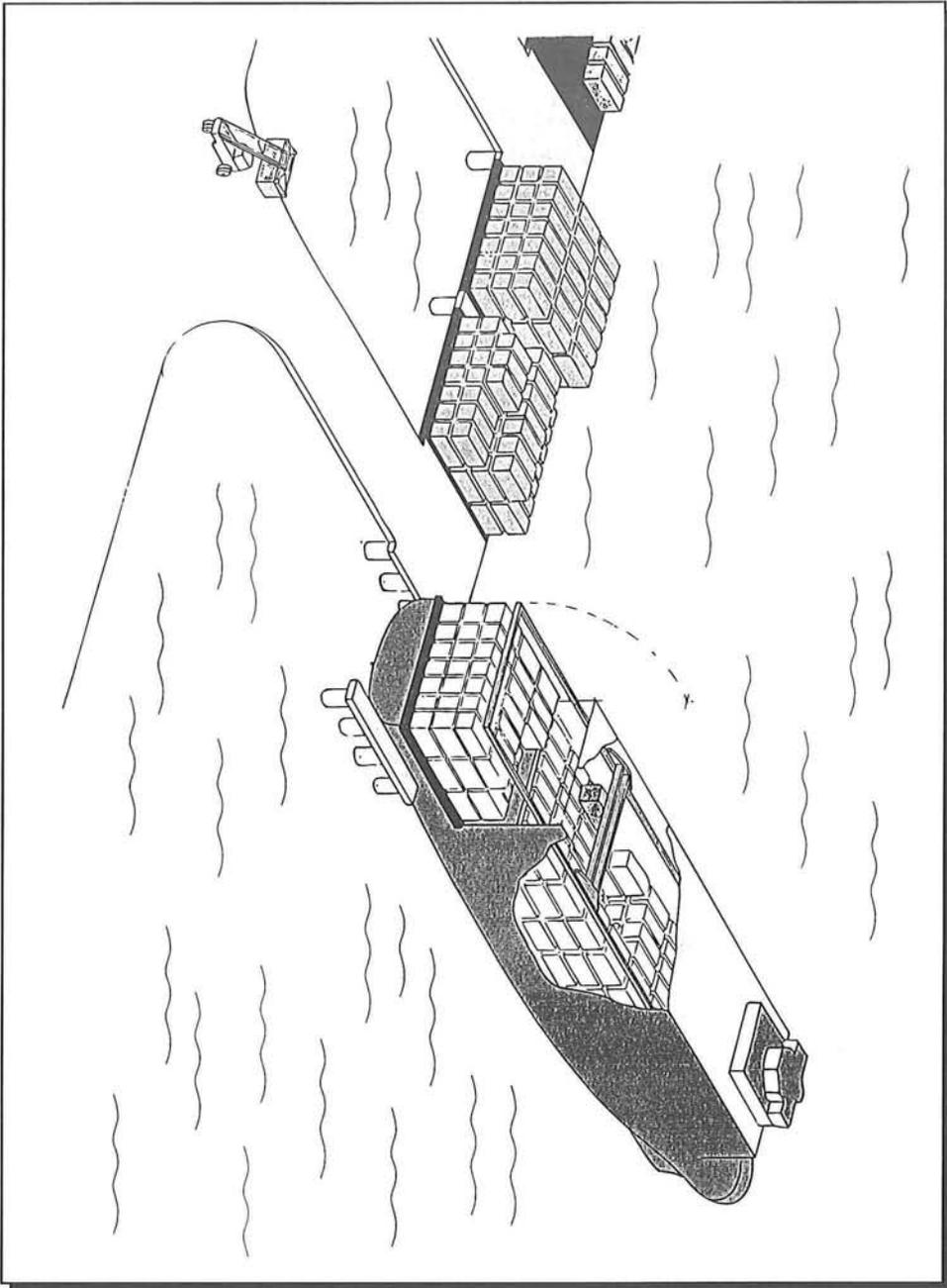


Figure 51: Super pallet loader

This principal of unpacking and on-board distribution system creates the possibility of sorting out destinations and repacking the MBU with boxes destined for the next port of call.

A major gain in turnaround time can be achieved if the on-board distribution can be carried out while leaving or entering port or even when sailing on open sea.

A super pallet terminal with overhead cranes instead of reach stackers and forklift trucks can also be used.

■ SIX PACK CRADLE CARRIER

When many different ports are serviced the destination-bonded packages necessarily become smaller. A package of six boxes on each MBU would provide enough flexibility in sorting out the different ports of destination and still offer the advantages of loading multiple boxes at a time.

Figure 52 shows a ship with a heavy lift overhead crane, which can reach over the quay side due to the outriggers. Dock Express ships successfully use this technology (a.o.) when loading heavy or voluminous project cargo.(Figure 53)

The lifting operation of the MBU, the on-board transport and the positioning is carried out by the heavy lift overhead crane of the ship.

On shore the MBU 's, the six pack cradles, travel on railway tracks. The ship will deliver the cradle in between "cell guide" alike posts which will help the cradle to find its position on the tracks.

The terminal overhead cranes take care of the loading or discharging of the MBU.

The cradles are stackable, 3 high when fully loaded, and also stackable when collapsed for repositioning purposes.

The cradles feature wheels for the rail guided transport on shore.

This concept is inspired by cassette-aboard-ship (CASH), developed by Ahlmark. (Figure 54)

The CASH ship features a single but large container unit to be lifted onboard the ship. The size of the unit has been set to L x W x H, 12 m x 3 m x 3.5 m. The height might differ. Nevertheless, it is not important logistically to evaluate the system just on the basis of the size of the units, as they were not intended to be intermodal in the proposed service.

The system features a cell-container ship served by two parallel operating travelling cranes. The cranes run longitudinally. The geometry will not make it possible for the cranes to substitute for each other in case of a breakdown.

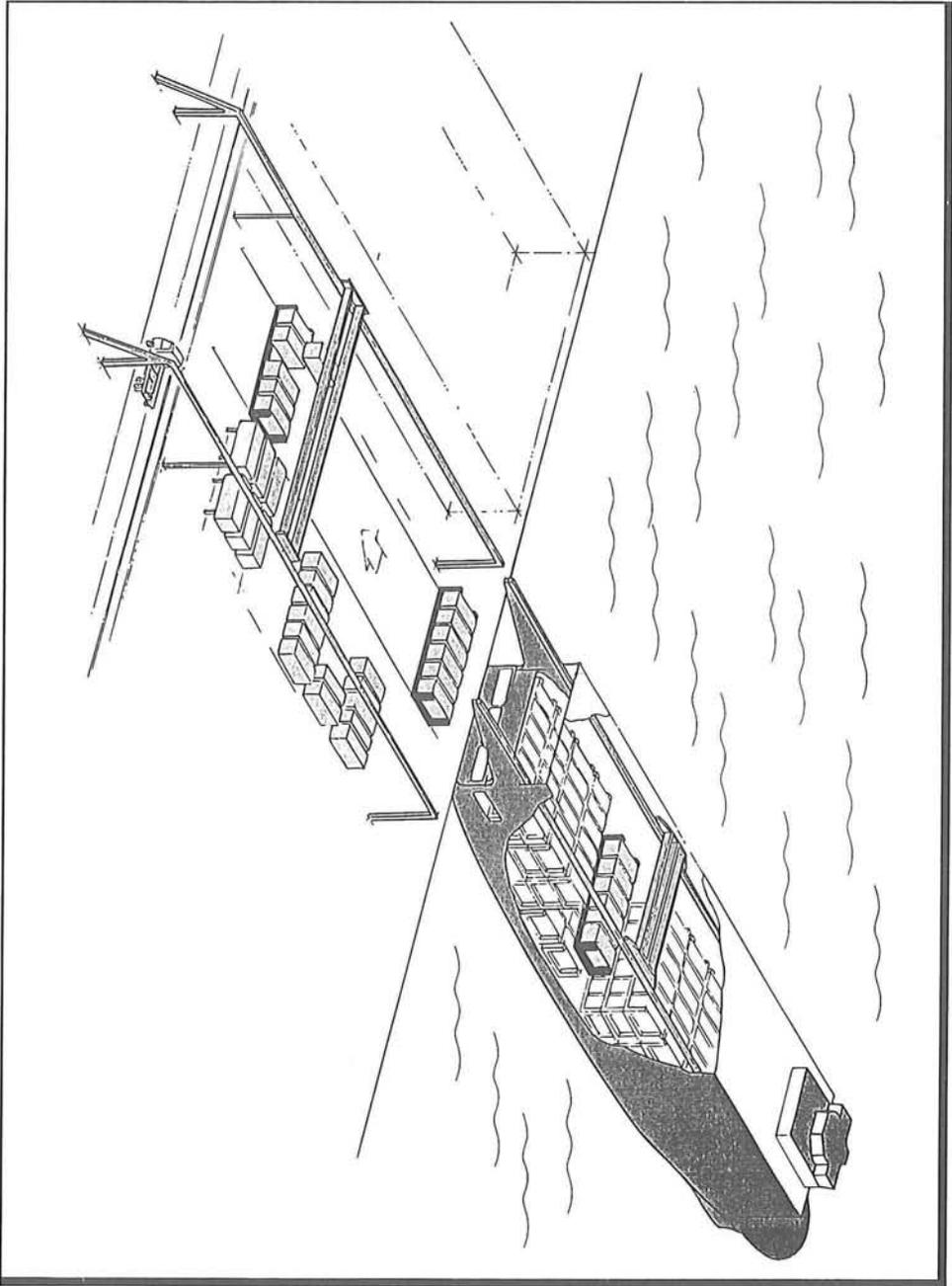


Figure 52: Six pack cradle carrier

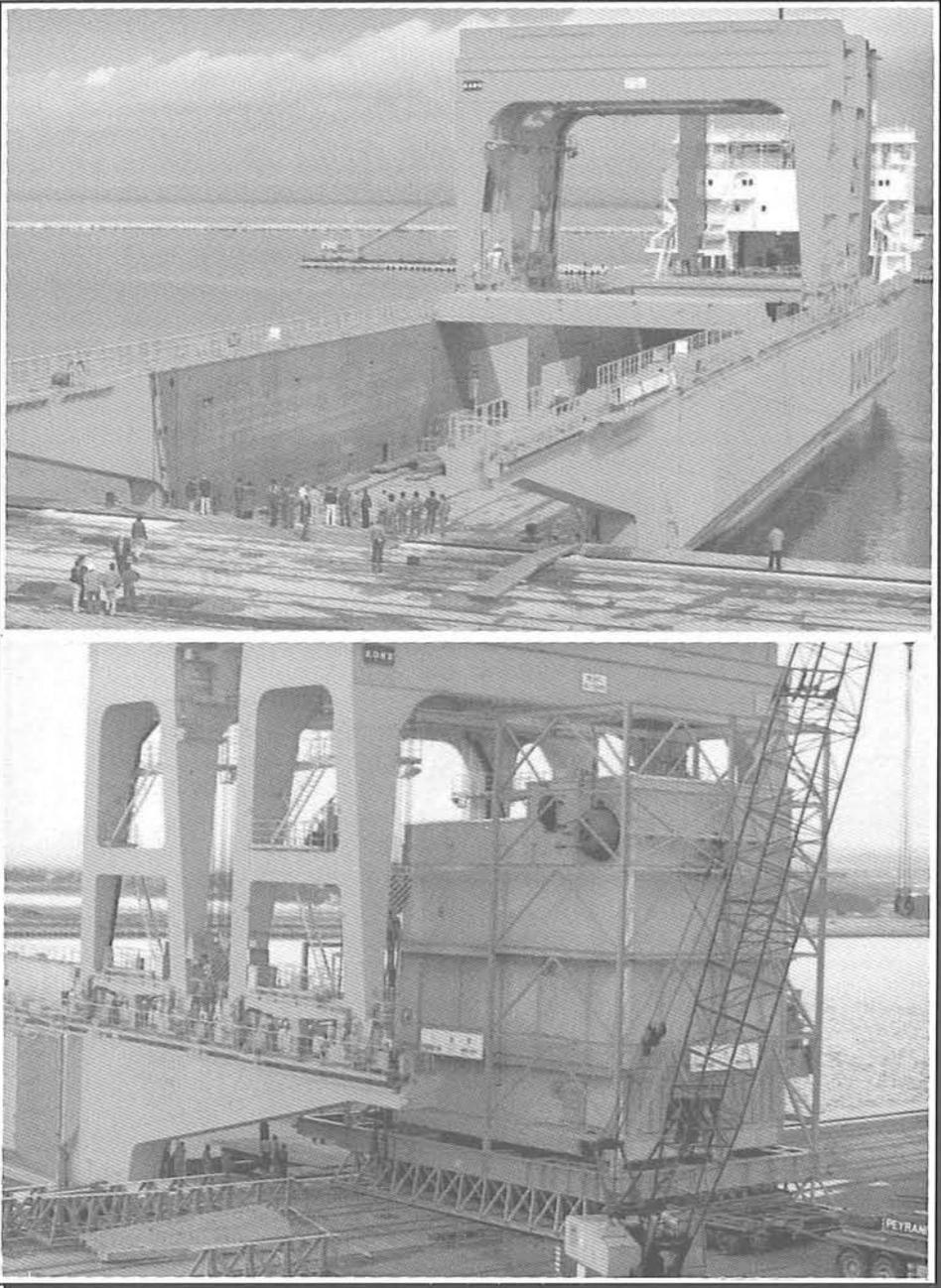


Figure 53

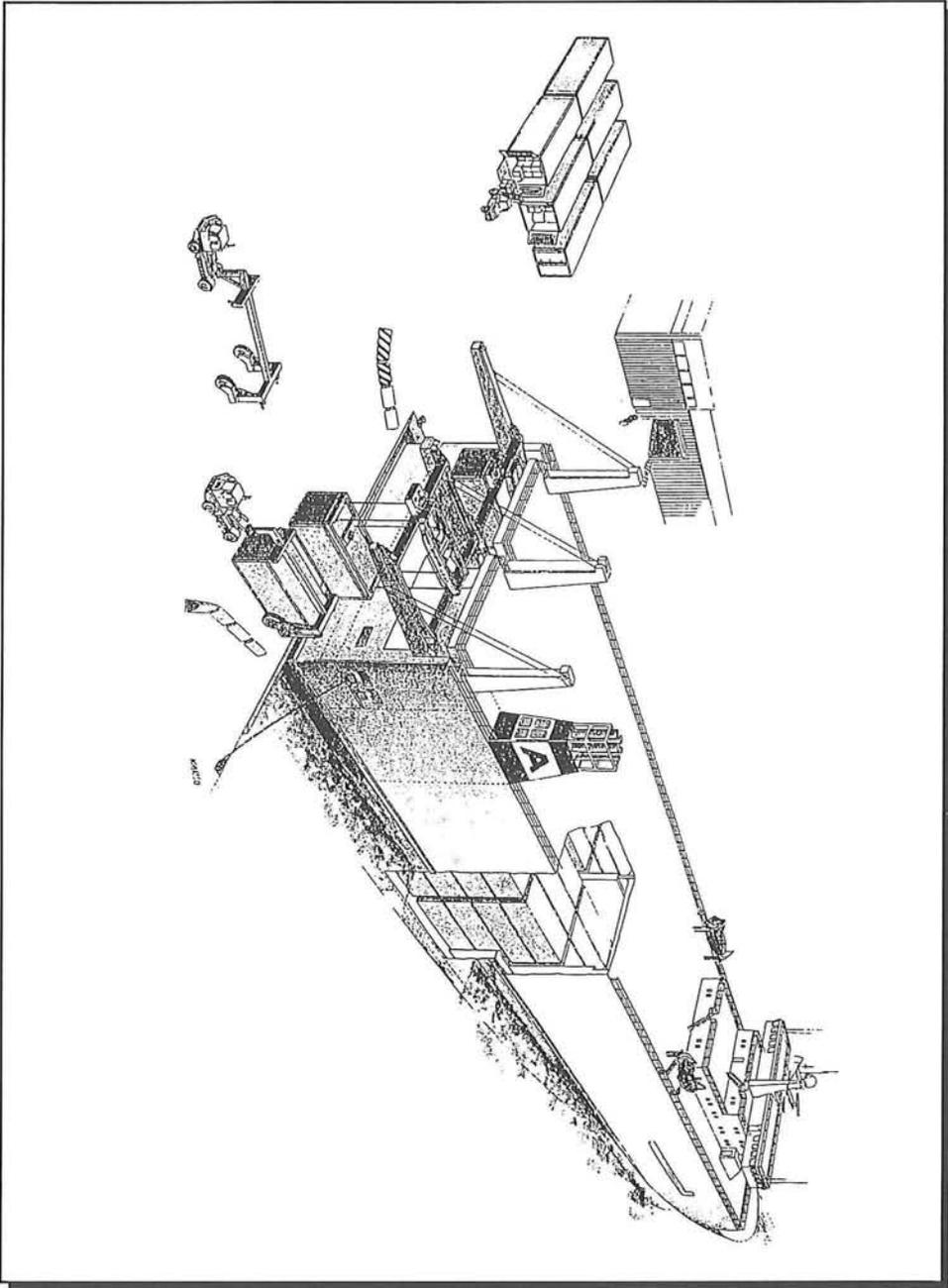


Figure 54

The cranes travel out over the stern of the vessel and handle the units to the quay astern of the ship. This means that the ship must be positioned orthogonally to the quay or in a special berth.

There are a number of pros and cons as regards berthing a ship orthogonally at quay, but most of the aspects are negative. Among the positive aspects may be mentioned easy access in winter and ice conditions, short quay length occupied etc. The negative side is the disturbance that a ship with its full length protruding from a quay side will cause to other ships entering the port. A disturbance will also be caused if fixed mooring attachments like dolphins are to be positioned in the port basin.

There are three major technical problems that must be solved in this type of system:

- * the handling and carrying of non-stackable units
- * the safe lift operation of non-stackable units
- * the terminal operation

■ CONVEYOR/ELEVATOR LOADER

Conveyor/elevator systems are used in for example the Seatrans "Gold River" project, where is it used to transfer paper reels from the warehouse via the apron converted trolleys (conveyor) to the sideport and via the elevator into the hold. (Figure 55)

In the industry and in reefer vessels a number of systems are developed to handle pallets automatically from quay to ship's hold. The equipment is used to bring the units from the quay onboard the ship to be handled by an elevator system which positions them on the right level and lane on the deck.

During the 1960's a number of ships were built which were equipped with an onboard installed handling device to move and stow units in the ship's hold. The most famous of these ships is the Finnflow system vessel operating for Finncarriers. (Figure 56)

Another example of interest is the Transatlantic's "M/S Scandic" which was equipped with a container stowage system in the lower hold. In this ship an RBC (Running Beam Conveyor) system was used, developed by Nordströms Linbanor, today the Babcock Engineering company, Consilium CMH Enköping Sweden. (Figure 57)

As this concept is relevant to this study it will be discussed in more detail.

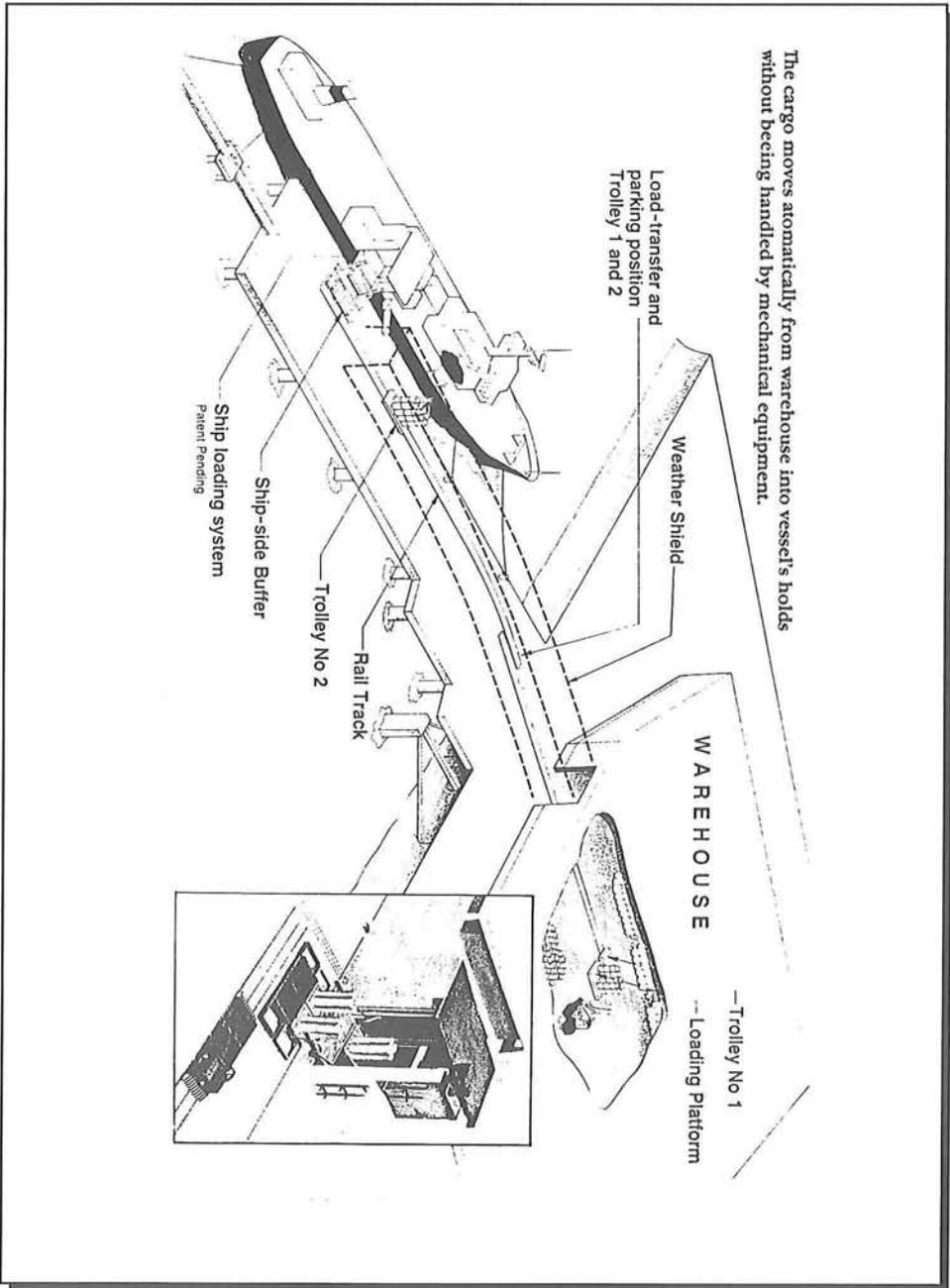


Figure 55

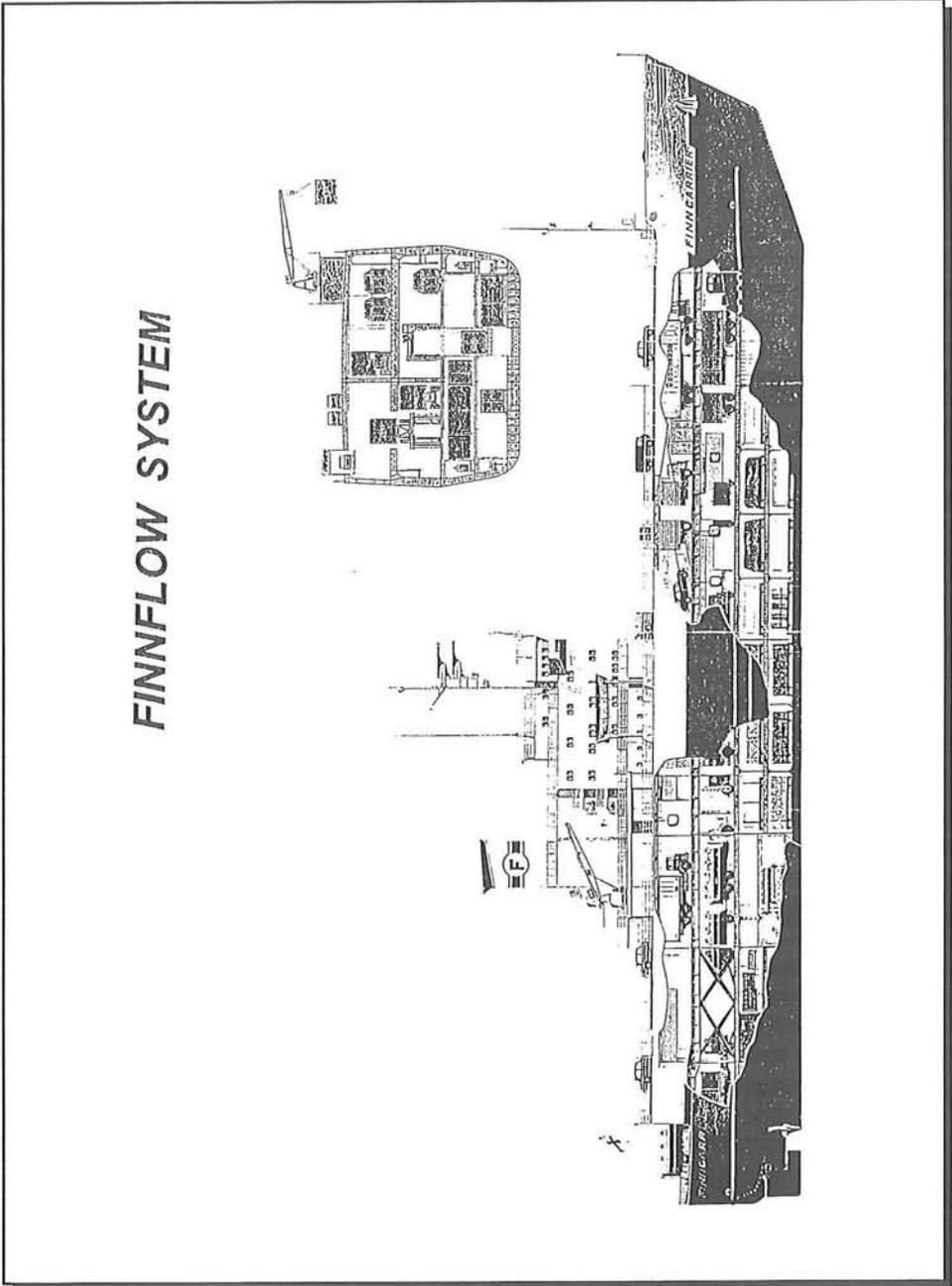


Figure 56

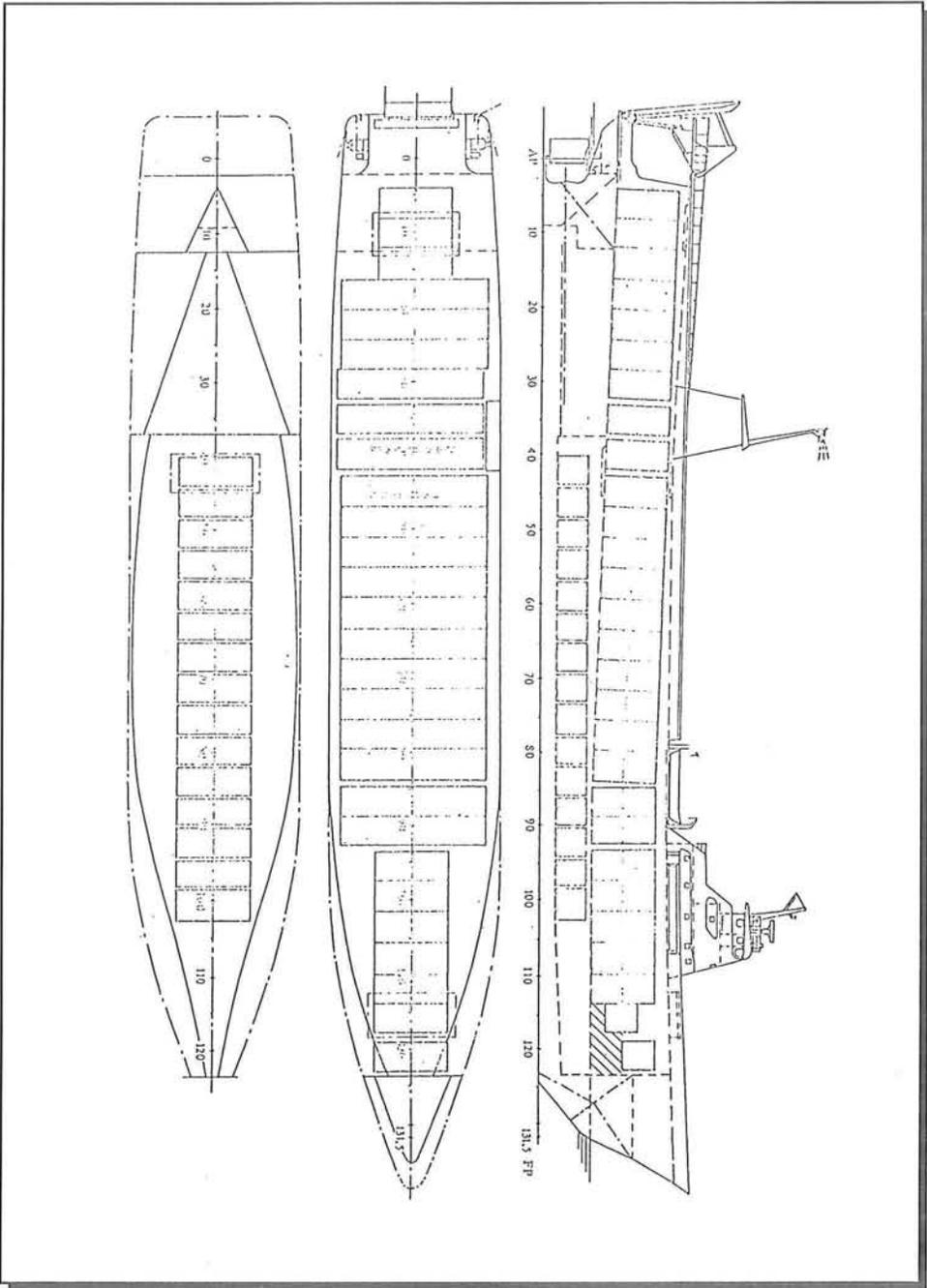


Figure 57

Ms. Scandic

At the end of the 1960's shipping systems were developed extensively. During this period the container was introduced and large investments were made to be able to unitise cargo and to handle the units. The container units made new demands on the shipping systems and the transports around the service.

A number of ships, designed for mechanized handling of containers, were also developed during this period. Terminal equipment for the handling of containers was also developed in different forms. During this period the shipowner Transatlantic in Gothenburg, Sweden invested in an experimental ship named "SCANDIC". The ship became the foundation for the technique of a number of Ro/Ro ships to come. "SCANDIC" was the first Ro/Ro ship which used its stern ramp to free itself from the requirement of service from the terminal to load or discharge the vessel.

The service in the Skagerrak - Kattegatt region by the vessel was based on a deal with the terminals. The ship was allowed to do the handling in terminal upon arrival without assistance from the quay. The ship of 1 700 tdw had a crew list of 11 members working in fortnightly shifts. It carried a 25 ton forklift truck for the handling of containers. The truck was operated by crew members. Most of the terminals allowed the ship to operate itself but a few demanded to be compensated for the loss of work for its stevedores. In Gothenburg the ship was operated by the stevedores.

The ship sailed as a feeder between the ports in the region and the transocean liner services in Gothenburg. Bore Lines developed a parallel service between Gothenburg and Finland which is still in operation.

In the lower hold of the "SCANDIC" a conveyor system was arranged for the automatic stowage of up to 15 pcs of 20' containers. The containers were positioned transversely in the ship. An elevator, arranged transversely fore of the machinery bulkhead, brought down the units to the conveyor system in the lower hold.

The experience of this trade was that the small but very simple vessel was very efficient, mainly due to the fact that the crew could manage the cargo handling. The laytime in port was minimised. The 25-tons forklift truck carried onboard became an efficient tool as the crew picked up the skill of driving it. The productivity could frequently reach 35-40 units per hour. The ship had a capacity of 90 TEUs on Main Deck plus 15 in lower hold which gave the ship very short stops in ports.

The conveyor system in the lower hold was used to fill the ship to last position.

The experience to be gained from the service was that it is possible to use a reliable and simple ship operation system to do the cargo handling operation in a

Part II: Shortsea Transport Systems

coastal service by using the crew to handle the cargo on and off the ship. The ship frequently noted up to 5 calls during a 24 h period. If only a few units were to be handled, the captain would keep the ship's ramp on the quay by using the thrusters without further mooring, and during this time the containers were shifted on and off the ship.

The "SCANDIC" service came to an end after 5 or 6 years of operation due to the cost of the total system. According to the managers and captains of the ship it was a political decision on the part of the operator which terminated the operation. It was probably due to the fact that the cost of unitising the cargo was put on the feeder ship's account, which made the cost account too high for the vessel. In this way it lost its service to the rail and road services. In their opinion the feeder traffic was far more efficient than other competing land transport alternatives. A number of jobs carried out by the vessel showed the flexibility of the service.

The service was closed down due to a reorganization of the transport system where the ocean going ship visited more ports, thus eliminating the need of a feeder service.

■ UNIT LOADER

From a concept point of view the Unit Loader, shown in **Figure 58**, is a hidden variety of the Super Pallet Loader. Instead of loading an MBU and subsequently starting the distribution cycles on-board this ship simply extends its on-board distributing system onto the terminal area by linking the railway tracks of the overhead crane.

The "Multiple Box Unit area" of the terminal features special positioning equipment which helps the travelling overhead crane of the ship to easily find the accurately positioned boxes. The 'shore-end' of this concept acts like a 'spreaded-out' super pallet.

Terminal activities and the ships sailing schedule are time independent. Loading can continue without the presence of a ship thanks to the specially reserved MBU area, where the ships self-loading equipment can do its own job. Similar, the self-discharging activities of the ship can take place without assistance from shore.

Linking the crane tracks from ship to shore requires an adapted, maritime crane with special power supply facilities.

■ TRAIN CARRIER

Figure 59 shows another variety of the physical interpretation of a Multiple-Box-Unit.

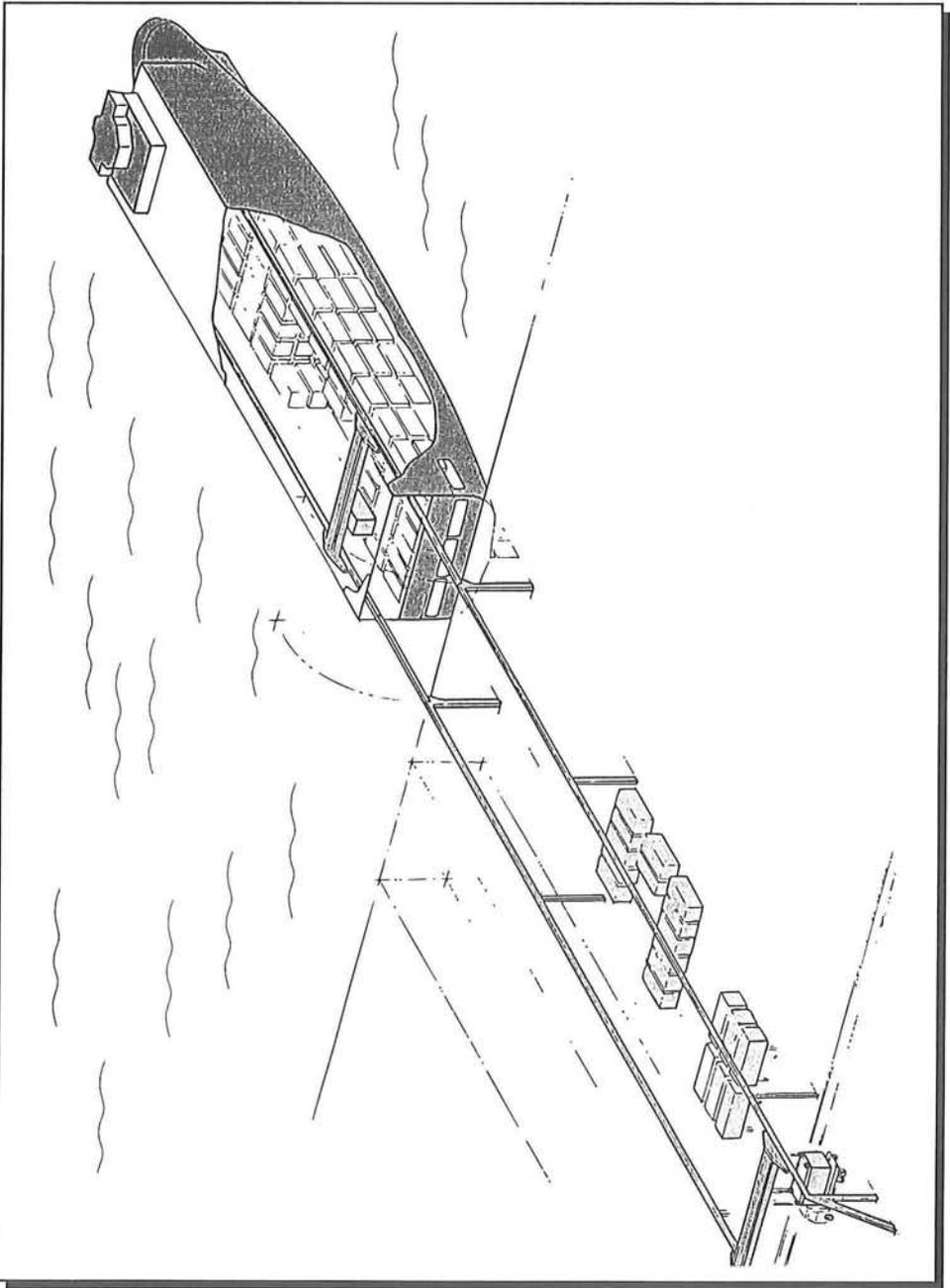


Figure 58: Unit loader

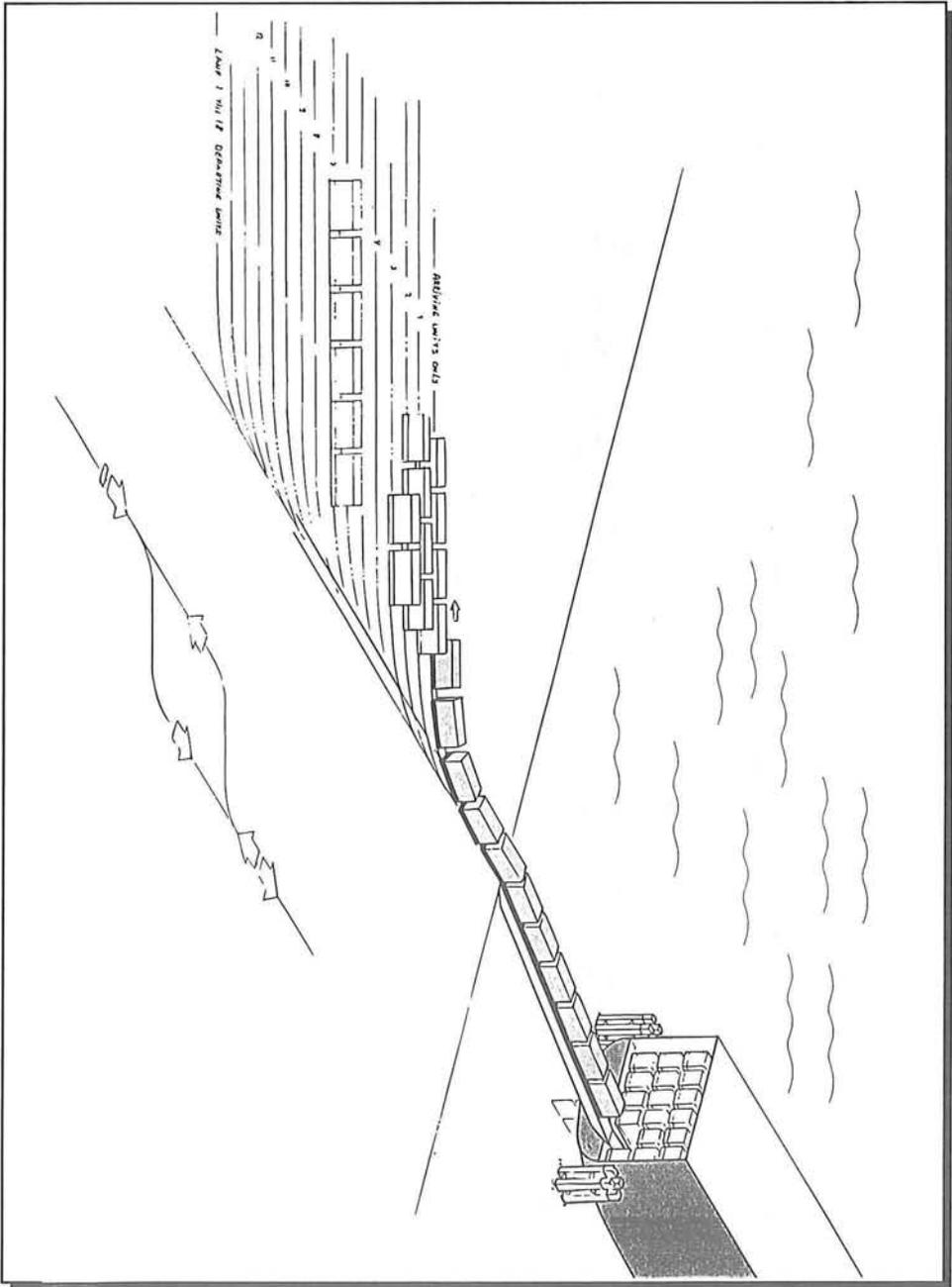


Figure 59: Train carrier

In this concept containers and swapbodies can be loaded onto "serving-tray-alike" platform cars. Trains of cars can be transferred onto the Train Carrier by means of an adaptable, swinging and elevating, loading bridge. This loading bridge can be of a single lane type, as drawn, or it could feature a number of parallel lanes which is shown on in Figure 60. A loading bridge of the latter type does not have to be able to swing to both sides.

Each train contains as many platforms as the ships loading length allows. Positioning one platform means that at the same time the entire train of cars is in position. An impression of the platforms is given in Figure 60.

The ship is of the so-called pencil case type, which implies longitudinal loading over the transom of the ship. In principal, each loading "tube" corresponds with a destination and each train of cars contains boxes with identical destinations only.

Interesting though is that it is possible to re-arrange the destination mix of the trains in case lack of capacity requires to do so. On shore, the resulting shifting operations can be carried out rather efficiently. The train arrangement area allows accurate positioning while overhead cranes or straddle carriers can service the area.

■ TRAIN LOADER

From a concept point of view the Train Loader (Figure 61) is similar to the Super Pallet Loader. It features internal overhead cranes and a vertical cellular stowage area. The difference between them is the way the MBU is transferred onto the ship.

Instead of using the semi-submersible heavy lift technology for loading a super pallet this concept is based on a MBU in the form of a triple stack platform train. The train is able to carry boxes which can be loaded onto the ships internal cell-guides via the loading bridge.

As soon as the train of triple stacked platforms is loaded and in position, the on-board distribution system can start unpacking the MBU and distributing the individual boxes over the stowage area. This can be done at any convenient moment; at the berthing place, during slow steaming while leaving or entering a port or perhaps even while sailing on open sea. Especially the latter as well as the slow steaming option would allow a remarkable reduction in turnaround time.

Existing technology for loading bridges, triple stack trains and maritime internal overhead cranes can be used for this concept. At the terminal, the platform train is simply discharged by an overhead crane. The ship can also be equipped with two trains via the stern, if the capacity requires this.

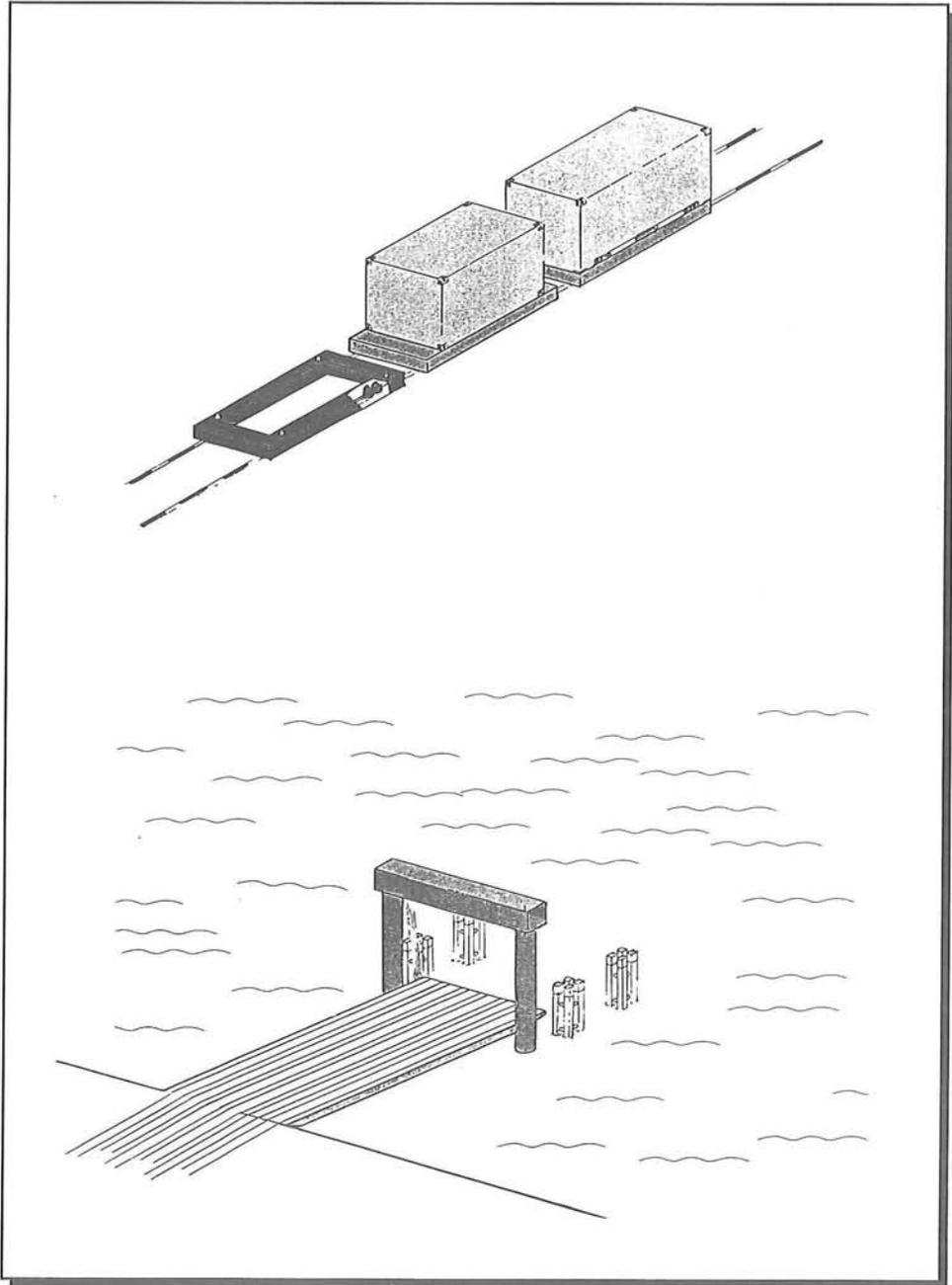


Figure 60: Adjustable loading bridge and platform cars

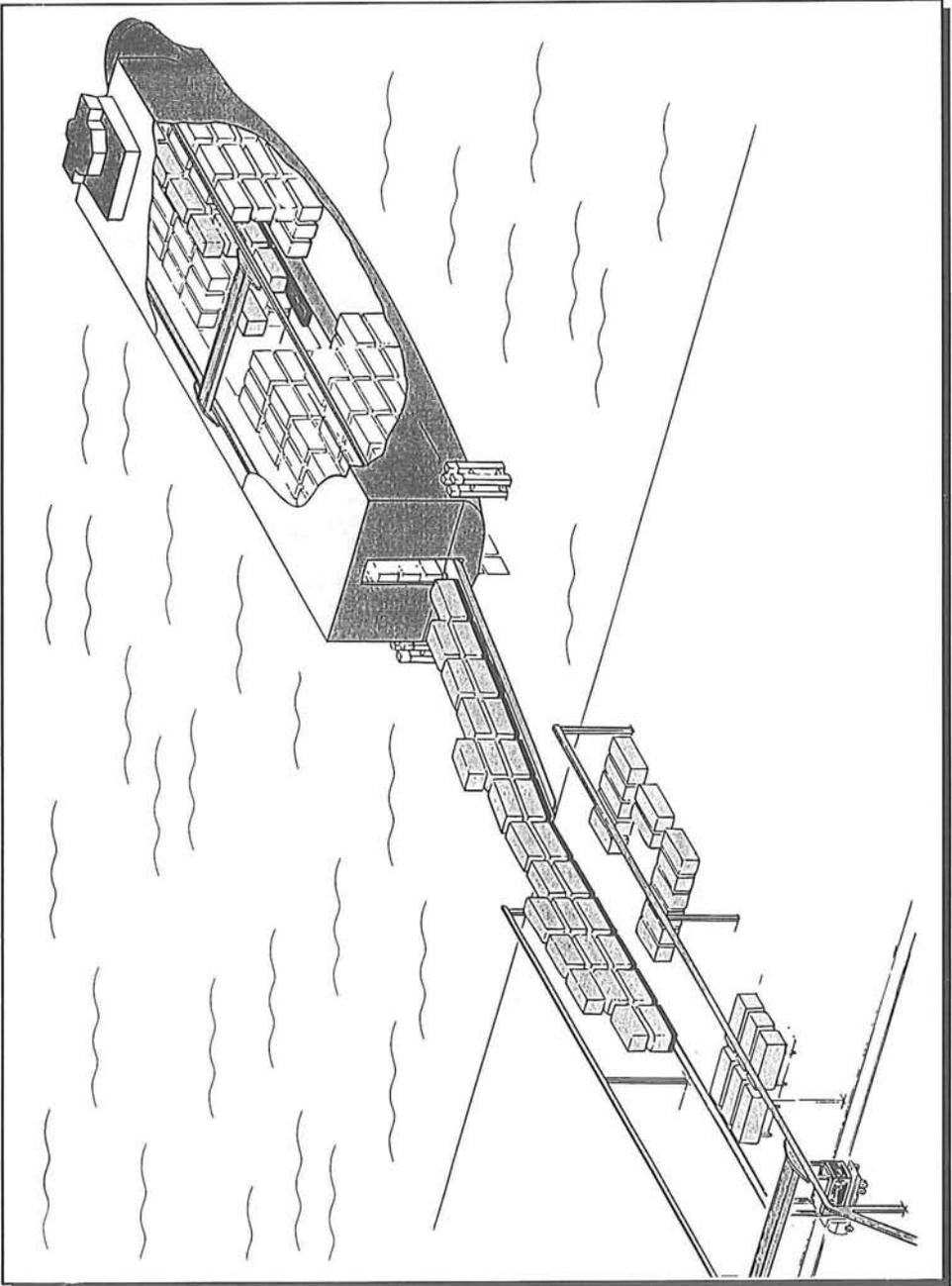


Figure 61: Train loader

PART III: CASE-STUDY SWEDEN

The coastline of Sweden is very long, approximately 2000 km from the top of the Botnic Gulf to the most Southern tip at Ystad. (Figure 62). It is ideal for shortsea shipping and therefore the government and local manufacturers are interested to understand its potential. Expecially since the cost of expanding the road- and railmodes is excessive and has a long leadtime. In Part III the basic parameters of such a shipping system will be discussed, such as the cargo-base, the ports of call, the roundtrip calculation, and the capacity of the system.

These elements are more important than the actual technological solutions, which will be presented in Part IV.

Any beautiful shipping system falls through without an adequate cargo-base. Therefore we start with the assessment of the potential for the shortsea shipping system in Chapter 9. The information in this chapter is based on Mari-Term's pre-feasibility study as well as on field research by Van der Hoeven & Kleijwegt.

CHAPTER 9: CARGO POTENTIAL

The general and break bulk cargo market consists of existing flows and future flows. The latter is formed by commodities which are now shipped by dedicated bulk transports, like steel and forest products.

Due to diversification of the manufacturing industries and more value adding activities with the primary producers, these commodities are shifting towards the general and breakbulk cargo market. Generally speaking, the northbound cargo flow consists of consumer goods while the southbound flow mainly involves industrial products. In the present situation the northbound transports collect higher freight rates due to an unbalance in required transport capacity. Southbound cargo is often accepted as return cargo at a low freight rate to cover return costs.

Market developments as described above are hard to quantify. Nevertheless they represent an important contribution to the feasibility of a shortsea shipping system and therefore an estimate will be made of the future cargo potential.

Parts of the total market of road transport, the railways and bulk/coastal shipping lie within reach of the new shipping system. This market survey focusses on determining the size and the composition of the total market and provides an indication of all cargo flows from and to each and every transport area.

DATA ACQUISITION

Publications of SCB, the Statistical Bureau of Örebro, and issues of the shipping magazine "Svensk Sjöfarts Tidning" provide important information.

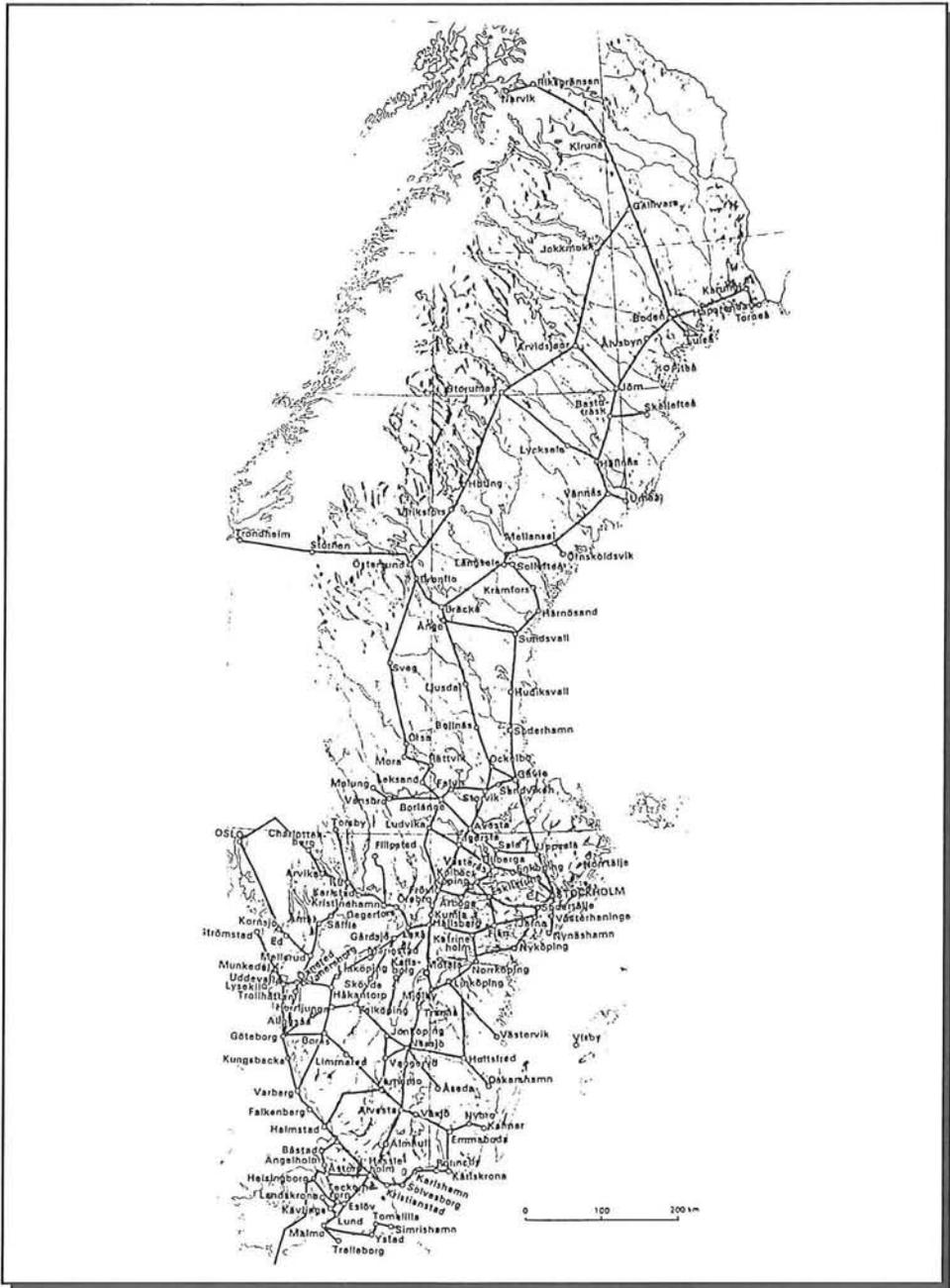


Figure 62

Van der Hoeven and Kleywegt have interviewed some of the major shippers while further data came from an inquiry carried out by the Chalmers Technical University. Especially their list of producers and shippers proved to be useful. Besides, MariTerm's pre-feasibility study provided the general framework.

ROAD TRANSPORT

In 1990 the total amount of goods transported by road accounted 405,1 million tons, according to SCB publications.

Road transport (including all commodities)	Volume (ton)	Performance (tonkm)
Short Distance under 2 ton	10,800,000	500,000,000
Short Distance over 2 ton	315,000,000	7,200,000,000
Long Distance over 100 km	73,100,000	19,300,000,000
In/Export	3,800,000	1,800,000,000
Transit	2,400,000	3,000,000,000

Table VI

Table VI shows the total annual transport volume and transport performance for all commodities. Especially the long distance transport performance looks very promising at first sight. SCB states that when only the general cargo and break bulk goods are considered this number reduces remarkably.

Road Cargo (transferable)	Volume (ton)	Average Haul (km)	Performance (tonkm)
North Bound	1,261,000	264	332,904,000
South Bound	1,132,000	264	298,848,000

Table VII

Part III: Case-Study Sweden

The Statistical Bureau estimated the following flows of potential shortsea shipping cargo along the Swedish east coast. The average haul is a calculation result derived from the long distance figures.

RAILWAYS

The Swedish Railways have stopped publishing their official figures in 1978. SCB, however, does publish approximations for 1990. A major part of the total railway transports concern iron ore bulk transports from Lapland to service the steel industry in the north of Sweden. The following table shows the estimated figures for 1990.

Railways (including all transports)	Volume (ton)	Performance (tonkm)
Iron Ore (Lapland)	22,100,000	3,200,000,000
Individual Railcars	26,800,000	15,500,000,000
Swapbodies, Containers	4,900,000	2,700,000,000

Table VIII

SCB has done an approximation of the amount of cargo which could be shifted onto the coastal service. Only a fraction of the total amount of cargo appears to be of interest.

Table IX contains the figures as projected by SCB. The average haul is derived from the figures for individual railcars and combined transports (swapbodies, containers, etc.).

Rail Cargo (transferable)	Volume (ton)	Average Haul (km)	Performance (tonkm)
North Bound	800,000	575	460,000,000
South Bound	1,500,000	575	862,500,000

Table IX

SHIPPING

Although the new shortsea shipping system is basically developed to take up competition against landtransport it is also interesting to see what share of the shipping market it could attract. The general cargo and break bulk goods market gains volume on account of the dedicated paper and steel products market. If this cargo can be transported in cargo units like containers and swapbodies it enters the market the new system is competing in.

A possible approach to approximate the market size is based on the data referring to domestic trade. These figures provide the total amount of cargo, with a domestic origin or destination, loaded and discharged in Swedish ports. These quantities are not specified with regards to type of cargo i.e. there is no categorization in terms of general cargo, bulk cargo, chemicals, forest products or unitized cargo.

On the other hand there is detailed information on the commodity trade which provides loading and discharging figures for nearly 30 different commodities in home trade. Once more there is the lack of categorization which makes this information less useful for direct application.

Port statistics (1990) are available which provide accurate information on amounts of cargo being loaded and discharged at each Swedish port. This information is fairly detailed and shows figures for each cargo type or transport type.

A problem with these figures is that it is unknown what part of it concerns goods in domestic trade and what part is in foreign trade.

The statistics lack two important linkages i.e.:

- * Cargo category v.s. domestic or foreign trade
- * Cargo category v.s. commodity

Considering the importance of having some indication of the market size it is necessary to define an acceptable approximation method.

Part III: Case-Study Sweden

The approach suggested here is to estimate a percentage for each cargo type which is loaded and discharged. This percentage primarily expresses the distinction between domestic and foreign trade and secondly which part of the remaining domestic goods is indeed transferable to the shuttle service or, in other words, what portion is suitable for transport in cargo units and can be expected to enter the market of the new system.

Publications in the shipping magazine "Svensk Sjöfart Tidning" provide figures about amounts of cargo being loaded or discharged at all Swedish ports. Each of the volumes indicated in **Table X** contains a percentage which can be transferred. The values of these percentages have been estimated by MariTerm AB.

The far-right column of **Table X** shows the potential market. The determination of the transferable percentage of the present shipping market the percentages have been directly applied to the grand totals for the various cargo categories.

Finally the following remarks should be noticed:

- * Oil transports are not included in the totals
- * The figures are based on port statistics reflecting the cargo handling activities. It is possible that a portion of the administered loaded and discharged volumes concern one and the same shipment.

THE TOTAL MARKET SIZE AND MARKET SHARE

The total market of goods which might be transferred to the shuttle service is the sum of road, rail and shipping contributions (**Table XI**).

The potential market size for the new shortsea shipping system amounts to approximately 12 million tons per annum. This comprises all goods which can be transported in cargo units. After stating this, two questions arise :

- * What market share can the system gain in the future ?
- * What future market share does the system require in order to be feasible?

The first question leads to a certain required transport capacity which can be optimized, given the market share in mind.

The second question leads to a required market share which justifies a certain transport capacity.

It is not possible to produce a market share expectation at this stage though in the scope of a feasibility study this is not really a critical problem. Parallel to the questions and statements above there are basically two ways of looking at this problem :

DISCHARGING	VOLUME (tons)	%	MARKET (tons)
General Cargo	3,309,000	100	3,309,000
Bulk Cargo	10,848,000	5	542,400
Chemicals	725,000	20	145,000
Wood Pulp	162,000	10	16,200
Total 1990	15,044,000		4,012,600

LOADING	VOLUME (tons)	%	MARKET (tons)
General Cargo	2,481,000	100	2,481,000
Bulk Cargo	6,618,000	5	330,900
Wood Logs	3,706,000	10	370,600
Chemicals	175,000	20	35,000
Timber	1,254,000	10	125,400
Total 1990	14,234,000		3,342,900

1990	DISCHARGING	LOADING
CONTAINERS	31,651 TEU	33,472 TEU

Table X

- * Assume a percentage of market share and develop corresponding scenarios each representing a typical configuration of the shuttle service including design parameters of vessels and handling systems.
- * Create a number of commercially attractive roundtrip schedules and compute the corresponding required market shares.

From a technical feasibility point of view as well as from a cost structure point of view, the latter method provides more useful results than the first one. This approach allows systematic alteration of the basic variables like sailing speed,

Total Market Size (transferable goods)	Volume (tons)	Volume (tons)
Road Cargo North Bound	1,261,000	
South Bound	1,132,000	
		2,393,000
Rail Cargo North Bound	800,000	
South Bound	1,500,000	
		2,300,000
Shipping Discharging	4,013,000	
Loading	3,343,000	
		7,356,000
Containers	65,123 TEU	
Total Market Size	65,123 TEU	12,049,000

Table XI

visiting frequency and the number of ports being serviced. The ships deadweight is not a free variable as it is linked to a required minimum in respect to the operation in ice.

The range of required market shares will show discontinuities due to the discrete character of some of the basic variables.

Finally, it would require extensive market research in order to get an idea about what actual market share can really be obtained by the system in the future. It is not the objective of this study to provide an exact market share figure.

UTILIZATION RATIO

The purpose of a utilisation ratio

Similar to a public bus service, where passengers get on and off the bus at different places and travel different parts of the entire bus route, the Shuttle Service picks up and delivers cargo units at a number of different ports and takes them along during different intervals.

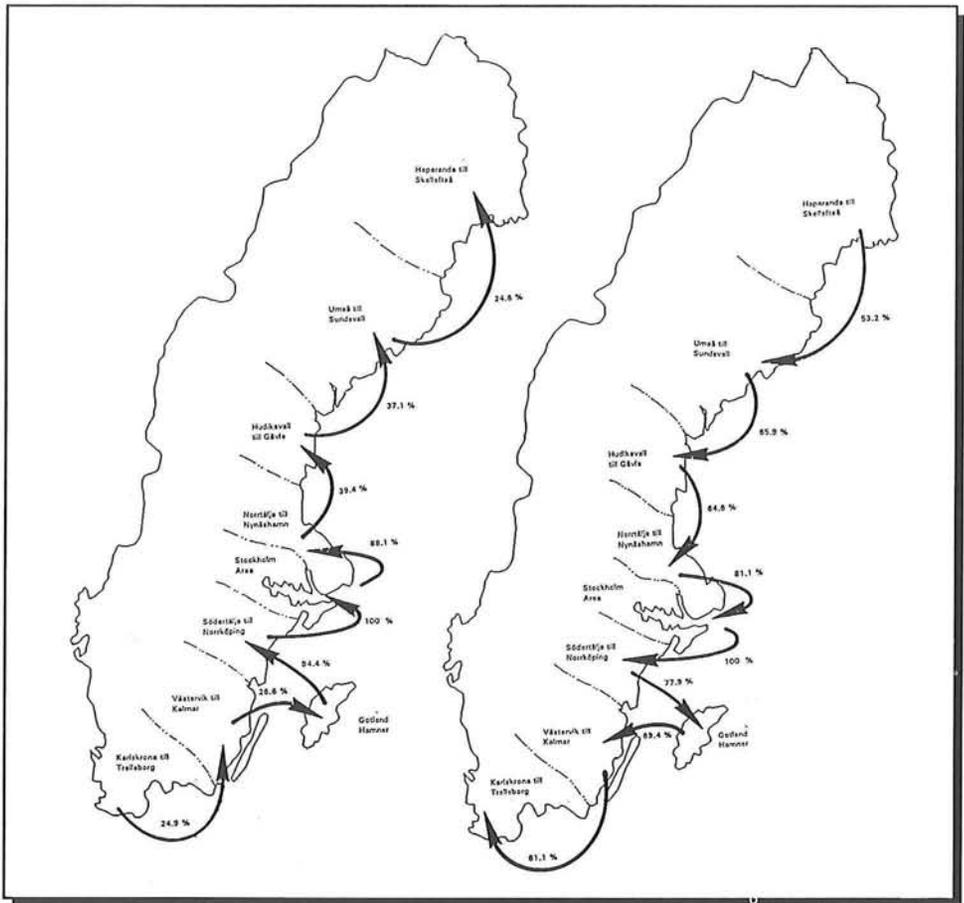


Figure 63: NorthBound (left) and southbound (right) flow

The ships deadweight will be used to its full extent when sailing the waters around Stockholm as this is the origin and destination of most of the cargo. The resulting number of cargo units on board the ship after each loading and discharging operation decreases when servicing the areas further north or south of the densely populated Stockholm area. This means that during a major part of their operational time the shuttle vessels sail at less than their maximum draught and carry an average payload less than their maximum deadweight.

Consequently the design parameters of the vessels and the design of the handling system are influenced by the utilisation ratio. An important result of the utilisation analysis is that the space requirements are not critical. An other result is the need for sufficient ballast capacity to be able to load off to maximum draught in case the navigation in ice requires to do so.

Utilisation analysis

An analysis of the origins and destinations of the cargo volumes will provide utilisation ratios for each and every voyage leg covered by the shuttle vessels. The flow charts on this and the following page show the results of the calculations.

As there is no reliable market share projection at this stage, the whole potential cargo market will be considered here. The transport requirements per area in both north and south bound direction will be converted into non-dimensional figures.

These non-dimensional figures can be used directly in terms of a utilisation ratio and indirectly to quantify the actual tonnage of the obtained cargo flows when matched with a market share indication, in case the latter becomes available. The actual tonnage of the individual flows has a major influence on the dimensions of both ship and handling systems and on the port visiting frequency of the shuttle vessels.

The statistical information from SCB and Svensk Sjöfart Tidning does not reveal destinations and origins which correspond with the loading and discharging figures. This means that there is no direct quantification method for the potential cargo flows from area to area in either north or south bound direction.

The following method has been introduced to obtain the utilisation ratio and its fluctuation during the progress of the ships voyage :

- * Use the percentages for transferable cargo to determine the total amount of potential cargo loaded and discharged in each port.
- * Calculate the sum of the loading and discharging volumes for each transport area using the SCB area arrangement.
- * SCB presents figures on the domestic trade from area to area. Use that information to decompose the destination flows of the cargo volumes loaded in all nine areas and, similarly, to trace the origins of arriving cargo volumes.
- * This step is very disputable and will be discussed later on.
- * Combine the two figures of the previous step to get the resulting cargo flows from area to area.
- * The results are presented in matrix form which offers the possibility to distinguish between the north and south bound flows as this corresponds with the upper and lower triangle of this matrix.

- * For both directions the cumulative figures can be determined expressing the annual amount of cargo which requires transport in both north and or south bound direction.
- * Finally the results are made non-dimensional by dividing by the largest value, the boxed pivot value.

The calculation process contains a disputable step which is the application of domestic trade figures which are not categorized in terms of transport type as mentioned before. The question arises whether it is realistic to expect that the potential volumes follow the same trade patterns as can be traced from the area to area figures of the domestic trade.

Reasons which justify the use of this method are :

- * The options are limited and this method stays relatively close to reality and provides at least some tool to work with.
- * The result is a list of non-dimensional numbers which can be altered easily in case fundamentally better figures would become available.
- * The domestic trade figures do not include oil transports and, although only 5 % of the bulk transports are transferable to the new system, the bulk goods form an important basic trade pattern when considering the absolute quantities they represent.

Results and interpretation

The method is intended to provide a tool to allocate a given volume of potential cargo to the various transport areas, to add the corresponding origins and destinations and to produce flow characteristics. The final results of the calculation process are presented in **Tables XII to XV**.

The three columns in the middle of both tables show annual amounts of cargo. It is *EXPRESSLY* stated that these numbers are for calculation purposes only and that their absolute values have *NO OTHER* use than to show the last steps towards the non-dimensional utilisation ratio.

This method provides the following results :

- * Average utilisation ratio for both north and south bound directions
- * Utilisation ratio for each area
- * Handling activity indication for each and every area

Tables XIV and XV reflect the flow characteristics for both directions. These numbers will serve as input data for **Part V** which deals with the feasibility of the system.

Part III: Case-Study Sweden

AREA	LOADING (tons)	DISCHARGING (tons)	RESULTING NORTH BOUND CARGO FLOW	UTILISATION RATIO
Trelleborg till Karlskrona	441.6	00	441.6	24.9 %
Kalmar till Västervik	77.4	48.7	470.3	26.5 %
Gotland Ham- ner	1224.6	21.5	1673.4	94.4 %
Norrköping till Södertälje	390.4	290.4	1773.4	100 %
Stockholm Area	169.1	379.3	1563.2	88.1 %
Nynäshamn till Norrtälje	229.2	1093.8	698.6	39.4 %
Gävle till Hu- diksvall	108	148.2	658.4	37.1 %
Sundsvall till Umeå	129.3	350.7	437.0	24.6 %
Skellefteå till Haparanda	00	437	00	
				AVERAGE
	2769.6	2769.6		54.4 %

Table XII: Annual potential north bound cargo flow (1000 tons) & utilisation ratio (%)

AREA	LOADING (tons)	DISCHARGING (tons)	RESULTING SOUTH BOUND CARGO FLOW	UTILISATION RATIO
Haparanda till Skellefteå	712.9	00	712.9	53.2 %
Umeå till Sundsvall	196.1	25.9	883.1	65.9 %
Hudiksvall till Gävle	49.3	66.9	865.5	64.6 %
Norrhälje till Nynäshamn	544.6	323	1087.1	81.1 %
Stockholm Area	475.7	222.3	1340.5	100 %
Södertälje till Norrköping	259.9	556.6	1043.8	77.9 %
Gotland Hamner	180.2	293.1	930.9	69.4 %
Västervik till Kalmar	72.5	184.2	819.2	61.1 %
Karlskrona till Trelleborg	00	819.2	00	
				AVERAGE
	2491.2	2491.2		71.7 %

Table XIII: Annual potential south bound cargo flow (1000 ton) & utilisation ratio (%)

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AREA	LOADING	DISCHARGING	NETT. ON-BOARD (UTILISATION RATIO)	HANDLING ACTIVITIES
Trelleborg till Karlskrona	24.9 %		24.9 %	24.9 %
Kalmar till Västervik	4.4 %	2.7 %	26.6 %	7.1 %
Gotland Hamner	69.1 %	1.3 %	94.4 %	70.4 %
Norrköping till Södertälje	22.0 %	16.4 %	100 %	38.4 %
Stockholm Area	9.5 %	21.4 %	88.1 %	30.9 %
Nynäshamn till Norrtälje	13.0 %	61.7 %	39.4 %	74.7 %
Gävle till Hudiksvall	6.1 %	8.4 %	37.1 %	14.5 %
Sundsvall till Umeå	7.3 %	19.8 %	24.6 %	27.1 %
Skellefteå till Haparanda		24.6 %		24.6 %
Total	156.3 %	156.3 %		
Average			54.4 %	

Table XIV: North bound cargo flow characteristics

AREA	LOADING	DISCHARGING	NETT. ON-BOARD (UTILISATION RATIO)	HANDLING ACTIVITIES
Haparanda till Skellefteå	53.2 %		53.2 %	53.2 %
Umeå till Sundsvall	14.6 %	1.9 %	65.9 %	16.5 %
Hudiksvall till Gävle	3.7 %	5.0 %	64.6 %	8.7 %
Norrköping till Nynäshamn	40.6 %	24.1 %	81.1 %	64.7 %
Stockholm Area	35.5 %	16.6 %	100 %	52.1 %
Södertälje till Norrköping	19.4 %	41.5 %	77.9 %	60.9 %
Gotland Hamner	13.4 %	21.9 %	69.4 %	35.3 %
Västervik till Kalmar	5.4 %	13.7 %	61.1 %	19.1 %
Karlskrona till Trelleborg		61.1 %		61.1 %
Total	185.8 %	185.8 %		
Average			71.7 %	

Table XV

Part III: Case-Study Sweden

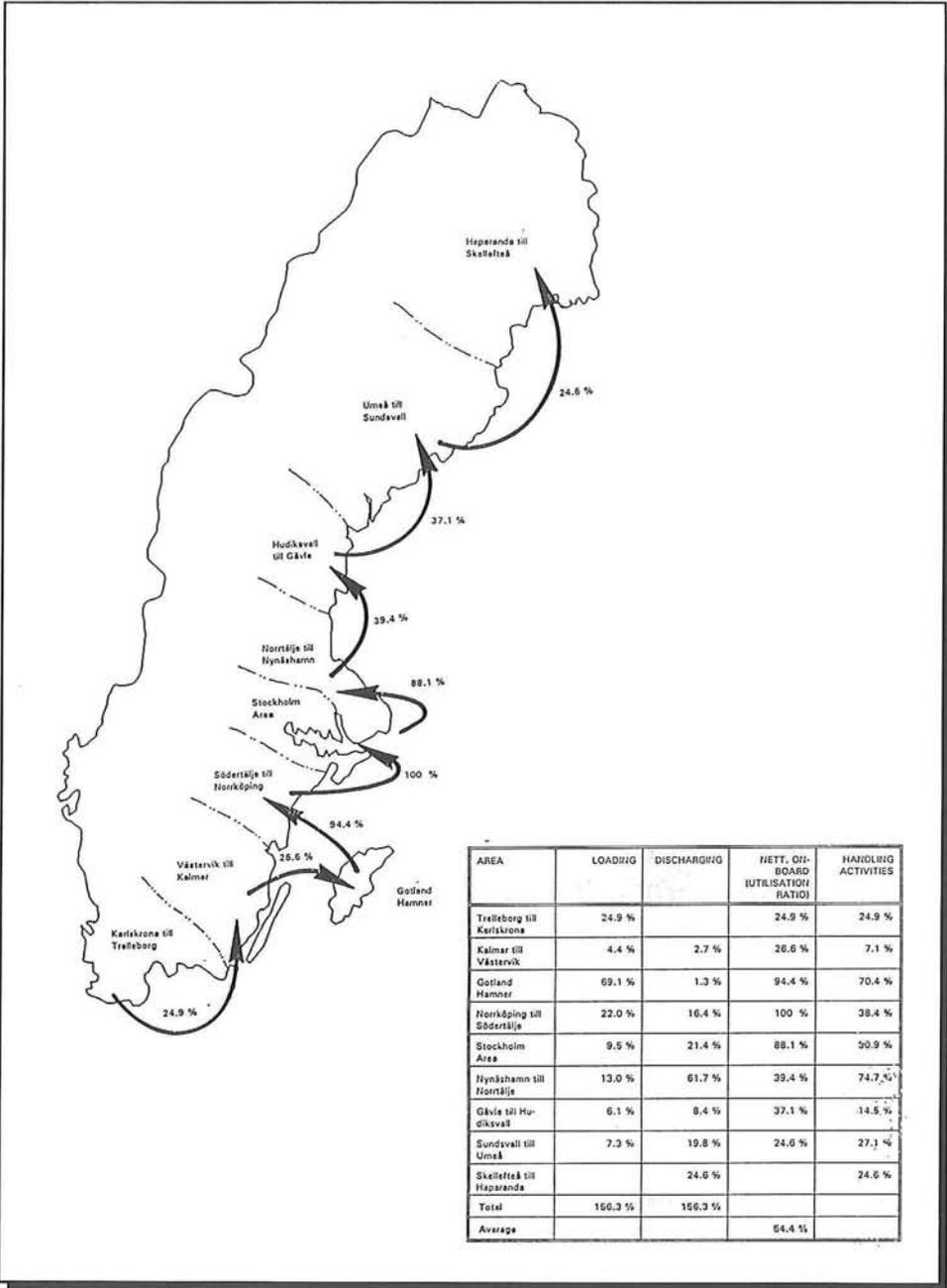


Figure 64: Nothbound cargo flow

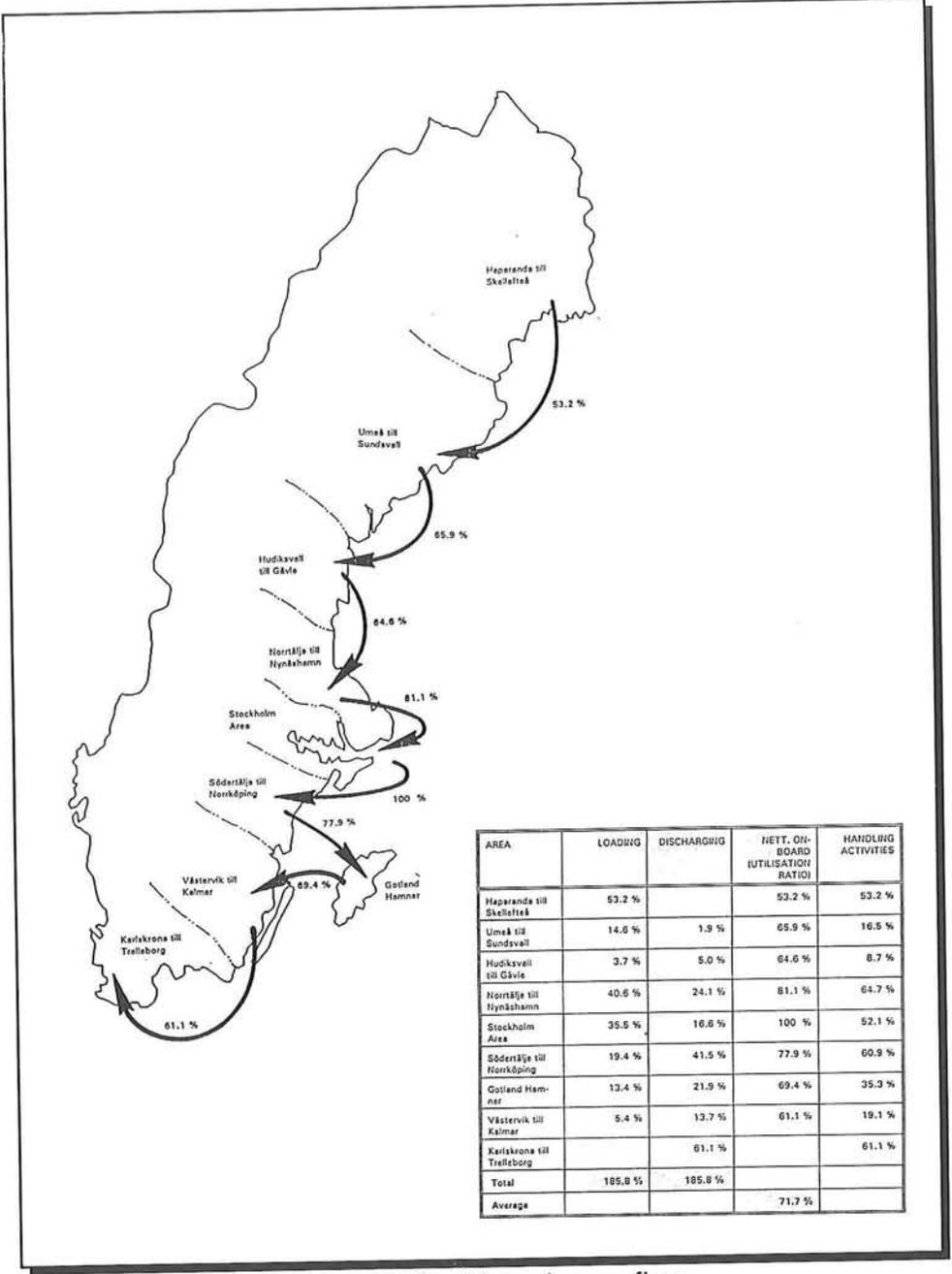


Figure 65: Southbound cargo flow

CHAPTER 10: PORTS OF CALL SELECTION

The new shortsea shuttle service needs a number of ports to load and discharge cargo. These 'ports of call' must be chosen very carefully as the number and location of the 'ports of call' determine the workability of the system and transport costs.

At present, it is the purpose to create a shipping system along the east-coast of Sweden. For this reason only the ports located along the east-coast will be considered in this chapter. However, in the future it might be necessary or desirable to extend the service area to:

- * Finland, for attracting more cargo from the northern part of the Botnic and Baltic area
- * Poland, for collecting resources needed for the Swedish industry
- * Germany, connection with the market of continental Europe
- * Denmark, connection with the market of continental Europe

SELECTION PROCEDURE PORTS

In Svensk Lots 1992, all Swedish ports are mentioned by area. Not all these ports are appropriate ports for the new service to call to, and a selection must be made.

The selection procedure is divided into two steps:

- * first, a selection has to be made to select all applicable ports out of all available ports along the east-coast of Sweden.
- * second, out of all selected ports, the optimal 'ports of call' configuration has to be chosen.

The selection of applicable ports, out of all Swedish ports along the east-coast is based on the following criteria:

- * minimal port dimensions
- * accessibility of the port
- * location shippers and receivers

The minimal dimensions of the Shuttle-vessels depend on the ice-conditions in the Baltic area, the size of the cargo-flow, speed of the vessels and the service level.

The accessibility of the ports is very important as this has an important influence on the total sailing time. For this reason it should not take too much time to sail from open sea into the port. During winter the ports must be accessible, meaning that the ports should be clear of ice. This can be done by small ice-

breakers or by natural current. If the port is situated at a river, the current of the river will help clear the port. In case there is no natural current, a flow can be created by means of thrusters, especially when such thrusters are combined with waste water from local industry. The accessibility of the port from the land-side must be provided by a reliable road and/or rail infrastructure.

The location of the shippers and receivers of the shuttle service system determines which ports are the most logical ones to call at depending on the lead distances to the port.

Minimal port dimensions

The first selection measure to pick applicable ports out of all Swedish ports is based on minimal dimensions of the ship. It must be possible for the ship to enter and leave port easily, leaving sufficient space for manoeuvring and mooring.

The minimal port dimensions are initially based upon the Chalmers University design of the ship. This design has especially been made for the ice-conditions in the Baltic area and its dimensions are set for optimal performance in ice. Considering the Chalmers design, and constraints of the ice-conditions concerning minimal dimensions, the minimal ports dimensions are required as mentioned in Table XVI.

	Chalmers design	Minimal port dimensions
Loa	121,00 m	110,00 m
Breadth	20,15 m	19,00 m
Draught	6,00 m	5,75 m
Deadweight	4.000 tons	

Table XVI

Together with the selection by minimal port dimensions the following ports are eliminated:

- * Ports which have a special purpose, like fishing-ports and oil harbours
- * Private owned ports
- * Ports not located at the east-coast of Sweden, meaning outside the range Haparanda - Trelleborg

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After the selection on minimal port dimensions the ports given in **Table XVII** remain applicable to be used by the new service.

Area	Port (45 in total)	DW (ton)	B (m)	Loa (m)	D (m)	
Trelleborg till Karlskrona	Trelleborg	30000		200	7.6	
	Ystad			150	6.7	
	Åhus			160	7.7	
	Sölvesborg			170	7.7	
	Karlshamn			190	9.0	
Kalmar till Västervik	Kalmar	14000	25	155	7.2	
	Oskarshamn	30000		180	10.5	
	Västervik			160	8.5	
Norrköping till Södertälje	Norrköping		33	260	11.5	
	Oxelösund		41	265	12.8	
	Södertälje		32	200	9.0	
Eskilstuna till Uppsala	Hässelbyverket				6.0	
	Bålsta				6.8	
	Västerås				6.8	
	Köping				6.8	
Gotland	Visby			200	7.4	
	Storungs			150	9.0	
	Slite			200	7.8	
Nynäshamn till Norrtälje	Nynäshamn	20000	35	280	13.0	
	Stockholm			245	11.0	
	Kappelskär			150	8.0	
	Hallstavik			28	185	7.0
	Hargshamn			28	185	10.4
	Skutskär				175	6.9
Gävle till Hudiksvall	Gävle		28	220	10.4	
	Vallvik			185	7.5	
	Söderhamn			23	180	7.9
	Iggesund			22	160	7.3
	Hudiksvall			32	160	9.9
	Kubikenborg				192	10.5
Sundsvall till Umeå	Sundsvall	16000		200	12.5	
	Vivstavarv			180	7.3	
	Härnösand			170	9.9	
	Utansjö			170	8.2	
	Kramfors			150	6.3	
	Köpmanholmen			160	9.0	
	Örnsköldsvik			45000	10.0	
	Husum			16000	220	10.6
	Rundvik				165	7.0
Umeå/Holmsund		33	215	10.0		
Skellefteå till Haparanda	Skellefteå	25000		160	8.5	
	Piteå	70000		250	11.5	
	Luleå	20000			11.4	
	Törehamn	5000			6.0	
	Karlsborg	12000		150	6.0	

Table XVII

Accessibility of the ports

The coastline of Sweden is very irregular. This irregular coastline provides many natural shelters and ports. However not all these ports are easily accessible from the sea-side which results in different entrance times for each port.

The accessibility of the ports from the land side must be provided by a reliable infrastructure which at least consists of an extended road system. Ports not connected with or not within close reach of an international throughroute (minimal two lanes) are left out of consideration.

The accessibility of the ports from sea can be determined by the locations of the ports, on the existing maps

Table XVIII gives the selected ports, which are appropriate ports for the new service to call at, after application of the accessibility criteria.

Area	Port (24 in total)	DW (ton)	B (m)	Loa (m)	D (m)	
Trelleborg till Karlskrona	Trelleborg	30000		200	7.6	
	Ystad			150	6.7	
	Åhus				7.7	
	Karlshamn			190160	9.0	
Kalmar till Västervik	Kalmar	14000	25	155	7.2	
	Oskarshamn	30000		180	10.5	
Norrköping till Södertälje	Oxelösund		41	265	12.8	
Gotland	Visby			200	7.4	
Nynäshamn till Norrtälje	Nynäshamn	20000		280	13.0	
	Kappelskär			150	8.0	
	Skutskär			175	6.9	
Gävle till Hudiksvall	Gävle		28	220	10.4	
	Vallvik			185	7.5	
	Iggesund		22	160	7.3	
Sundsvall till Umeå	Sundsvall	16000		200	12.5	
	Härnösand			170	9.9	
	Körmanholmen			160	9.0	
	Örnsköldsvik			45000	10.0	
	Husum			16000	220	10.6
	Umeå/Holmsund			33	215	10.0
Skellefteå till Haparanda	Skelleftehamn	25000		160	8.5	
	Piteå/Haraholmen	70000		250	11.5	
	Luleå	20000			11.4	
	Karlsborg	12000		150	6.0	

Table XVIII

An indication of the sailing distances is given in Figure 67.

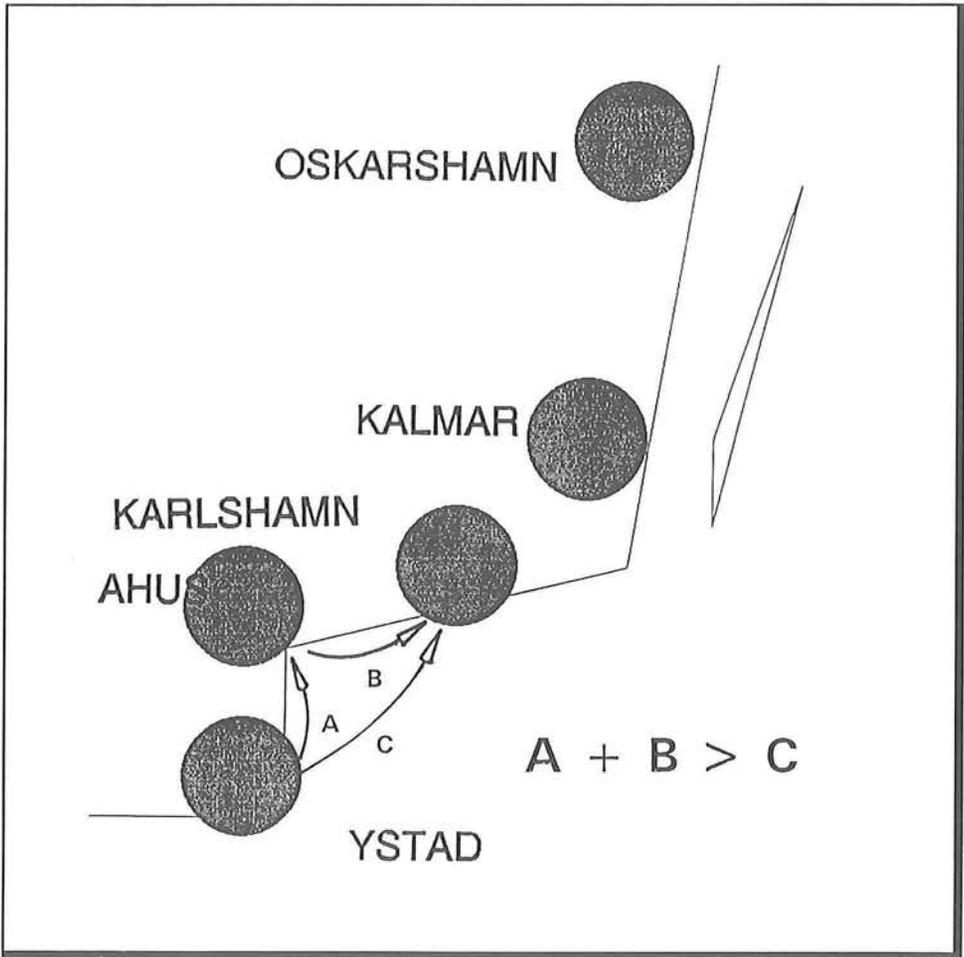


Figure 67: sailing distances

SELECTION OF 'PORTS OF CALL'

Selection criteria

A selection of 'ports of call', out of all potential ports to call to, has to be made. In order to rationalize the selection procedure, a selection criterion is needed to decide whether the 'ports of call' collection is optimal or not. To make the shuttle system a competitive transport alternative, the total transport costs must

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be minimized. A reduction of total transport costs can be obtained by reducing a.o. the landtransport costs.

The landtransport costs have the following correlations:

- * linear with total tonkm performed by landtransporters
- * depends on the number of 'ports of call'
- * depends on the location of 'ports of call', especially the distances (over land) between the ports
- * depends on the amount of cargo, suitable for the shuttle service, which is handled in each port

However not only the landtransport costs must be taken into consideration but also the seatransport costs. The seatransport costs are also dependent on the selected 'ports of call'. In contrast to the landtransport costs, which increase when the number of ports is decreased, the seatransport costs will decrease when less ports are serviced. In order to optimize the total transport costs it is desirable to know the landtransport costs for different 'ports of call' configurations.

Considering the relationships stated above, it is reasonable to take **minimization of the landtransport costs** as selection measure to obtain the optimal 'ports of call' collection.

Possible 'ports of call' configurations

All possible and different configurations of 'ports of call' configurations which can be made out of all selected ports can be calculated with the following statistical formula:

$$\frac{N!}{P!(N-P)!}$$

In this formula N is the number of potential ports from which a number of P ports is selected.

In this case there are 24 potential ports. For sorting out what the optimal selection of 'ports of call' by number of ports would be (in the range 6 to 14), the number of 'ports of call' configurations to be evaluated are stated in the table below. The total number of 'ports of call' configurations is enormous and it would take, even with a computer, a lot of time to evaluate all configurations. A solution to the problem can not be found easily by approaching the problem along the statistical way. A more practical approach has to be taken in order to find a solution for obtaining the optimal 'ports of call' collection.

Number selected ports N	Number 'Ports of Call' P	Number configurations of 'Ports of Call'
24	6	134596
24	7	346104
24	8	735471
24	9	1307504
24	10	1961256
24	11	2496144
24	12	2704156
24	13	2496144
24	14	1961256
Total number of configurations		14142631

Table XIX

Service area port

For practical reasons, the problem of making a rational 'ports of call' selection is approached from another angle. Not by looking what all the possible 'ports of call' configurations can be, but by looking from the landside to determine what level of service can be provided by every port.

A shuttle service port should serve as a cargo distribution center for hinterland transport and as a transfer spot for cargo which is transported by the shuttle vessels.

The level of service which a port can offer depends in the first place on the availability of cargo in the port itself and in the second place of the availability of cargo within the service area of the port. The service area of the port is defined by an imaginary service radius. In Figure 68 a service radius of 150 km has been drawn for the ports Ystad, Karlshamn and Oskarshamn. It is called an imaginary radius because the service radius is defined as the distance over the road and not as the airspan. In this way the service area for each selected port is defined.

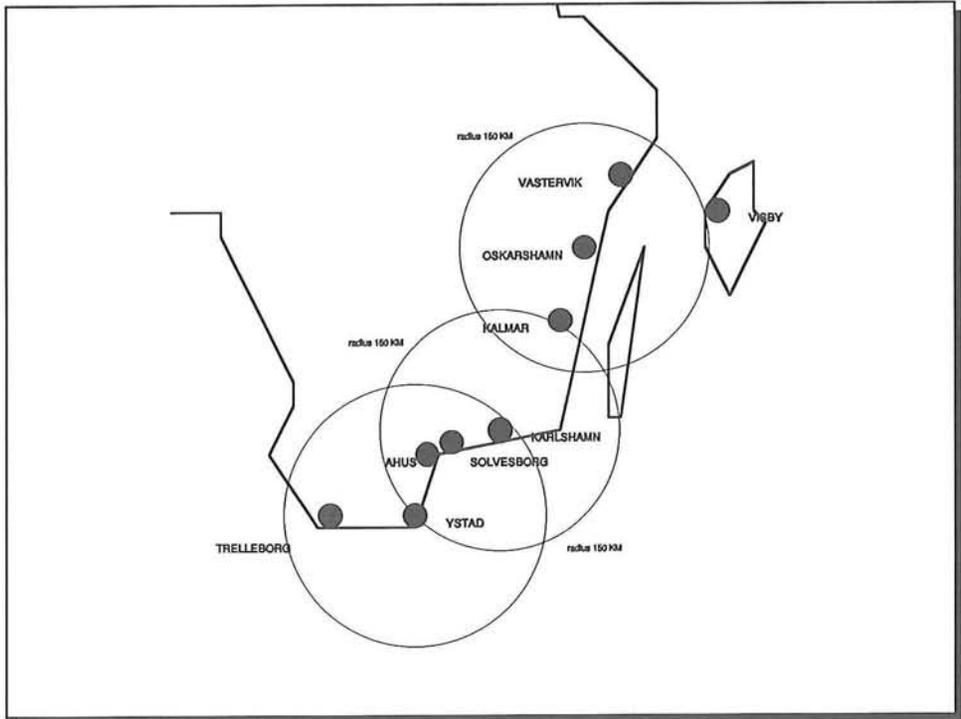


Figure 68: service radius 150 km

The reason for applying the ports with a service area, is to make it possible to define the amount of cargo available for each port. Within a certain service radius all the available cargo must be transported to this port by landtransporters. This gives an amount of tonkm to be performed by the landtransport for all applicable ports.

Before it is possible to calculate the tonkm to be performed by the landtransport for each port, the following information is needed:

- * distances between the ports over the road (km)
- * the amount of loaded and discharged cargo in every port, further called the cargoflow in port

The distance table gives the distances over the road (km) and is based on a recent roadmap of Sweden.

The cargoflow needed for the calculation only contains transferable cargo.

Calculation of optimal 'ports of call' configuration

With the information on the cargoflow and the distances between the ports it is possible to calculate the optimal 'ports of call' configuration for every service radius.

This calculation is divided into three phases:

- * first phase calculates the tonkm to be performed by landtransport within the service area of each port
- * second phase determines the optimal number and specific ports of the 'ports of call' configuration
- * third phase optimizes the 'cargoflow allocation' to the ports of call and gives total tonkm to be performed by landtransport

First phase:

- * Choose service radius, equal for all ports
- * Delete all ports at a distance larger than the service radius of the port under consideration
- * Multiply, in row direction, for each port the distances in the distance table with the cargoflow of the port
- * Add, in column direction, the amounts created by the multiplication

The last two steps determine the total tonkm to be made, corresponding with an imaginary relocation of all cargoflows available in ports within the service area to the port under consideration

The result of the calculation is a list with the total tonkm to be performed by landtransport for each port.

Second phase:

- * Do until the cargoflows of all ports has been allocated:
 - Take from the list of all applicable ports (those without an asterix), the port with the smallest amount tonkm to be performed by landtransport (is the selection criterion)
 - Give the selected port and the ports within the service area of the selected port an asterix. Set the cargoflow of the selected port and the ports within the service area of the selected port to zero. This ensures that these amounts of tonkm has no influence on the calculation process of the next port (the cargoflows are allocated to the selected port)

The results of the second phase of the calculation are stated in **Table XX**, every service radius shows the optimal 'ports of call' configuration in number and by specific ports:

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Service radius (km)	1 0	1 2 5	1 5 0	1 7 5	2 0 0	2 2 5	2 5 0	2 7 5	3 0 0	3 2 5	3 5 0
▽ Ports											
Trelleborg Ystad Åhus Sölvesborg * Karlshamn	●	●	●	●	●	●	●	●	●	●	●
Visby	●	●	●	●	●	●	●	●	●	●	●
Kalmar Oskarshamn Västervik *	●	●	●	●	●	●	●	●	●	●	●
Norrköping * Oxelösund Södertälje *	●	●	●	●	●	●	●				
Västerås * Köping *											
Nynäshamn Stockholm * Kappelskär Norrköping * Hargshamn * Skutskär	●	●	●	●	●	●	●	●	●	●	●
Gävle Vallvik Söderhamn * Iggesund Hudiksvall *	●	●	●		●	●			●		●
Sundsvall Härnösand Köpmanholmen Örnsköldsvik Husum Umeå/Holmsund	●	●	●	●	●	●	●	●	●	●	●
Skelleftehamn Piteå/Haraholmen Luleå Karlsborg	●	●	●	●	●	●	●	●	●	●	●
Total number ports	14	13	10	9	9	9	8	7	7	7	6

*) do have a cargo-flow appropriate for the shuttle but are not applicable ports

Table XX

In the third phase the total tonkm to be performed by landtransport has to be calculated. In the second step of the calculation the cargoflows of the ports have been allocated to the 'ports of call'. However, the ports are chosen on minimal tonkm to be performed by landtransport. It is possible that, especially with higher numbers of 'ports of call', that the allocation of the cargoflows between the 'ports of call' is not optimal. With the data available it is very simple to make an optimal allocation of the cargoflows.

Third phase:

- * Make a distance table of all the ports with a cargoflow and the 'ports of call'
- * Select the nearest 'port of call' for each port with a cargoflow. Multiply the distance with the cargoflow to create the tonkm to be covered by landtransport.
- * Calculate the total tonkm.

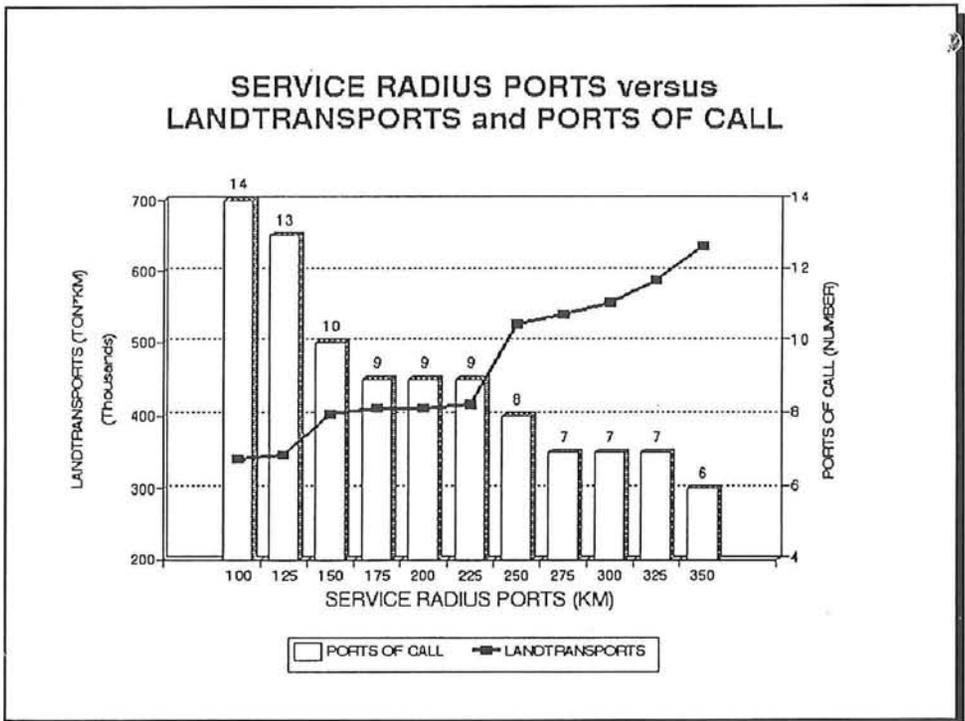


Figure 69: Results of optimal 'port of call' configuration calculation

In order to show the relations between the number of ports, service radius and tonkm to be performed by landtransport the results are stated in Figure 69.

Discussion of results

In Figure 69, the following characteristics can be distinguished:

- * the landtransport costs depend on the number of 'ports of call'
- * the smaller the service radius the lower the tonkm to be covered by landtransport
- * the configuration of the 'ports of call' is less important than the number of the 'ports of call'

The characteristics as mentioned above, could be arrived at without making a calculation as performed in this chapter.

On the other hand finding these characteristics through calculation, underwrites the fact that the calculation is reliable. Additional to this, the calculation does not only distinguish the characteristics but also quantifies them. This enables an optimization between the landtransport and the seatransport costs of the different 'ports of call' configurations

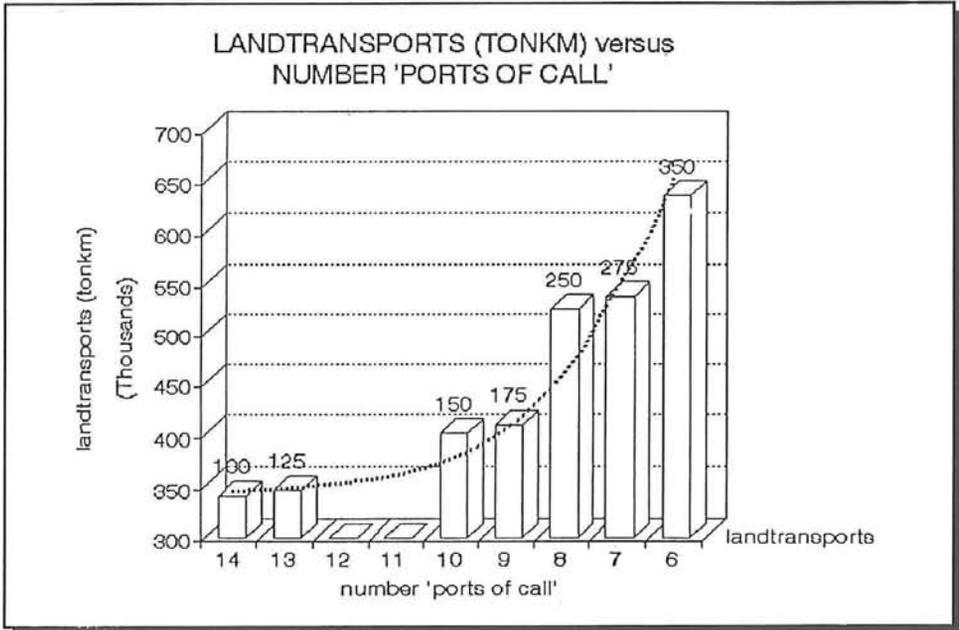


Figure 70: Relation between landtransport and number of ports

From the configurations with equal number of 'ports of call' only those ports have to be taken in consideration with lowest amount tonkm to be performed by landtransport (this can be seen in figure 3, a.o. with 9 'ports of call'). The other configurations are sub-optimal.

The optimal configuration for a certain number of 'ports of call' can be defined more accurately by determining the exact service radius where the number of 'ports of call' changes.

CONCLUSION

The selected number of potential ports to call at is 24.

In order to create the optimal 'ports of call' configuration out of these 24 ports, the configuration with the lowest landtransport costs has to be selected.

After defining 11 different service area radii for the ports, the configurations with the lowest landtransport costs are found for these 11 radii. Within these 11 configurations several sub-optimal configurations are found. After deleting the sub-optimal configurations, 7 'ports of call' configurations can be taken into consideration:

Service area radius (km) ▶	100	125	150	175	250	275	350
Ports:							
Ystad	●	●	●	●	●	●	●
Karlshamn	●	●					
Visby	●	●	●	●		●	●
Kalmar	●				●		
Oskarshamn	●	●	●	●		●	●
Oxelösund	●	●	●	●	●		
Nynäshamn	●	●	●	●		●	●
Kappelskär	●	●	●		●		
Skutskär							
Gävle	●			●			
Vallvik		●	●				
Iggesund							
Sundsvall	●	●	●	●	●	●	
Örnsköldsvik	●	●					●
Umeå/Holmsund	●	●	●	●	●	●	
Skelleftehamn	●	●					
Luleå	●	●	●	●	●	●	
Karlsborg							●
Total 1000 tonkm	341.5	346.6	401.8	409.4	524.7	537.8	636.4
Total number ports	14	13	10	9	8	7	6

Table XXI

CHAPTER 11: ROUNDRIP TIME EXPLORATION MODEL

The advanced shortsea shipping service for the eastcoast of Sweden depends on a number of variables, of which some have already been discussed in the previous chapters.

There are more choices to be made, and in order to present these in a systematic way, a roundtrip time exploration model is made.

DESCRIPTION ROUNDRIP CYCLES

The first ship starts in the most southern port of the 'ports of call configuration' (Chapter 10) with loading the amount of cargo which is available for the service in that port (Chapter 9). After the ship is loaded, it leaves for the next port until it arrives in the most northern port. After discharging in the most northern port, the ship is completely empty and can start loading cargo for the southbound leg. After the loading operation the ship starts to travel down the coast until it ends in the first port.

At that moment the first ship has completed a roundtrip. The time span of this roundtrip is called the **roundtrip time**.

In the meantime a second ship has started its roundtrip. The time interval between the departure of the first and the second ship is called the **calling interval**. Another important figure is the **transit time** port to port N-S: the time needed to transport a box from the North to the South or vice versa; the transit time port to port N-S is half the roundtrip time.

There is a direct relation between calling interval, transit time port to port N-S and the number of ships, which can be explained as follows:

A transit time port to port N-S of three days means that when the first ship starts a roundtrip it will travel north bound for three days and south bound for another three days. At the end of the sixth day the first ship has completed one full roundtrip and it is back at the port where it left six days ago.

By a calling interval of 24 hours there has been the daily start of a roundtrip requiring another five vessels. On the seventh day the first ship starts its second roundtrip.

This scenario offers daily sailing in both directions. The restriction of a three days transit time port to port N-S span in combination with a given calling interval determines the required number of ships.

Calling twice a day requires twice the number of ships (12 ships) whilst a sailing schedule of every second day will do with just three ships.

The transport capacity of the system, by a given ship size and transit time port to port N-S, halves by doubling the calling interval.

FOCUS ON TIME AND TIME RELATED ASPECTS

In order to find out whether the shuttle service can be a competitive transport mode in comparison to land transport, an analysis of all feasible roundtrip possibilities is necessary. A competitive transport mode means competitive on cost and time basis.

There are two critical time factors which determine whether the service is commercial competitive on time aspects:

- * Transit time port to port of a box, stands for the time a box is on its way from the port where it is loaded to the port of its destination
- * Calling interval, time interval between two successive calls at a particular port by a shuttle ship

The two factors mentioned above are strongly related to the sailing speed of the vessels. The sailing speed of the vessels is determined by:

- * Sailing distance, which is directly dependent on the geographical location of the ports of a particular 'ports of call' configuration
- * Available sailing time

The available sailing time is the remainder of available roundtrip time minus the total turnaround time in port during a roundtrip.

- * Available roundtrip time
 - Maximum allowable transit time port to port N-S, which is a choice with a commercial background
 - Calling interval, which is also a choice with a character of commercial attractiveness
- * Total turnaround time in port per roundtrip, depends on:
 - Cargo handling time
 - Number of box-handlings on a roundtrip
 - Average handling time of a box
 - Port in/out time, which covers the time of entering, mooring, operations and manoeuvring within the port area

Before further investigation of the roundtrip scenario's is possible, the relations mentioned above must be studied carefully, in order to be able to ascertain the influence of certain variables on the time behaviour of the system.

IDENTIFYING VARIABLES & RELATIONS

Regarding time aspects, each roundtrip can be identified by the following six variables:

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- * Sailing distance, directly dependent on the geographical location of the ports of call of a particular configuration
- * Calling interval, time interval between two successive calls at a port. The expression 'calling interval' is used in analogy with other transport concepts, like public bus services
- * Box capacity of the ships, maximum number TEU's and C715 swapbodies carried by the ships
- * Number of ships, total number of ships used in the system configuration
- * Average box handling time, is the total time involved with a loading and discharging operation divided by number of handled boxes
- * Sailing speed, average sailing speed of the ships at sea

The complexity of the roundtrip analysis is not caused by the number of variables but by the inter-relatedness of five of the six variables.

There is one variable which is dependent and can be expressed in all the others, the sailing speed.

$$SSS = \frac{SD}{AST}$$

with:

$$AST = RTTS - (THT + TPIOT)$$

in which:

$$RTTS = \left(\frac{CI}{24}\right) * NS$$

in which:

$$RTTS = \frac{360}{NRTS}$$

and:

$$NRTS = \frac{360}{(NS * \frac{CI}{24})}$$

and:

$$THT = NBH * ABHT$$

This means:

$$SSS = \frac{SD}{((\frac{CI}{24}) * NS) - ((NBH * ABHT) + TPIOT)}$$

With the following symbols:

SSS	= Sailing Speed Ships
SD	= Sailing Distance
AST	= Available Sailing Time
NRTS	= Number Roundtrips per Ship
RTTS	= Round Trip Time Ship
THT	= Total Handling Time
TPIOT	= Total Port In & Out Time
CI	= Calling Interval
NS	= Number of Ships
NBH	= Number of Boxes Handled
ABHT	= Average Box Handling Time

TIME EXPLORATION MODEL

Considering all difficulties and lack of knowledge concerning the boundaries of the variables mentioned above, it is logical to create a multiple stage model.

A multiple stage model can be used for:

- * **the exploration stage:** scanning the boundaries of the solution space.
- * **the 'focus' stage:** get a closer and more detailed view of the solution space.
- * **the evaluation stage:** create insight in the generated solutions and look for logical correlations, will also be carried in this chapter. The evaluation stage is also used to check to the model on non-conformities

Part III: Case-Study Sweden

The roundtrip analysis model is created in a spreadsheet program (Quattro Pro) and is shown in **Figure 71** and **Figure 72**

NUMBER OF SHIPS	AVERAGE HANDLING TIME/BOX (SECI)											
	2	3	4	5	6	7	8	9	10	11	12	
Roundtrips/ship:	180.0	120.0	90.0	72.0	60.0	51.4	45.0	40.0	36.0	32.7	30.0	
Roundtrip time/ship:	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0	240.0	264.0	288.0	
Port in/out time:	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	
Transit Time (days):	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	
AVERAGE HANDLING TIME/BOX (SECI):												
45	Total handling time:	22.2	22.2	22.7	22.2	22.2	22.2	22.2	22.2	22.2	22.2	
	Remaining sailing time:	6.8	30.8	54.9	78.8	102.8	126.8	150.8	174.8	198.8	222.8	
	Speed ships (Kn):	274.3	60.2	33.8	23.6	18.0	14.6	12.3	10.6	8.3	6.3	
60	Total handling time:	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	
	Remaining sailing time:	-0.7	23.3	47.3	71.3	95.3	119.3	143.3	167.3	191.3	215.3	
	Speed ships (Kn):	-2783	79.4	38.1	26.0	19.4	16.6	12.9	11.1	9.7	8.6	
75	Total handling time:	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	
	Remaining sailing time:	-8.1	15.9	39.9	63.9	87.9	111.9	135.9	159.9	183.9	207.9	
	Speed ships (Kn):	-229.2	116.3	46.4	29.0	21.1	16.6	13.6	11.6	10.1	8.3	
90	Total handling time:	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	
	Remaining sailing time:	-15.5	8.5	32.5	56.5	80.5	104.5	128.5	152.2	176.5	200.5	
	Speed ships (Kn):	-119.6	217.8	67.0	32.8	23.0	17.7	14.4	12.1	10.6	9.2	
105	Total handling time:	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	
	Remaining sailing time:	-22.9	1.1	25.1	49.1	73.1	97.1	121.1	145.1	169.1	193.1	
	Speed ships (Kn):	-80.8	1706.8	37.8	37.7	36.3	18.1	14.4	12.8	11.0	9.6	
120	Total handling time:	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	
	Remaining sailing time:	-30.3	-6.3	17.7	41.7	65.7	89.7	113.7	137.7	161.7	185.7	
	Speed ships (Kn):	-61.1	-292.6	104.8	44.4	28.2	20.7	16.3	13.6	11.6	10.0	
135	Total handling time:	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	
	Remaining sailing time:	-37.7	-13.7	10.3	34.3	58.3	82.3	106.3	130.3	154.3	178.3	
	Speed ships (Kn):	-49.1	-134.7	190.5	64.1	31.8	22.6	16.3	14.2	12.0	10.4	
150	Total handling time:	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	
	Remaining sailing time:	-45.2	-21.2	2.8	26.8	50.8	74.8	98.8	122.8	146.8	170.8	
	Speed ships (Kn):	-41.0	-87.6	662.9	69.0	36.4	24.7	17.4	15.1	12.6	10.8	

Figure 71

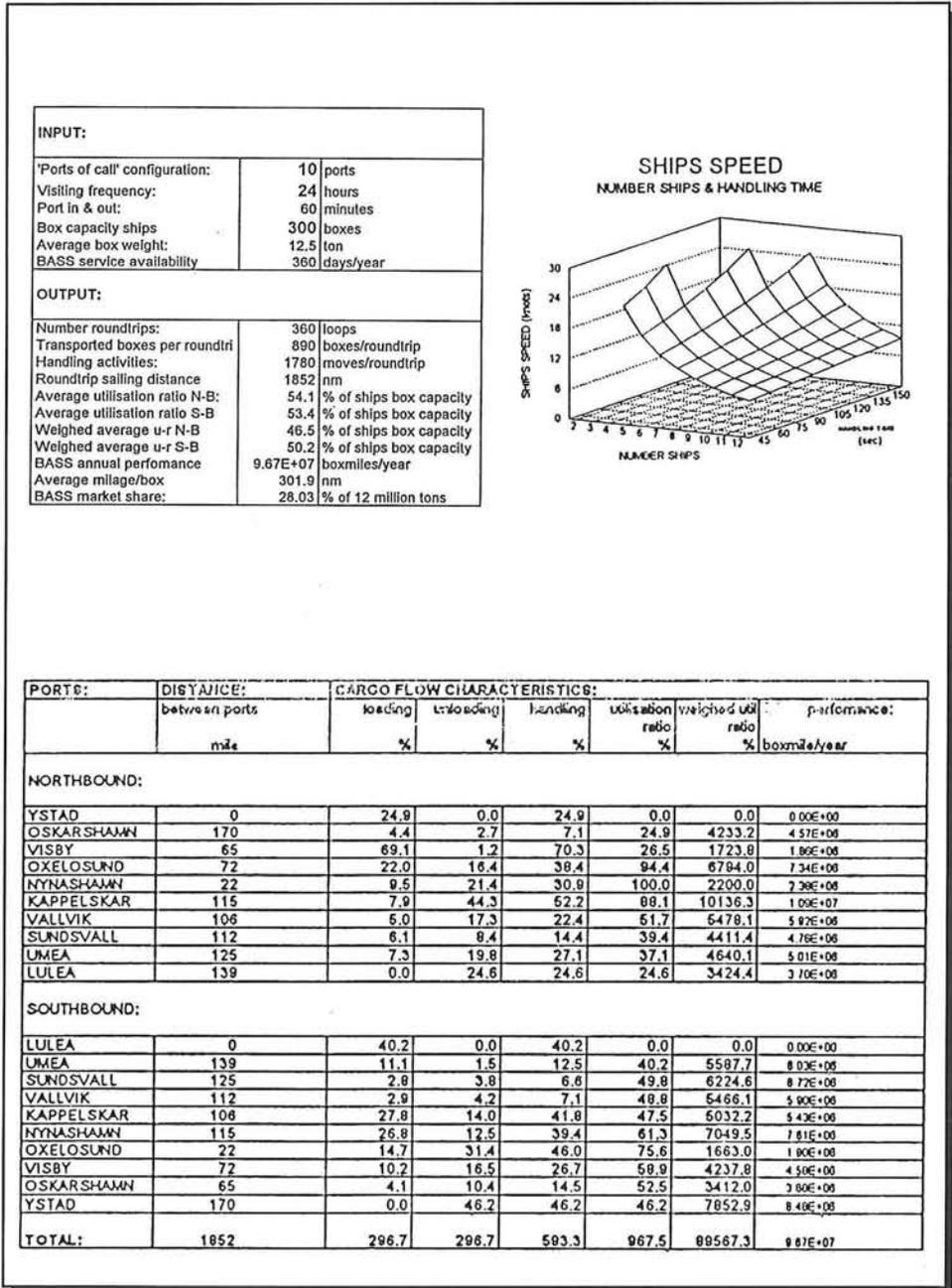


Figure 72

RANGE OF VARIABLES

In order to gain insight in the six variables of the roundtrip model, and the sensitivity of these variables to changes, the variables are changed systematically.

The five independent variables are called entry variables, since they are set to a certain value for calculating the free variable, the sailing speed.

The sailing speed is called a free variable because its value is determined by the entry variables.

For the exploration stage the ranges are applied for the entry variables as given in **Table XXII**:

Entry variables:	Range:	Step:
Sailing distance	6 to 14 ports	1 port
Calling interval	12, 24 and 48 hours	
Box capacity of the ships	200 to 400 boxes	50 boxes
Number of ships	2 to 12 ships	1 ship
Average box handling time	60 to 150 seconds	15 seconds

Table XXII

Exploration of the solution space

The solution space of the exploration stage, with the variable ranges as mentioned above, consists of the possibilities given in **Table XIII**

The solution space exists of 11880 combinations of the entry variables. With these 11880 combinations the corresponding 11880 sailing speed solutions can be calculated.

A matrix presentation of the variables, creating a five dimensional data space, does not provide information which creates insight in the sensitivity of the variables.

Graphical presentation of the dimensions is the solution, but has the limitation in the world we live in, to the number of three dimensions. Normally a sheet of paper has only two dimensions but using landscape graphs an imaginary third one can be created. The use of landscape graphs requires the reduction of the

Variable:	Possibilities:
Sailing distance	9
Calling interval	3
Box capacity of the ships	5
Number of ships	11
Average box handling time	8
Solution Space	11880

Table XXIII

number of variables from six to three. Three variables can be meaningfully visualized on a piece of paper.

Having the possibility to visualize only three of the six variables, the entry and free variables have to be reorganized into three input and three output variables.

Setting half the number of variables to a fixed value requires careful selection and combination of the remaining variables in order the information value

The following output variables are chosen:

- * Sailing speed, is a free variable, can not be used as an input variable
- * Number of ships, gives interesting relation between number of ships and the sailing speed. The range of the number of ships is rather big, which causes a great reduction in the number of spread sheets to be calculated
- * Average box handling time, the variable which influences the sailing speed most. Every concept must be studied carefully for its turnaround time in port, which depends entirely on the 'average box handling time' of the concept.

Summarizing the reorganization of the variables:

- * Three input variables are chosen: sailing distance, calling interval and box capacity of the ships. In this way the number of spread sheets to be calculated are reduced to 135.

- * Three output variables are chosen: sailing speed, number of ships and average handling time. Each spread sheet calculates the 88 different combinations of the number of ships and the average box handling time together with the corresponding sailing speeds. These points are visualized in a landscape graph.

Model structure

The model roughly consists of three calculation blocks and a landscape graph, The calculation blocks are not independent of each other, for example, several parameters computed in the second calculation block are also used in the first and second calculation block.

The landscape graph gives the visualization of the output of the third calculation block. It is meant as a tool permitting interpretation of the relationships between the variables

First block

The first block is a data block (Table XIV), and has an input and output part. The variables and parameters defined in the input part are used in the two other blocks. The parameters given in the output part are calculated in the two other blocks or with results from the two other blocks.

In the **input part** the following parameters are defined:

- * 3 entry variables used as input variables:
 - 'Ports of call configuration', range 6 to 14 ports
 - Calling interval, range 12, 24 and 48 hours
 - Box capacity ships, range 200 to 400 boxes
- * Port in & out time, this is the time to enter the port, to moore the ship and leave the port again. As the service will be a regular service it is considered a standard procedure, like a ferry, and the time involved is set at 60 minutes.
- * Average box weight, this is the weight of the box together with the average cargo weight. The average box weight is set at 12.5 ton, 2 ton for the box and 10.5 ton for the cargo, based on figures provided by shippers in Sweden.
- * Shuttle service availability, set at 360 days per annum.

INPUT:		
'Ports of call' configuration:	10	ports
Visiting frequency:	24	hours
Port in & out:	60	minutes
Box capacity ships	300	boxes
Average box weight:	12.5	ton
service availability	360	days/year
OUTPUT:		
Number roundtrips:	360	loops
Transported boxes per roundtrip	890	boxes/roundtrip
Handling activities:	1780	moves/roundtrip
Roundtrip sailing distance	1852	nm
Average utilisation ratio N-B:	54.1	% of ships box capacity
Average utilisation ratio S-B	53.4	% of ships box capacity
Weighed average u-r N-B	46.5	% of ships box capacity
Weighed average u-r S-B	50.2	% of ships box capacity
annual performance	9.67E+07	boxmiles/year
Average milage/box	301.9	nm
market share:	28.03	% of 12 million tons

Table XXIV: First block

The output part:

- * Number roundtrips, these are the number of roundtrips to be performed by the service according to the calling interval and the service availability.
- * Transported boxes per roundtrip, number of boxes transported per roundtrip by each ship.
- * Handling activities; number of moves to be performed for loading and discharging the boxes.
- * Roundtrip sailing distance, total sailing distance per roundtrip, this distance varies with the 'ports of call configuration'. (Figure 73). More ports count for more sailing miles to get to, in and out every port.
- * Average utilization ratio N-B, this figure stands for the average box capacity used of the total box capacity during the North bound trip.

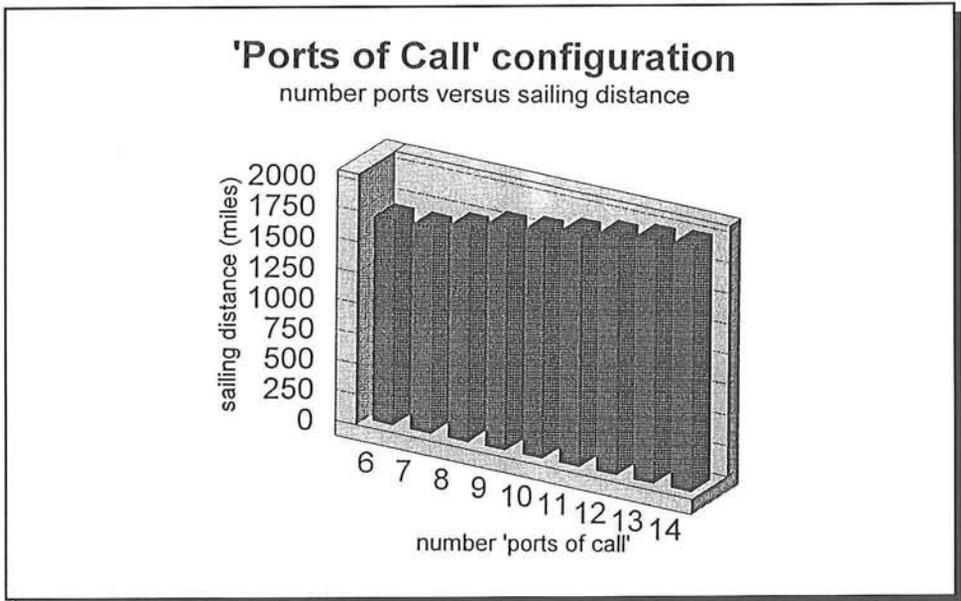


Figure 73: Sailing Distance

- * Average utilization ratio S-B, the same figure as above but now for the South bound leg.
- * Weighed average u-r N-B, this stands for the weighed average utilization ratio North bound. The difference with the forgoing number is that in this case the utilization ratio for every leg (between two ports) is multiplied with the sailing distance of this particular leg. Summarizing all legs and dividing by the total sailing distance of the legs, the difference in length of the sailing legs is accounted for. (Figure 74)
- * Weighed average u-r S-B, same figure as above but now for the South bound leg.
- * Shuttle service annual performance, the annual total amount boxmiles performed by the service.
- * Average milage/box, stands for the average sailing distance of a box.

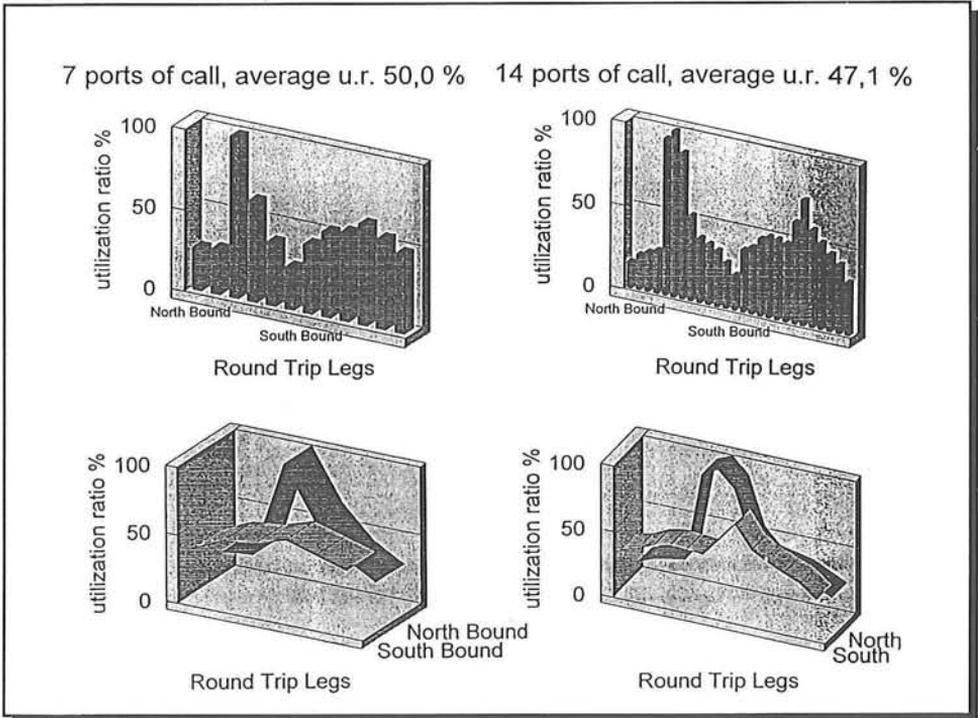


Figure 74: Utilization ratio's

* Shuttle service market share, is the total number of transported boxes on an annual basis, times the average weight of the cargo in the boxes ($12.5 - 2.0 = 10.5$ ton) gives a figure for the total amount of cargo transported by the service in tons. In Chapter 6 the total market size of transferable goods has been determined on 12 million tons. The market share of the service expresses the total amount of cargo transported as a percentage of those 12 million tons.

Second block

The second block is the calculation block (Table XXV), where for the 'ports of call selection' the cargo flow characteristics are calculated.

In the first column the 'ports of call' configuration is given twice: north bound and south bound enabling the calculation of the total roundtrip. The sailing leg distances of the roundtrip are stated in the second column. The figures in the second column stand for the leg distance between the two successive ports, which is the reason why the number after the first port is zero.

Part III: Case-Study Sweden

PORTS:	DISTANCE: between ports mile	CARGO FLOW CHARACTERISTICS:			utilisation ratio %	weighed util ratio %	performance: boxmile/year
		loading %	unloading %	handling %			
NORTHBOUND:							
YSTAD	0	24.9	0.0	24.9	0.0	0.0	0.00E+00
OSKARSHAMN	170	4.4	2.7	7.1	24.9	4233.2	4.57E+06
VISBY	65	69.1	1.2	70.3	26.5	1723.8	1.66E+06
OXELOSUND	72	22.0	16.4	38.4	94.4	6794.0	7.34E+06
NYNASHAMN	22	9.5	21.4	30.9	100.0	2200.0	2.38E+06
KAPPELSKAR	115	7.9	44.3	52.2	88.1	10136.3	1.09E+07
VALLVIK	106	5.0	17.3	22.4	51.7	5478.1	5.92E+06
SUNDSVALL	112	6.1	8.4	14.4	39.4	4411.4	4.76E+06
UMEA	125	7.3	19.8	27.1	37.1	4640.1	5.01E+06
LULEA	139	0.0	24.6	24.6	24.6	3424.4	3.70E+06
SOUTHBOUND:							
LULEA	0	40.2	0.0	40.2	0.0	0.0	0.00E+00
UMEA	139	11.1	1.5	12.5	40.2	5587.7	6.03E+06
SUNDSVALL	125	2.8	3.8	6.6	49.8	6224.6	6.72E+06
VALLVIK	112	2.9	4.2	7.1	48.8	5466.1	5.90E+06
KAPPELSKAR	106	27.8	14.0	41.8	47.5	5032.2	5.43E+06
NYNASHAMN	115	26.8	12.5	39.4	61.3	7049.5	7.61E+06
OXELOSUND	22	14.7	31.4	46.0	75.6	1663.0	1.60E+06
VISBY	72	10.2	16.5	26.7	58.9	4237.8	4.56E+06
OSKARSHAMN	65	4.1	10.4	14.5	52.5	3412.0	3.66E+06
YSTAD	170	0.0	46.2	46.2	46.2	7852.9	8.46E+06
TOTAL:	1852	296.7	296.7	593.3	967.5	89567.3	9.67E+07

Table XXV

The roundtrip time exploration model works with a 'non-dimensional flow characteristics' module, which is based on the market size and composition of the cargo flow as discussed in Chapter 9.

The columns for loading, unloading, handling and utilization ratio are initially calculated in tons.

Given the highest utilization ratio, the index 100, the loading, unloading, handling and utilization ratio can be expressed as a 'non-dimensional flow characteristics' module, having the great advantage of being able to calculate several box capacities of the ships with the same spread sheet.

The column "loading" gives the percentage of the box capacity which is loaded in a particular port. For example a loading percentage of 26,4% by a box capacity of 300 boxes means a loading operation of 79 boxes.

The same procedure can be followed for the unloading and handling column in which the latter can be multiplied with the average box handling time to obtain the total handling time. This results in the total handling time distribution as shown in Figure 75.

The last column of the second calculation block gives the shuttle service performance in boxmiles per year. This figure is very useful when the cost analysis is made, it stands for number of boxmiles which can be charged to users of the service.

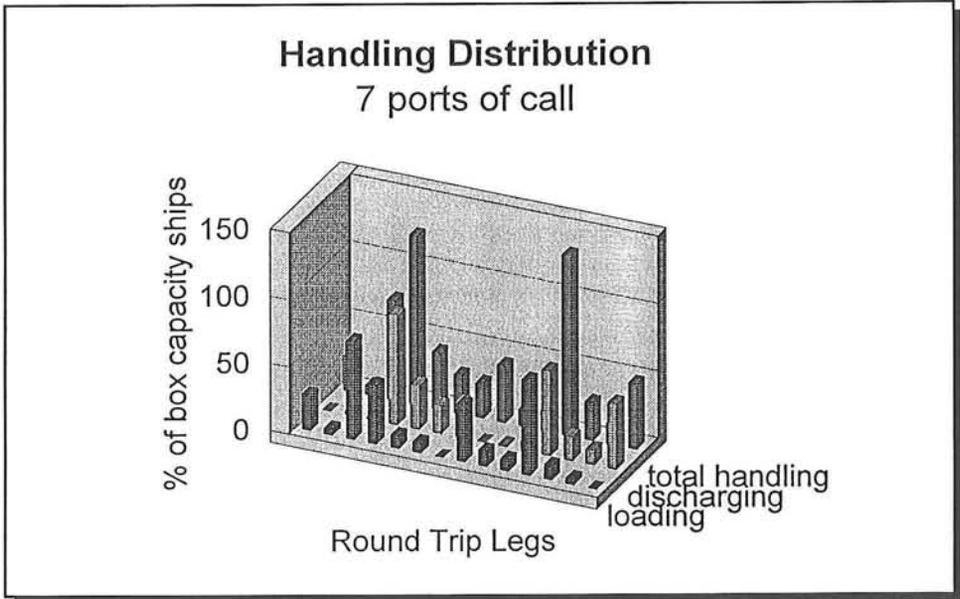


Figure 75: Handling Time Distribution

Third block

In the third block (Table XXVI) the entry variables, number of ships and average box handling time, which have become output variables, have been varied over their range.

The sailing speed is calculated for the combinations of the number of ships and the average box handling time.

The following parameters have to be determined for each number of ships in order to be able to calculate the sailing speed:

- * **Roundtrips per ship per year**, service availability (see first block) is divided by the Calling interval (see first block) and the Number of ships (see third block).
- * **Roundtrip time per ship**, the available roundtrip time per ship must be the service availability divided by the number of roundtrips.
- * **Port in/out time**, is time port in&out (see first block) times the number of ports minus one
- * **Transit time port to port N-S**, is half the roundtrip time

Part III: Case-Study Sweden

NUMBER OF SHIPS		2	3	4	5	6	7	8	9	10	11	12
Roundtrips/ship:		180.0	120.0	90.0	72.0	60.0	51.4	45.0	40.0	36.0	32.7	30.0
Roundtrip time/ship:		48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0	240.0	264.0	288.0
Port in/out time:		19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Transit Time (days):		1,0	1,5	2.0	2.5	3.0	3.5	4.0	4.5	6.0	5.5	6.0
AVERAGE HANDLING TIME/BOX (SEC):												
45	Total handling time:	22.2	22.2	22.7	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
	Remaing sailing time:	6.8	30.8	54.9	78.8	102.8	126.8	150.8	174.8	198.8	222.8	246.8
	Speed ships (Kn):	274.3	60.2	33.8	23.6	18.0	14.6	12.3	10.6	8.3	6.3	7.6
60	Total handling time:	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
	Remaing sailing time:	-0.7	23.3	47.3	71.3	95.3	119.3	143.3	167.3	191.3	215.3	239.3
	Speed ships (Kn):	-2783	79.4	38.1	26.0	19.4	16.6	12.9	11.1	9.7	8.6	7.7
75	Total handling time:	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1	37.1
	Remaing sailing time:	-8.1	15.9	39.9	63.9	87.9	111.9	135.9	159.9	183.9	207.9	231.9
	Speed ships (Kn):	-229.2	116.3	46.4	29.0	21.1	16.6	13.6	11.6	10.1	8.3	8.0
90	Total handling time:	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5
	Remaing sailing time:	-15.5	8.5	32.5	56.5	80.5	104.5	128.5	152.2	176.5	200.5	224.5
	Speed ships (Kn):	-119.6	217.8	67.0	32.8	23.0	17.7	14.4	12.1	10.6	9.2	8.2
105	Total handling time:	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9
	Remaing sailing time:	-22.9	1.1	25.1	49.1	73.1	97.1	121.1	145.1	169.1	193.1	217.1
	Speed ships (Kn):	-80.8	1708.8	37.8	37.7	36.3	18.1	14.4	12.8	11.0	9.6	8.6
120	Total handling time:	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3	59.3
	Remaing sailing time:	-30.3	-6.3	17.7	41.7	65.7	89.7	113.7	137.7	161.7	185.7	209.7
	Speed ships (Kn):	-61.1	-292.6	104.8	44.4	28.2	20.7	16.3	13.6	11.6	10.0	8.8
135	Total handling time:	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7
	Remaing sailing time:	-37.7	-13.7	10.3	34.3	58.3	82.3	106.3	130.3	154.3	178.3	202.3
	Speed ships (Kn):	-49.1	-134.7	190.5	64.1	31.8	22.6	16.3	14.2	12.0	10.4	9.2
150	Total handling time:	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2
	Remaing sailing time:	-45.2	-21.2	2.8	26.8	50.8	74.8	98.8	122.8	146.8	170.8	194.8
	Speed ships (Kn):	-41.0	-87.6	662.9	69.0	36.4	24.7	17.4	15.1	12.6	10.8	9.6

Table XXVI: Third Block

Before the sailing speed can be calculated, the total handling time per roundtrip has to be calculated for every 'average box handling time' first. Already known from the second block, the total percentage of the box capacity to be handled, together with the box capacity from the first block this number only has to be multiplied with the average box handling time to know the total handling time.

The remaining sailing time is the roundtrip time minus the port in&out time and minus the total handling time. Dividing the total sailing distance per roundtrip (see the second block) by the remaining sailing time gives the required sailing speed for that shuttle system configuration.

In the situation that the total turnaround time of a certain scenario equals the available roundtrip time, the remaining sailing time will be reduced to zero and sailing speed will get an extreme value. Increasing the turnaround time even

more, results in a shortage of sailing time which is reflected by a negative sign of the corresponding sailing speeds.

Speed figures with negative values correspond with impossible solutions.

Landscape graphs

The landscape graph gives the visualization of the output of the third calculation block. It shows the relationships between the sailing speed of the vessels, number of ships and average box handling time (Figure 76).

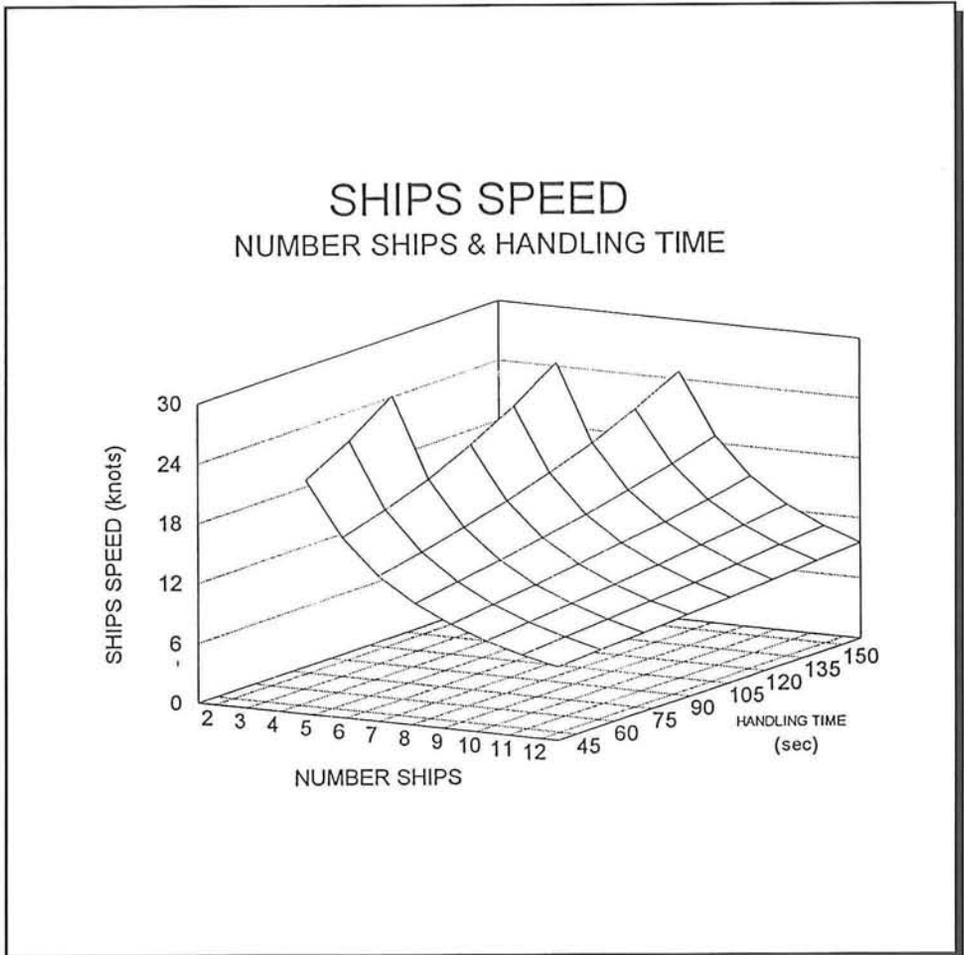


Figure 76

EVALUATION OF MODEL INFORMATION

The exploration stage of the roundtrip analysis now has been finished. The produced output of the roundtrip analysis model, the solution space, is calculated.

The generated model information must be validated before it can be used in the 'focus stage'. During the 'focus stage' all the solutions which are not suitable, commercially attractive or technically feasible, will be sorted and left out of further consideration. The 'focus stage' will be dealt with in **Chapter 12**.

'Ceteris paribus'

Evaluation of the relationships between the entry variables and the free variable will be carried out via the 'Ceteris Paribus' method. Ceteris Paribus means variation of one variable whilst keeping the others unchanged.

	RSS	SD	VF	BC	AB H	NS
Required Sailing Speed	♦					
Sailing Distance	fig 77	♦				
Calling interval	fig 78		♦			
Box Capacity	fig 79			♦		
Average Box Handling Time	fig 80				♦	
Number of Ships	fig 81					♦

Table XXVII

Table XXVII shows that the model embodies 15 different relations between the variables. The relations between the free variable, the required sailing speed, and the five entry variables are discussed and shown in the figures as mentioned in the table.

Required sailing speed versus sailing distance

The relationship between the required sailing speed and the sailing distance is determined by the effect of adding one port results in both an increase in distance as well as an increase of total port manoeuvring time.

Variable	Value
Sailing speed	free
Sailing distance	6 to 14 ports
Calling interval	24 hours
Box capacity ships	300 boxes
Average box handling time	150 seconds
Number of ships	5 ships

Table XXVIII

Figure 73 has already shown that the sailing distance does not increase linearly with the number of ports, this explains the irregularity, non-linearity, shown in Figure 77.

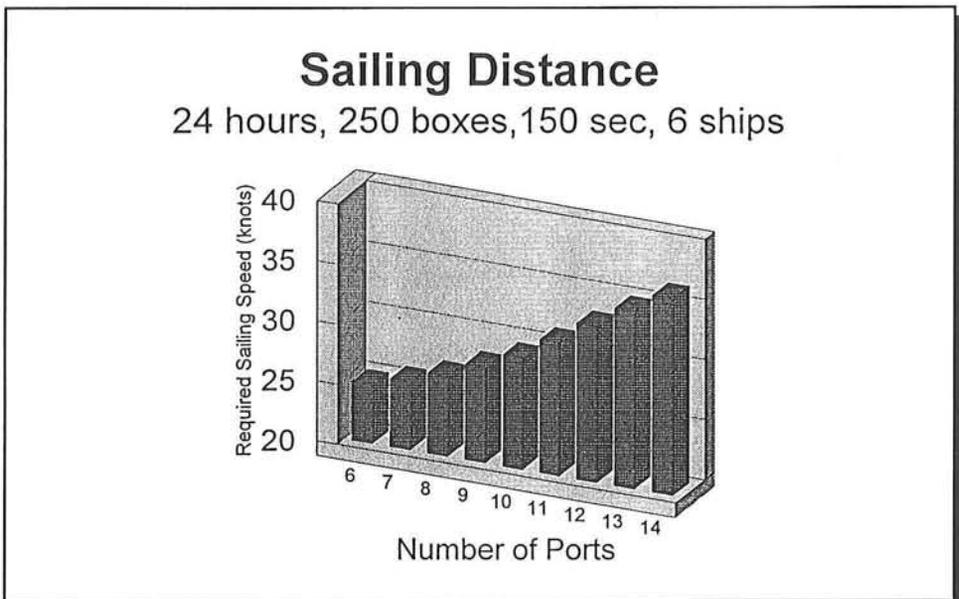


Figure 77: Required Sailing Speed versus Sailing Distance

Required sailing speed versus calling interval

Variable	Value
Sailing speed	free
Sailing distance	6 ports
Calling interval	12, 24, 48 h
Box capacity ships	300 boxes
Average box handling time	60 seconds
Number of ships	5 ships

Table XXIX

The calling interval has a linear relationship with the roundtrip time: doubling the calling interval doubles the roundtrip time. The remaining sailing time is the result of the roundtrip time minus the total handling time. The fact that the relationship between the sailing speed and the calling interval is not linear (Figure 78) can be explained: a constant value (the sailing distance) is divided by a linear increasing function (the remaining sailing time).

Required sailing speed versus box capacity ships

Variable	Value
Sailing speed	free
Sailing distance	6 ports
Calling interval	24 hours
Box capacity ships	200-400 boxes
Average box handling time	120 seconds
Number of ships	5 ships

Table XXX

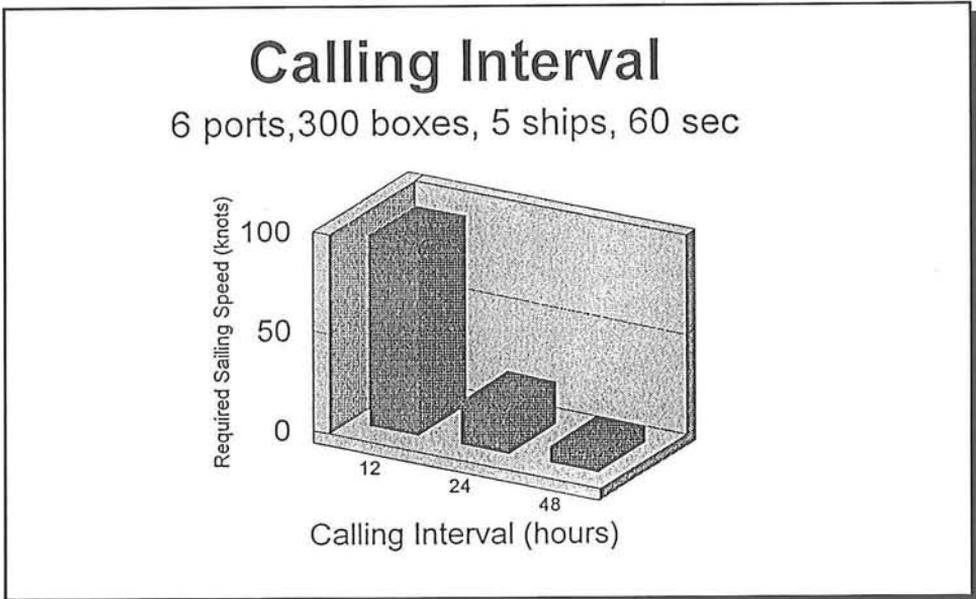


Figure 78: Required Sailing Speed versus Calling Interval

By increasing numbers of the box capacity the total handling time increases, which is a linear relationship. The remaining sailing time decreases when the total handling time increases, compensated by an increase of the sailing speed as can be seen in Figure 79.

The non-linear relationship between the sailing speed and the box capacity of the ships is caused by almost the same reason as that of the calling interval but this must be divided by a linear increasing function instead of a linear decreasing function.

Required sailing speed versus average box handling time

The average box handling time has the same linear relationship with the total handling time as the box capacity of the ships, given in the relationship represented in Figure 80.

Required sailing speed versus number of ships

The number of ships determines the number of roundtrips per ship. The number of roundtrips determines the roundtrip time. The behaviour of "number of ships" (Figure 81) can be compared with the behaviour of the calling interval.

Box Capacity Ships

6 ports, 24 hours, 6 ships, 120 sec

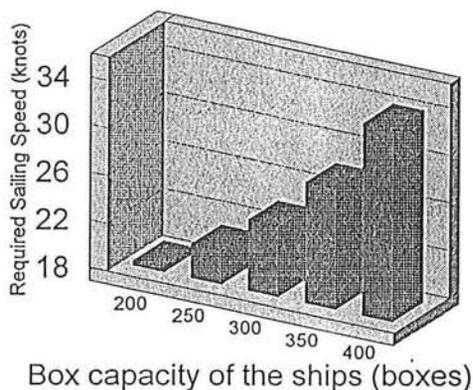


Figure 79: Required Sailing Speed versus Box Capacity Ships

Variable	Value
Sailing speed	free
Sailing distance	6 ports
Calling interval	24 hours
Box capacity ships	300 boxes
Average box handling time	45-150 seconds
Number of ships	5 ships

Table XXXI

Additional model parameters

In block three the commercially important parameter, the transit time port to port N-S, is computed. The transit time port to port N-S gives the maximum 'ti-

Average Box Handling Time

6 ports, 24 hours, 5 ships, 300 boxes

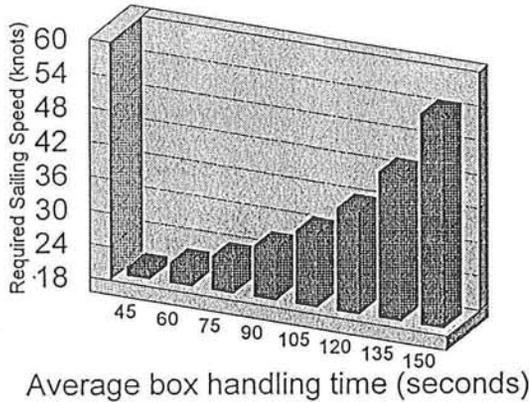


Figure 80: Required Sailing Speed versus Average Box Handling Time

Variable	Value
Sailing speed	free
Sailing distance	6 ports
Calling interval	24 hours
Box capacity ships	300 boxes
Average box handling time	60 seconds
Number of ships	2-12 ships

Table XXXII

me span' of a box aboard a shuttle ship. Due to its importance these variables are discussed in more detail.

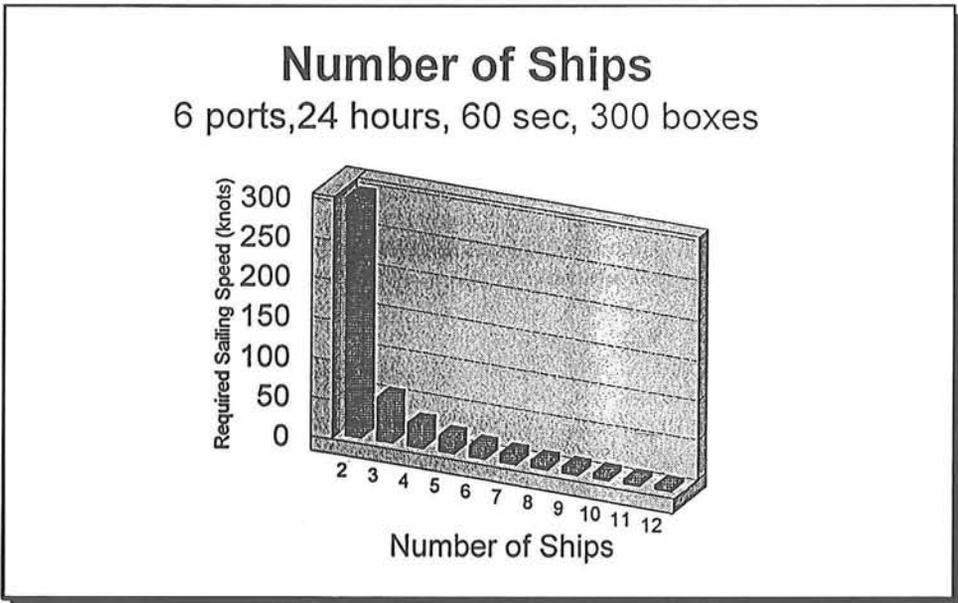


Figure 81: Required Sailing Speed versus Number of Ships

Transit time port to port n-s versus number ships and calling interval

The following relations are known:

- * the transit time port to port N-S is half the roundtrip time
- * total number roundtrips is shuttle service availability per year' divided by the calling interval
- * number roundtrips per ship is total number roundtrips divided by the number of ships
- * roundtrip time is service availability per year' divided by the number of roundtrips per ship

This results in the following equation for the transit time port to port N-S (in days):

$$TT \text{ Port Port N-S} = \frac{1}{2} (\text{Number Ships} * (\frac{\text{Calling Interval}}{24}))$$

Figure 82 shows the relationship between the transit time port to port N-S versus the calling interval and the number of ships.

The dark band in the graph displays the area with a transit time port to port N-S 'time span' of 2 to 4 days.

TT Port to Port N-S

Number Ships and Calling Interval

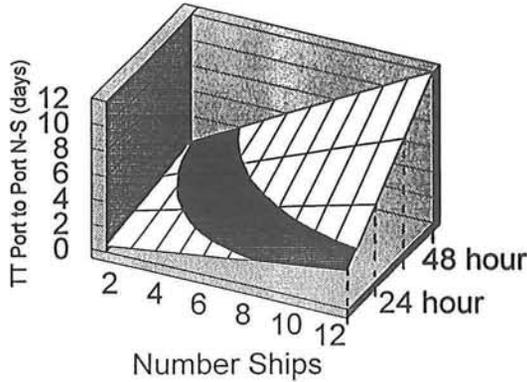


Figure 82: Port to Port Time N-S versus Number Ships and Calling Interval

Transit time port to port n-s versus sailing speed and market share

The opposite viewpoint is, "what is the relationship between the number of ships, calling interval and the sailing speed (8 ports, 300 boxes and 60 seconds)?"

The combination of the calling interval and number of ships stands for a transit time port to port N-S of 3 days (just as an example a transit time port to port N-S of 3 days is chosen):

For a fixed value, the transit time port to port N-S (together with fixed: number of ports, box capacity and average box handling time) the sailing speed maintains the same value for different combinations of the number of ships and the calling interval.

This phenomenon can be very useful in a later stage when the exact roundtrip schedule has to be calculated.

The market share has a linear relationship with the number of ships in the system. This result is not astonishing but has to be kept in mind when setting up the total system.

Calling interval hours	Number Ships	TT port to port N-S days	Sailing Speed knots	Market Share %
12	12	3	17.7	57.67
24	6	3	17.7	28.83
36	4	3	17.7	19.23
48	3	3	17.7	14.42

Table XXXIII

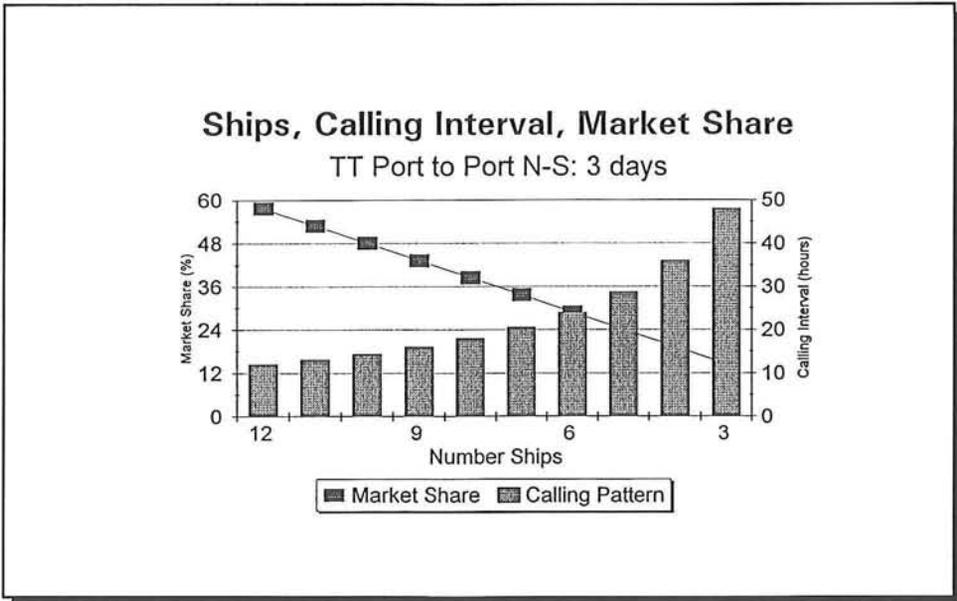


Figure 83: Number Ships versus Calling Interval and Market Share

Sailing distance versus average & weighed utilization ratios

The utilization ratios are dependent on the 'ports of call' configuration by the cargo flow distribution. The distribution of the total cargo flow is based on the geographical location of the ports.

In Figure 83 the utilization ratios for 7 and 14 ports are displayed for each sailing leg. On the Northbound leg one port has a much bigger cargo flow (of

course the one with the utilization ratio of 100 %) than the rest of the ports. The port with the much bigger cargoflow is Stockholm. Stockholm with its large number of inhabitants has a large cargoflow of both consumer goods and industrial products.

The average of all sailing leg utilization ratio's is called the average utilization ratio. The relationship of this particular ratio against the number of ports is shown in Figure 84.

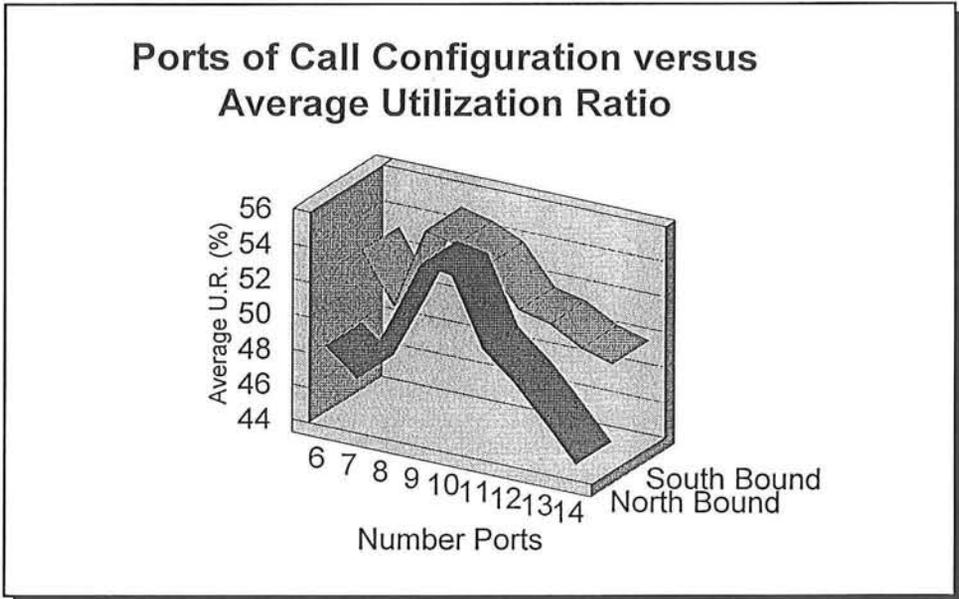


Figure 84: Ports of Call Configuration versus Average Utilization Ratio

A remarkable phenomenon appears with by 9 ports. The average utilization ratio goes up to 9 ports, to go down from 9 to 14 ports. This phenomenon can be explained with the cargoflow distribution. The cargoflow which was concentrated is broken down to two smaller parcels distributed over two ports. This causes higher utilization ratios for the other sailing legs which causes a higher average utilization ratio. The average utilization ratio goes down from 9 ports until the largest cargoflow is broken down again.

In Figure 85 the relationship between the weighed average utilization ratio and the number of ports is shown. The phenomenon explained above is even clearer to see in this graph.

Sailing distance versus shuttle annual performance

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The shuttle annual performance stands for the total number of boxmiles performed per year.

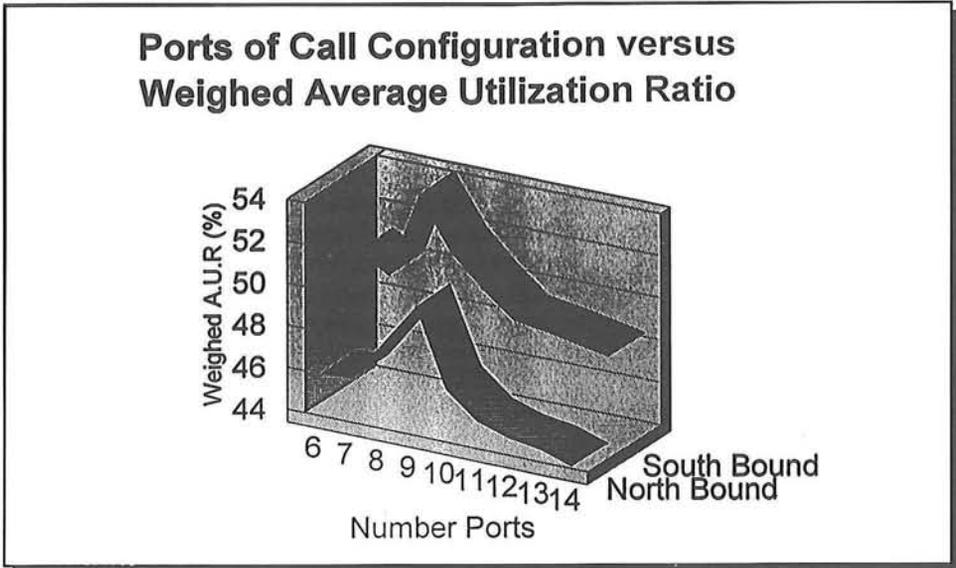


Figure 85: Ports of Call versus Weighed Average Utilization Ratio

The annual performance depends on the 'ports of call' configuration twice:

- * first it depends on the average utilization ratios of the ships which is dependent on the cargo flow distribution. The cargo flow distribution itself is dependent on the number of ports in the system.
- * second of the sailing distance which is also dependent on the number of ports in the system.

The relationship between the number of ports and the shuttle service annual performance is represented in Figure 86.

The dependency on the average utilization ratios is explicitly shown. With 9 ports the average utilization ratio is higher, which results in a higher amount of boxmiles performed.

The increasing sailing distance with an increasing number of ports establishes higher boxmile performance.

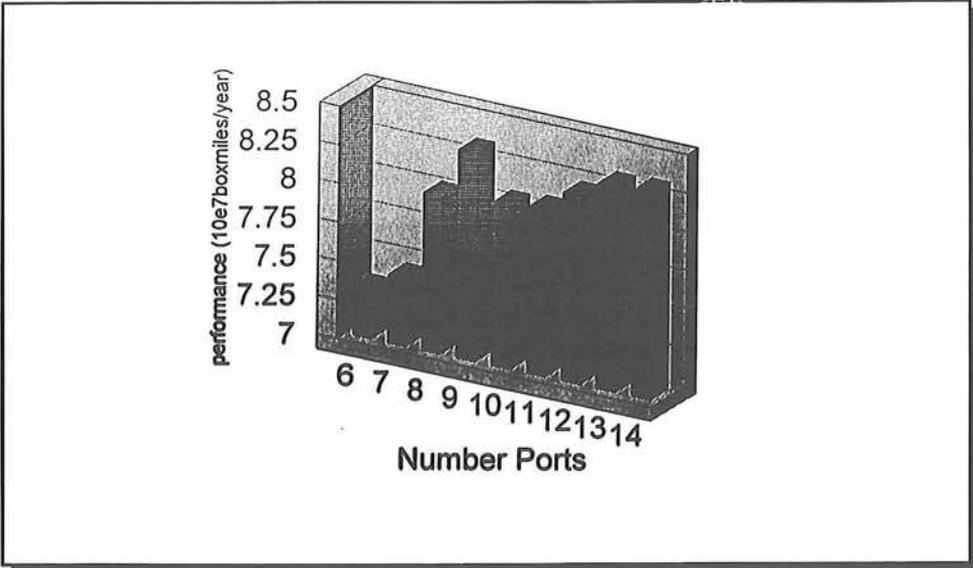


Figure 86: Shuttle service annual Performance versus Number of Ports

CHAPTER 12: SELECTION OF FEASIBLE ROUNDTRIP SCENARIOS

With the help of the calculations of the previous chapter, the feasible and attractive roundtrip scenario's will be selected.

DEMARICATION OF SOLUTION AREA WITHIN THE SOLUTION SPACE

The exploration model, described in the Chapter 11, has produced 11880 information carrying vectors, data points in the solution space.

Appraising each and every solution from this collection on its individual merits would not be an efficient approach because a large share of the entire solution space is filled with solutions which are not suitable, feasible or attractive enough to justify further research.

It would speed up the scenario selection process if the solutions space could be narrowed down to just those options which do meet the qualifications mentioned before. This is called demarcation.

Demarcation requires criteria for rejecting or adopting certain solutions of the entire collection in the solution space.

The criteria can be of diverse nature:

- * Commercial demands
- * Local conditions
- * Technical limitations

In the next paragraphs these criteria will be discussed both qualitative as well as quantitative.

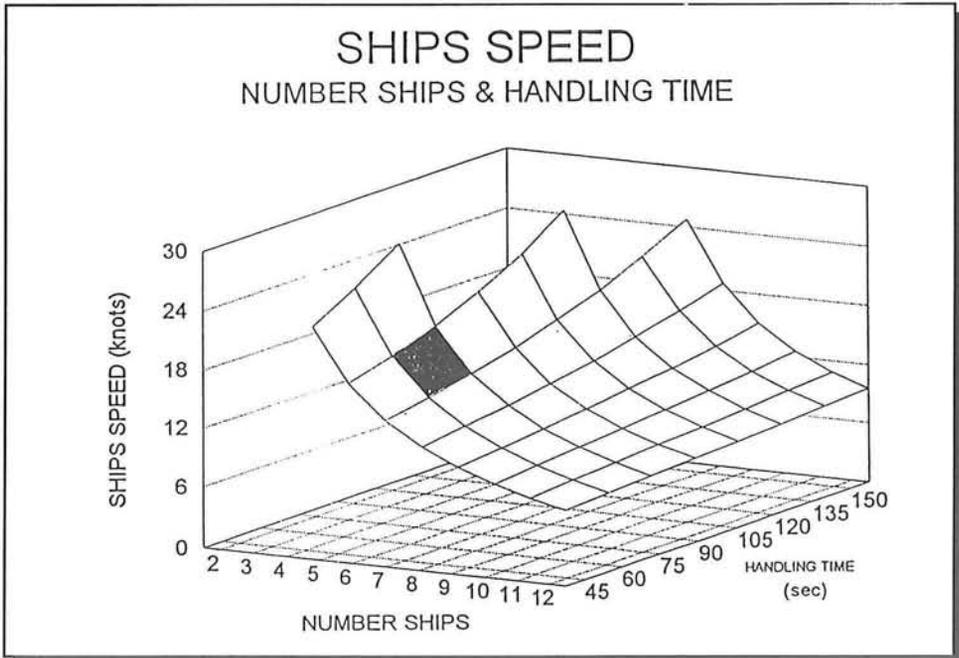
Quantifying the criteria is very critical and should be done with care and cautiousness: "Don't throw away the baby with the bathwater", as a dutch expression goes.

The demarcation process starts with applying the criteria to the information on the label of each landscape graph which results in rejecting those with inappropriate visiting frequency, number of ports or box capacity.

The demarcation of the remaining landscape graphs will be done by allocating value intervals to the free variables.

Feasible average handling times, a suitable number of ships and realistic sailing speeds need to be quantified in terms of their highest and lowest values. This will lead to the demarcation of areas which meet the criteria.

The visual interpretation is an area which can be discriminated on the surface of the landscape graphs.



COMMERCIAL DEMANDS, LOCAL SWEDISH CONDITIONS AND TECHNICAL LIMITATIONS

Criteria from commercial demands

Transit time and calling pattern determine the commercial attractiveness of a shuttle system as an alternative and additional mode of transport.

The logistical costs of goods transport is the sum of the transport costs and the time value of the goods. The time value is an expression for the interest on the amount of capital, the value of the goods, which is tied up in the logistical chain and for the depreciation of the goods during transport.

The analysis of the customers wishes, one of the goals of the visiting tour through Sweden and part of the critical success factor analysis (**Chapter 2**), indicates that the competitiveness of the system very much depends on its ability of offering short transit times. Road transport can perform a north/south transport within approximately two to three days, except for the weekends. The Shuttle System has to compete with land transport. A transit time of two days makes it an important challenger because that offers an equivalent for one of the strongest points of land transport.

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Shippers have indicated that a transit time of approximately three days could still be acceptable because the average capital tie-up is not so high that it cannot stand an extra day in the logistical pipeline.

The shuttle service should be able to offer a north south transit time of approximately three days or shorter. Two days can be considered as most desirable.

The other aspect of time, with reference to the commercial demands, is the calling frequency of the ships. The ships can call twice a day, once a day or every second day.

The critical success factor analysis states that the calling interval is not very critical. It is the regularity and reliability that counts for the majority of the interviewed shippers.

To a certain extent the shippers and receivers can adapt their logistical organisation to the system. All attractive calling intervals will be incorporated in this analysis. It is part of the complete picture and they can be of interest for the introduction scenario's of the system.

The commercial demands of transit time and calling pattern produce the first set of criteria for evaluation purposes:

- * Transit time (north/south) may not exceed the upper limit of approximately three days.
- * Calling interval is not a rejection criterium. All options (once, twice or every second day) are kept under consideration.

Transit time, calling interval and number of ships are directly related to each other. The landscape graphs show the number of ships with the calling pattern stated on the corresponding label.

The calling interval does not influence the sailing speed of the vessels. The transport capacity is linear dependent and doubles when the number of calls is doubled.

Criteria from local swedish conditions

The Swedish transport situation and the winter conditions also produce rejection criteria which can be quantified.

A survey has been carried out which resulted in a figure for the total market size of the shuttle service transferrable goods, of 12 million tons of general cargo and breakbulk goods, which in potential are suitable for transport by the container and swapbody shuttle.

This same survey projects that the system can attract 2.5 to 3.5 million tons from this volume in the future. These figures correspond with market shares which lie between 20 and 30 %.

The transport capacity which the shuttle can offer is a direct result of box capacity, calling pattern and cargo flow characteristics. The transport capacity of each scenario is translated into a market share percentage which has to balance the capacity.

Scenario's which offer much more than 30 % will be rejected.

Options with a "less than 20 % label" are interesting as an introduction scenario and will not be rejected at this stage.

Scenario's with labels in excess of 30 % are interesting for future expansions of the system. Excessive empty loading space can be accepted temporarily but can not be seen as a solution for a well balanced system which has to offer a good and longterm cost stable mode of transport in a competitive environment.

The Swedish winter conditions require a certain minimum deadweight of the vessels.

Requirements for successful operation in ice and for acceptance by the Swedish Administration of Shipping and Navigation, who direct the assistance of ice breakers, include a minimum deadweight of about 3000 tons.

A unit carrying ship of particular size will require a certain slot capacity, stowage positions for cargo units. When transporting a mixture of containers and swapbodies the expression "box-capacity" will be used as an indication of the ships size. Assuming that the average weight of a loaded box amounts to 12.5 tons it would require approximately 250 loaded boxes to fill a deadweight of 3000 tons. This necessitates a capacity of 250 boxes or more for each vessel. Taken into account the repositioning of empty units, which requires additional stowage positions, the upper limit of the box capacity scale should read approximately 350 boxes or more.

The Swedish transport situation and the winter conditions produce the second set of criteria for evaluation purposes:

- * Capacity of the system must be balanced by a market share which has a maximum value of 30 % of 12 millions tons per year.
- * The vessels should have a box capacity exceeding 250 boxes.

Criteria from technical limitations

The technical limitations are more difficult to quantify. At this stage there is little known about the behaviour of the system in the solution space. The technical limitations play a dominating role and setting stringent criteria could lead to losing valuable solutions.

The technical limitations which need to be quantified in order to introduce them as rejection criteria are:

- * Average handling time per box
- * Maximum sailing speed

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A preliminary estimate of the average handling time indicates a range from 45 till 75 seconds per box.

The results of **Chapter 13** will verify whether these are realistic and feasible figures. **Chapter 12** deals with the survey of the technical merits of each concept and an important part of it concerns the projection of handling time characteristics for the technically most suitable concept, including the effects of cargo handling at sea.

Technical limitations in terms of operational circumstances and maximum performance figures of handling equipment produce the following criterium:

- * Reject solutions which require average handling times less than 45 seconds or more than 75 seconds per box.

Sailing speed is the other technical constraint which dominates this selection process. The five independent variables of the system; number of ports, calling pattern, number of ships, box capacity and average handling time determine the required sailing speed. Sailing speed is a dependent variable and is plotted against the vertical z-axis of the landscape graphs.

When screening the calculation sheets the speed figures display the occurrence of extreme values which can be explained as running out of available sailing time when turnaround time increases at a given allowable roundtrip time.

When the total turnaround time of a certain scenario equals the available round-trip time the remaining sailing time will be reduced to zero and sailing speed will get an extreme value.

Increasing the turnaround time even, more results in a shortage of sailing time which is reflected by a negative sign of the corresponding sailing speeds.

The required sailing speed has to meet the following criteria:

- * Solutions with sailing speed figures with a non-positive value will be rejected.
- * Solutions with speeds in excess of 30 knots will be rejected, due the high energy consumption.

Recent feasibility studies indicate that the present state of technology allows for fast cargo ship designs with speeds in the 35 knots range. This study refers to the Kvaerner Masa-Yards concept of a slender hull, fast cargo vessel which has a special hull design. Although the technical feasibility is proven, it also stresses the fact that the cost involved with high speeds must be born by the freight income of the vessel. Given the fact that the transferable goods are of moderate value it sounds reasonable to draw the upper speed limit at a provisional value of 30 knots.

A speed of 30 knots is still very high, but at this stage it is more important to develop insight in the boundary behaviour of this evaluation process rather than to quickly reject solutions of which the feasibility can be doubted.

The technical limitations to average handling time and sailing speed produce the following provisional rejection criteria:

- * Average handling time should range between 45 and 75 seconds per box.
- * Average required sailing speeds should not exceed 30 knots

REJECTION AND ADOPTION OF SCENARIO'S

Multi stage evaluation process

The 11880 data points of the solutions space, which were produced by the exploration model, will be ran through a multi stage evaluation process. The rejection criteria for use in the first stage are described in the preceding three paragraphs. Basically, these criteria are the first level of the numerical interpretation of the qualifications; suitable, feasible and attractive.

The expectation is that after the first stage more knowledge comes available about the boundary behaviour of this evaluation process within the solution space. A better definition of the technical requirements and more specific indications of the technical feasibilities will lead to new criteria which will be used in the second stage of this trial and error search process.

The results of the first and the second stage is a list of potential scenario's including the technical specifications of sailing speed and cargo handling figures.

Screening sequence first stage

The first stage deals with the initial rejection of solutions which do not meet the criteria for the commercial demands, local conditions and technical limitations.

The following sequence of criteria has been applied:

- * Check all 135 labels (attached to 135 corresponding landscape graphs) on the minimum required box capacity of 250 boxes.
- * Check the remainder on realistic market share figures, which should not exceed 30 %.
- * Reject solutions with average handling times which do not range between 45 and 75 seconds per box.
- * Screen all output tables on the port to port time (north/south) and reject those which exceed the 3 days limit.
- * Reject solutions with a sailing speed in excess of 30 knots.

Application of these criteria demarcates a search area which is significantly smaller than the original solution space. The large number of initial solutions is

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reduced to a number of 225 solutions for roundtrip scenario's which have the potential of being commercially attractive and suitable for the local conditions. The original solution space, containing 11880 options, was reduced to 225 options as shown in Table XXXIV.

	CRITERION	REDUCTION	OPTIONS
			11880
1	Minimum box capacity (250 boxes)	2376	9504
2	Maximum market share (30 %)	4752	4752
3	Handling time (45 < average < 75 sec)	2970	1782
4	Maximum port to port time (3 days)	1296	486
5	Maximum speed (30 knots)	261	225
	N ^o of options after demarcation		225

Table XXXIV

The number of 225 remaining options is still too high. Other or more stringent criteria must be developed for further evaluation and rejection of solutions.

The 225 options are the first rough results of the solution space exploration. In order to get a more refined picture, all remaining options were put into a data base. The strength of a data base is that it provides possibilities to rank the solutions according certain criteria. The ranking criteria can be indicated including a sequence of hierarchical levels.

The following sequence of hierarchical levels was applied to rank the 225 remaining options:

- * Calling interval
- * Average handling time
- * Box capacity of the ships
- * Transit time (Port to Port, N-S)
- * Number of ports
- * Transport costs (Port to Port, N-S)

As in most design/configuration processes there is interaction between insight in the technical requirements, which gradually become better known, and what is

actually feasible. The latter often is the answer to a continuously changing question.

Interaction between scenario selection and concept selection

Characteristic for this scenario selection process is that it switches back and forth between the remaining solutions after the application of a selection criterion and the results from the concept selection process which produces performance figures. The concept selection process itself very much depends on the technical requirements which are brought forward by the scenario selection process.

Chapter 13, which covers the concept selection process and the performance calculations, can not be dealt with in advance of this chapter because without knowledge about the required performance figures no meaning full selection of a concept can be made and the calculations will be meaningless if there is no preliminary indication of what is required.

As a result of this trial and error search process between requirements and feasibilities, more knowledge became available about the technical aspects of the configuration problem of producing a well balanced proposal of a roundtrip schedule with a suitable shuttle ship concept. This provides new criteria which can be applied to the list of remaining options.

Closing in on calling schedule

The solutions which are based on a calling frequency of twice a day all offer market shares which exceed the limit of 30 %. These solution, with a 12 hour schedule, was already eliminated in the first evaluation process.

The remaining options include solutions which are based on ships calling every second day or at 48 hour intervals. A 48 hour schedule has the following disadvantages:

- * Calling at a fixed day is very important from a commercial point of view. The fact that a week has an odd number of seven days necessitates the use of a combined calling schedule of two intervals of two days and an interval of three days or three times two days and one additional sailing during the week. In both cases the calling schedule is not properly balanced and the timing of the three day interval or the additional sailing is different for each port.
- * In order to schedule fixed days for the port calls the ideal roundtrip time would be 7 days, which leaves 3½ days in both directions. A port to port time for a complete north - south transport exceeding the limit of three days will not be commercially attractive. Road transport can do it in approximately two days on a door to

door basis. Increasing the sailing speed and reducing the port to port time to three days results in waiting time if the next call must be on a fixed day of the week. This is very expensive.

- * When considering the end-situation of a fully developed shuttle service market, as opposed to the introduction period, the shuttle service should be able to offer sufficient transport capacity. In case a 48 hour calling interval is adopted the maximum ship size of 400 boxes must be put into operation, offering a maximum market share of a little less than 20 % of 12 million tons. Increasing the transport capacity can not be done by enlarging the box capacity of the ships because larger ships will spend too much time on cargo handling which results in unrealistic sailing speeds in excess of the natural speed barrier at 25 knots. Due to this, market growth can only be balanced by additional ships which does away with the 48 hour schedule.

In the case of the Swedish transport situation a calling interval of every second day will no longer be considered as suitable for a well balanced and commercially attractive sea transportation system. Introduction scenario's and winter scenario's will be composed as stripped versions of the intended end-situation.

Closing in on average handling time figures

After the first stage of the demarcation and selection process more knowledge has come available about the behaviour of the system and its boundaries. The most dominating factor which can be influenced is the average handling time per box. The average handling time can be influenced by choosing the best concept and by adding maximum performance characteristics to that particular concept.

During the progress of both the roundtrip analysis and the concept selection process it became clear that the average handling time per box should not exceed 60 seconds. An average of less than 45 seconds per box can be achieved when not too many boxes are handled in each port. In most ports the number of boxes is limited which means that for practical reasons it is safe to assume an average box handling time of 45 seconds per box.

It is the interaction between the scenario selection process and the concept selection process which produces the more specific figures which can be presented here.

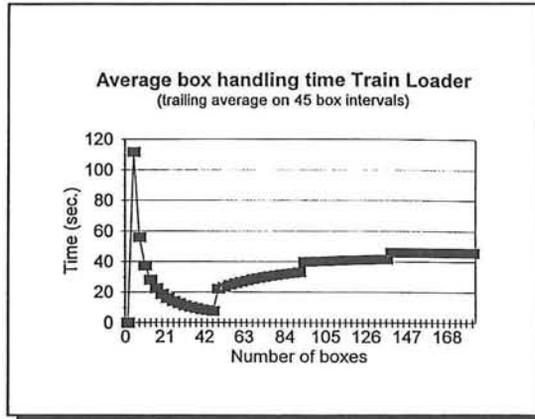


Figure 88: Average box handling times

Referring to the upgraded knowledge about the technical feasibilities the solutions which are based on a figure of more than 45 seconds per box can be eliminated.

The combined results of closing in on calling schedule and on average handling time allows for a reduction of 183 options, bringing the number of 225 remaining options down to 42 potential roundtrip scenario's.

Closing in on maximum sailing speed figures

In the first evaluation loop of the multi stage process the upper speed limit was drawn at 30 knots, basically to avoid losing valuable information which could help to acquire knowledge about the environment and boundaries of the multi stage evaluation process.

Recent studies of the Kvearner Masa-Yards Technology of Turku, Finland, provide detailed information and recommendations on the technical and economical feasibilities of fast sea transportation. Papers about this study were presented at the RoRo '92 Conference in Gothenburg, Sweden, and on the First European Round Table Conference on Short Sea Shipping in Delft, The Netherlands.

An important result of this study, in regards to the shuttle project, is the statement that for displacement type of vessels the speed ratio should not exceed the hull length speed barrier at a Froude number of 0,35.

The Froude number, F_n , is given by the following definition:

$$F_n = \frac{V_s}{\sqrt{(g * L_{wl})}} \quad \text{with } V_s \left(\frac{m}{s}\right), L_{wl} (m)$$

A displacement type of vessel owes its floating capability to static lift. According to the ancient laws of Archimedes the total weight of the ship and its cargo equals the weight of the amount of water which is displaced by the ship. This and other means of supporting a ship and its cargo are presented in the lift triangle (Figure 89).

The shuttle vessels are of the displacement type because the time value of the goods is not high enough to justify the fuel cost increase resulting from high transport speeds. High speeds are costly, not only because of the greater fuel consumption, but also because of increased engine size and weight, increased scantlings and length-to-breadth ratio of the vessel.

The major share of the shuttle cargo will be new-break-bulk goods due to product diversification and increased value adding activities by the industries,. However, apart from the relatively valuable general cargo the expectations are that the average freight rate which shuttle service cargo can collect is moderate.

Besides the fact that the moderate time value of the goods requires a displacement type of vessel also the operation in ice necessitates for a monohull displacement type, as does the general wish of keeping things simple and cheap.

Figure 90 indicates that a displacement type of vessel with a waterline length less than 150 meters is not suitable for sailing speeds in excess of 25 knots. Length, displacement and speed are the main parameters for calculating the necessary propulsion power.

The dotted line marks the $F_n = 0.35$ area which is a natural limitation for the displacement hulls of the vessels with slenderness ratios of less than 7. Exceeding this limit corresponds with bringing a displacement hull into semi-planing mode.

The slenderness ration, S.R., is given by the following definition:

$$S.R. = \frac{L_{wl}}{\frac{1}{\nabla^3}} \quad \text{With } L_{wl} (m), \nabla (m^3)$$

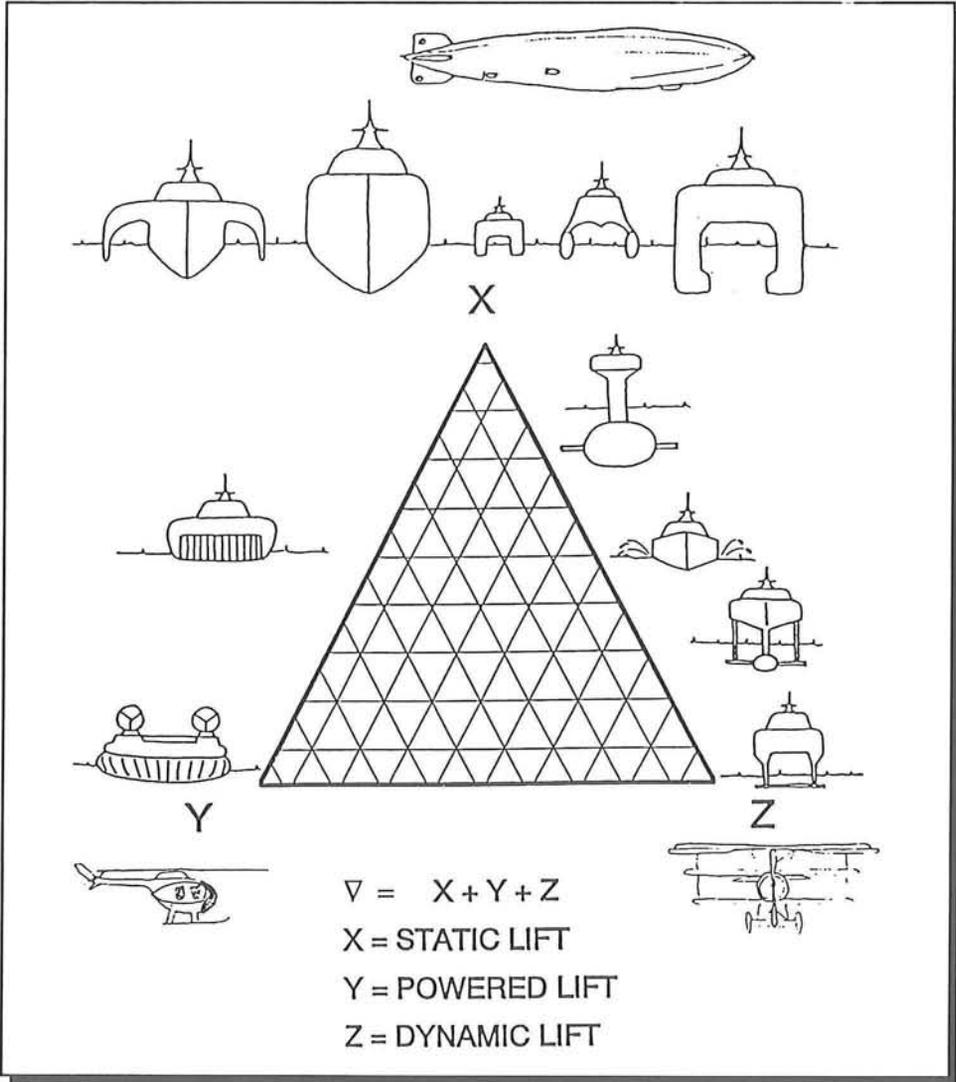


Figure 89: Lift triangle

Figure 91 shows the negative effects of sailing at high speeds on the payload/displacement ratio. The payload is an important indicator of the ships earning capacity. The greater fuel consumption, which demands for greater bunker capacity, the increased engine size and weight, increased scantlings and length-to-breadth ratio of the vessel add to an increase of the shipweight, leaving less payload at a given available displacement.

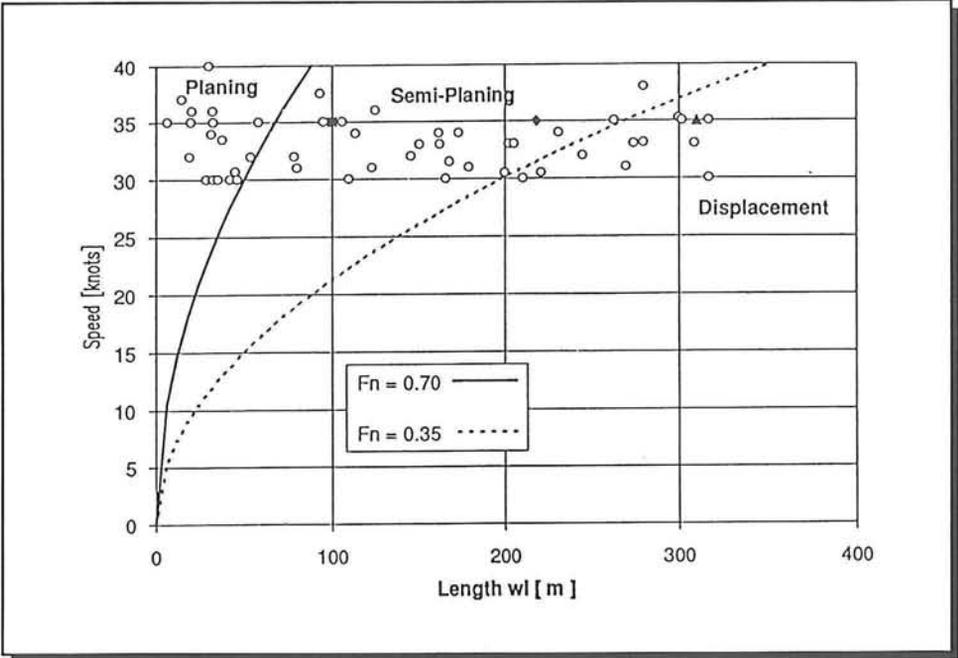


Figure 90: Hull length speed barrier at $F_n = 0,35$

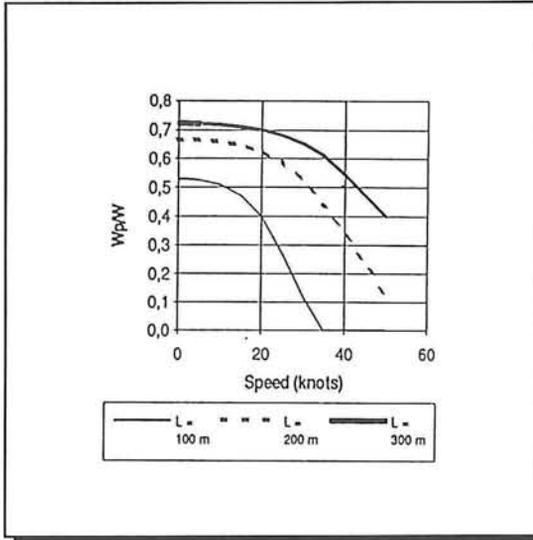


Figure 91: Payload/displacement ratio

A ship with a waterline length less than 150 meters should not exceed the 20 knots limit too much according to this figure, otherwise the payload/displacement ratio will decline to such an extent that the required freight rate increases to a level which can not be charged for cargo of moderate value.

Sailing speeds close to the hull length speed barrier correspond with progressively increasing fuel consumption. Apart from the cost aspects there is the problem of environmental impact. One of the initial triggers of this project of studying the feasibility of a sea transportation system along the Swedish east coast is the fact that sea transport is the most environmental friendly form of transport today and that it also has good potential for further improvement. Expanding land transport in order to cover the demand for additional transport capacity would result in a heavy negative impact on the environment in terms of pollution and direct loss of nature. From a fuel consumption point of view, ships perform better than land transport modes while, especially onboard ships, modern technology can be utilized effectively for the purification of exhaust emissions.

For reasons of limiting the fuel consumption and reducing the environmental impact, speeds in the range of the hull length speed barrier should be avoided.

Closing in on maximum sailing speed figures is based on the following statements:

- * Displacement type vessels should not sail at speeds which correspond with Froude numbers higher than 0,35. At a waterline length of less than 150 meter this means that the maximum speed will be 25 knots.
- * The time value of the goods is not high enough to justify a large payload reduction, which will be the result of sailing at high speeds.
- * From an environmental impact point of view high fuel consumption and high exhaust emission levels should be avoided.

Considering the above the maximum sailing speed of a shuttle vessel is 25 knots. From an economic as well as from an environment point of view sailing at these speeds should be discouraged. The economic evaluation, provides figures which show the effect of increasing the sailing speed on the transport costs.

Remaining roundtrip scenario's

The total number of 11880 solutions of the exploration model have been ran through the first two stages of the multi stage evaluation process.

The remaining 42 options are presented in **Table XXXV**.

At an average box handling time of approximately 45 seconds per box the ships offer a cargo unit capacity ranging between 250 and 300 boxes which corresponds with required payload figures of approximately 3200 and 3800 tons respectively. The corresponding deadweight and displacement figures meet the requirements which follow from the ice conditions in Sweden.

The calling shedule provides daily sailings and on a seven days a week basis this offers transport capacities which results in market shares of approximately 24 % and 28 % of 12 million tons, respectively for the configurations with the smaller and the larger vessels.

Some of the remaining options still show speeds in excess of 25 knots. The reason that they have not been rejected yet is that in the concluding calculations of the roundtrip proposals the average handling time might turn out a little more favourable than 45 seconds, when the exact numbers of discharged and loaded boxes are available for each port.

The 42 remaining options will be economically evaluated later. The economic evaluation is not meant as a last step in the process of rejecting options in order isolate one remaining optimum. The economic evaluation describes the cost structure and cost development of each roundtrip configuration and provides insight in the effects of changes in the number of ports and ship sizes.

Number Ports	Calling Pattern	Box Capacity	Market Share	Perform 10e7*box miles/year	Port to Port Tim days	Average BH Time seconds	Sailing Speed knots	Number Ships
	hours	ship	%					
6	24	250	24.8	7.32	2	45	25.7	4
7	24	250	25.0	7.28	2	45	26.7	4
8	24	250	24.0	8.02	2	45	28.2	4
6	24	250	24.8	7.32	2.5	45	18.8	5
7	24	250	25.0	7.28	2.5	45	19.3	5
8	24	250	24.0	8.02	2.5	45	20.3	5
9	24	250	23.4	8.35	2.5	45	21.6	5
10	24	250	23.4	8.06	2.5	45	22.5	5
11	24	250	23.4	8.07	2.5	45	23.7	5
12	24	250	23.4	8.22	2.5	45	24.9	5
13	24	250	23.4	8.33	2.5	45	26.0	5
14	24	250	23.4	8.34	2.5	45	27.0	5
6	24	250	24.8	7.32	3	45	14.8	6
7	24	250	25.0	7.28	3	45	15.1	6
8	24	250	24.0	8.02	3	45	15.9	6
9	24	250	23.4	8.35	3	45	16.8	6
10	24	250	23.4	8.06	3	45	17.4	6
11	24	250	23.4	8.07	3	45	18.2	6
12	24	250	23.4	8.22	3	45	19.1	6
13	24	250	23.4	8.33	3	45	19.8	6
14	24	250	23.4	8.34	3	45	20.4	6
6	24	300	29.7	8.79	2	45	27.4	4
7	24	300	30.0	8.73	2	45	28.4	4
8	24	300	28.8	9.63	2	45	30.0	4
6	24	300	29.7	8.79	2.5	45	19.7	5
7	24	300	30.0	8.73	2.5	45	20.2	5
8	24	300	28.8	9.63	2.5	45	21.3	5
9	24	300	28.0	10.00	2.5	45	22.6	5
10	24	300	28.0	9.67	2.5	45	23.5	5
11	24	300	28.0	9.69	2.5	45	24.8	5
12	24	300	28.0	9.87	2.5	45	26.1	5
13	24	300	28.0	10.00	2.5	45	27.3	5
14	24	300	28.0	10.00	2.5	45	28.4	5
6	24	300	29.7	8.79	3	45	15.4	6
7	24	300	30.0	8.73	3	45	15.7	6
8	24	300	28.8	9.63	3	45	16.5	6
9	24	300	28.0	10.00	3	45	17.4	6
10	24	300	28.0	9.67	3	45	18.0	6
11	24	300	28.0	9.69	3	45	18.9	6
12	24	300	28.0	9.87	3	45	19.8	6
13	24	300	28.0	10.00	3	45	20.5	6
14	24	300	28.0	10.00	3	45	21.2	6

Table XXXV: Remaining roundtrip scenario's

PART IV - TECHNOLOGICAL SOLUTIONS

CHAPTER 13: EVALUATION OF THE SHIP-CONCEPTS

The first phase of this study has brought forward seven concepts which incorporate the Multiple-Box-Unit, MBU, philosophy, which is build upon the four key elements; reduction of ship-shore moves, economies of scale, time independence and pre-stacking.

The concept evaluation and selection process nominates the Conveyor/Elevator loader and the Train Loader to be the most suitable concepts and the performance parameters of these concepts will be further examined and quantified.

SELECTION OF SUITABLE CONCEPTS

In **Chapter 8** the ship-terminal concept development phase has been described. The introduction of the MBU philosophy and its physical interpretation has led to seven concept proposals.

In that phase criticism was not accepted nor were killer phrases allowed like "that is impossible", "that won't work" or "never seen before".

All concepts are developed for the potential merits they can offer if they can embody the Multiple-Box-Unit principal.

The MBU principal is an example of history repeating itself.

Similar to bringing goods together in a large steel box, the container, it might just well be possible to create large, virtual packages of containers.

In that situation each individual ship-shore move represents the simultaneous loading or discharging of a large number of box units in one single operation cycle.

Under the condition that the "scaled-up" loading operation does not require additional labour, a reduction of the average labour costs per box can be achieved due to economies of scale.

A further reduction of costs requires that the terminal operations are independent of the presence of a ship, which means that loading and discharging should incorporate an intermediate phase which widens the time window.

The physical interpretation of the intermediate phase is the introduction of a new unit which can contain multiple boxes.

The terminal handling methods and equipment do no longer need to focus on the shortest possible turnaround time of the ship but can be optimized for low labour input and slow speed processes for loading or discharging the "Multiple-Box-Unit". This MBU is available at the terminal independent of the presence of a vessel.

Part IV: Technological Solutions

The advantages of introducing an intermediate phase reaches its full potential if and only if the ship can perform the loading and discharging of an MBU without assistance from shore. Consequently, the ship should be of the self-loading and self-discharging type with the ships crew controlling the operations.

In potential all seven concepts provide the advantages of the MBU principle. However, not all proposals are equally suitable and they can have different performance characteristics.

A qualitative analysis has produced the reasons why five of the seven concepts are less suitable than the remaining two.

The remaining two concepts will be compared on their technical performance and feasibility.

REJECTION OF FIVE CONCEPTS ON QUALITATIVE GROUNDS

Super pallet carrier

The super pallet carrier is not suitable for a multiport shuttle system.

P.O. Anderson of Iggesund, Sweden has developed the super pallet carrier for collecting unitized forest products at a number of ports which need transport to one single destination. It could also serve in a distribution system, provided that all cargo is loaded in one single port and that the boxes are sorted out on destination and packed on the appropriate pallet.

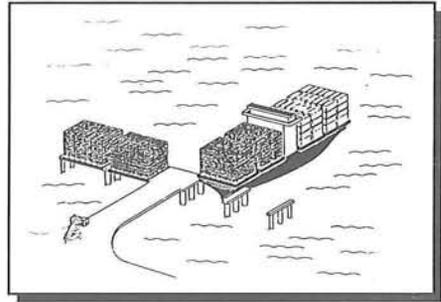


Figure 92: Super Pallet Carrier

The shuttle service is a system which has the mixed character of collecting and distributing, similar to a public bus service.

A group of people waiting at a certain bus stop can have many different destinations, while a group of passengers descending a bus most likely came on the bus at different origins. The groups that get on the bus are different from the groups which leave the bus.

Apparently the individual members of each group have the opportunity to change from one group to the other.

The shuttle service should incorporate this group changing behaviour in its philosophy. The super pallet carrier does not.

Super pallet loader

The super pallet loader takes away the disadvantage of the super pallet carrier of not being suitable for a multi port shuttle system.

This concept incorporates the group changing behaviour which was mentioned in the discussion on the super pallet carrier.

The onboard distribution system allows the super pallet loader to take aboard a Multiple-Box-Unit with mixed destinations and to distribute the individual boxes over the stowage area.

All boxes destined for the next port of call can be collected and prepared for discharging via the MBU.

The loading/discharging technique is based on the sea-lift principal, which uses the ships ballast system to lift or lower heavy units. This has some operational disadvantages:

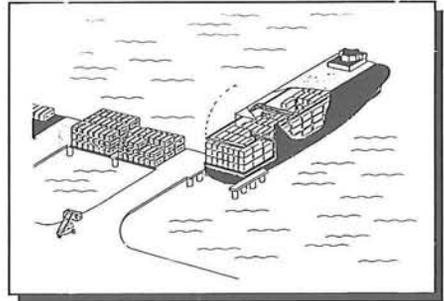


Figure 93: Super Pallet Loader

- * Each loading or discharging operation requires ballasting and de-ballasting of the ship. This can be very time consuming. Present semi-submersible/sea-lift techniques are used in situations where the loadingtime can be expressed in hours rather than in minutes.
- * If the number of boxes which need loading or discharging exceeds the maximum box capacity of the MBU the ship has to be repositioned transversely along the quay side for loading or discharging an "exchange MBU". The additional hauling and mooring will consume relatively much time.
- * The Super Pallet Loader is carrying the MBU right at the aft end of the ship. This will cause excessive trim moments which are very hard to compensate. The ship will have considerable trim after loading an MBU or just before discharging one. This reduces the operational flexibility.
- * The cargo on the MBU is unprotected.
 - The loading/discharging technique requires an unobstructed aft end of the ship.
 - The ships are small sized with a necessarily low freeboard.
 - Trim angles can be considerable
- * Improved cargo protection would require box shaped MBU's

Part IV: Technological Solutions

- * The MBU is positioned at the aft end of the ship. In that situation the use of more than one distribution crane is possible if and only if stowage area is split in a port and starboard side. This reduces the operational flexibility.
- * The larger the box capacity of an MBU the longer additional moves can be avoided. In case of the super pallet loader the unbalance in weight distribution will get worse when the box capacity of the MBU is enlarged.

Six pack cradle carrier

The six pack cradle carrier is an other attempt to take away the disadvantage of the super pallet carrier. Instead of creating possibilities for re-arranging packages of units this concept is based on the idea of reducing the group size to such an extend that the origins and destinations are the same for all individual boxes in a particular package.

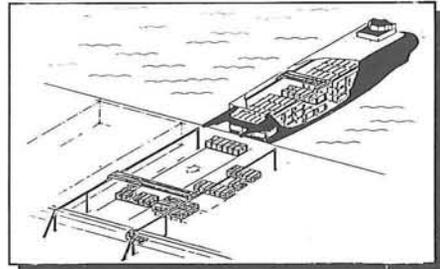


Figure 94: Six Pack Cradle Carrier

This approach does incorporate all pro's which come with the MBU philosophy, but it has the following disadvantages:

- * Packages of 6 boxes represent a maximum weight of 120 tons. The cradles need to be designed for that load and they will be of considerable weight and size. Total weight of cradle and boxes can reach a maximum value of approximately 150 tons.
- * Automatic spreaders for picking up a load ranging from 30 to 150 tons, with a breadth of about 18 meters, are not available. This has to be developed.
- * Overhead cranes in that workload range are not fast, especially not when used onboard a free moving ship. The loading cycle will consume considerable time. Despite the fact that in potential the average handling time per box can be short, the effective average values will be high due to the fact that very often the cradles will contain less than their maximum of six boxes.
- * The terminal lay-out will show two pairs of tracks for the onshore transport of the cradles. One for loading purposes and the other one for discharging. The consequence is that the ship has to be

repositioned. Combined loading and discharging, dual way cradle handling, requires that the ship is not repositioned which results in a more sophisticated terminal design and cradle transport on shore.

- * Placing a cradle onto the shore tracks or on its position aboard the ship will be time consuming as a weight of 30 to 150 tons can not be handled fast.
- * The number of cradle positions on the ship is necessarily higher than the result of dividing the box capacity of the ship by the box capacity of the cradles. This is caused by the fact that the numerous vacant positions on the MBU's need to be compensated.
- * Due to their shape and size the cradles dictate the hull design of the ship. A relatively large ship is necessary to accommodate sufficient cradles.
- * The cradle is an MBU with a small box capacity. The system will require many of these cradles, which eventually causes a repositioning problem.

Unit loader

From a concept point of view the Unit Loader is a hidden variety of the Super Pallet Loader. Instead of loading an MBU and subsequently starting the distribution cycles on-board this ship extends its on-board distributing system onto the terminal area by linking the railway tracks of the overhead crane.

The "MBU area" of the terminal features special positioning equipment which helps the travelling overhead crane of the ship to find the accurately positioned boxes. The 'shore-end' of this concept acts like a 'spreaded-out' super pallet.

Terminal activities and the ships sailing schedule are time independent. Loading can continue without the presence of a ship thanks to the specially reserved MBU area, where the ships self-loading equipment can do its own job. Similar, the self-discharging activities of the ship can take place without assistance from shore.

Although the travelling distances are long for each box, resulting in long average handling times per box per crane, it is possible to achieve a considerable reduction by putting in more cranes which work in parallel mode.

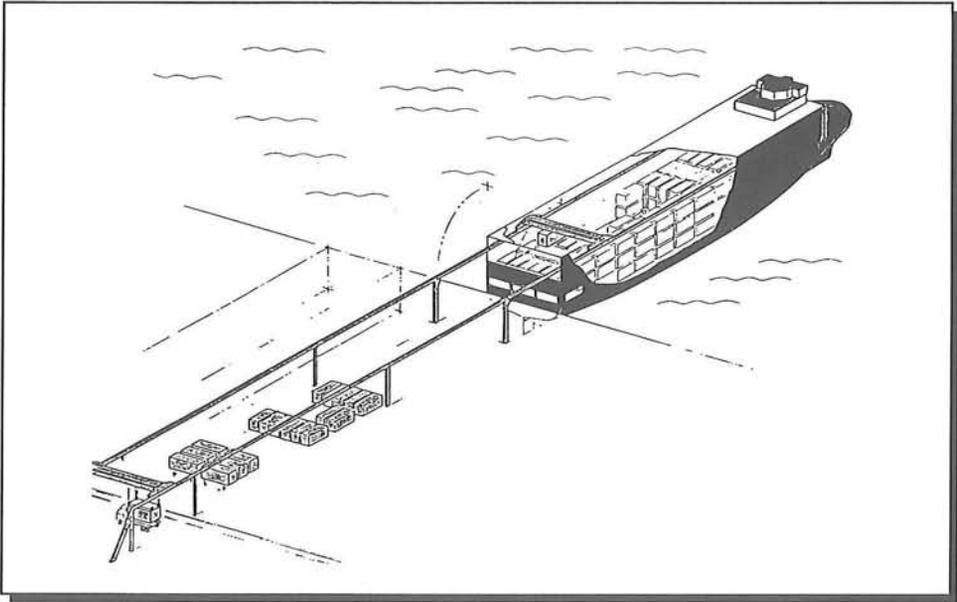


Figure 95: Unit Loader

The advantages of the unit loader are:

- * There are no MBU moves, which eliminates the necessity of the development of a MBU transfer technique.
- * The Unit Loader can set very sharp average handling times per box, especially when there are opportunities for dual way handling; discharging and back-loading in the same crane cycle.
- * On-shore the overhead cranes can obtain high speeds in comparison to the speed inside the ship.
- * The terminal area is clean.

The disadvantages are:

- * It is not possible to take advantage from preparing the first off-going MBU while the ship is at sea or from processing the last MBU which came on board while the ship has already left its mooring. Each box is handled against a fixed average handling time.

- * Short average handling times can be set if and only if multiple cranes can operate in parallel mode. Parallel operation requires as many longitudinal overhead tracks as the box width of the ship, all running ashore over an equal number of linkage tracks and terminal extensions.

- * The problem with parallel mode is that it introduces a lot of terminal activities, which were originally the issue to avoid. Due to the parallel operation of the cranes there are no possibilities for transverse changes of lane. This "keep-your-lane" situation reduces the operational flexibility of the ship and it necessitates that the boxes on shore must be positioned in the appropriate lane before the loading operation begins. The appropriate position, which depends on the distribution plan of the ship and on the actual situation onboard, is known only as soon as the vessel has left the preceding port. This narrows the time window for the shore activities.

- * The option of operating in series mode with multiple ship-wide overhead cranes does not have the disadvantage of reducing the operational flexibility. However, in order to avoid collisions or unproductive waiting time, the harmonica effect, the number of cranes is limited. Two or three cranes is the maximum feasible. With that number of cranes short average handling times are not feasible.

- * Parallel mode is very sensitive to failure. It is not possible to have one of the other cranes to take over in case of a system failure in one of the lanes.

Overall, the concept is not suitable.

Train carrier

In this concept containers and swapbodies can be loaded onto "serving-tray-alike" platform cars. The MBU's are trains of lorries, which can be transferred onto the Train Carrier by means of a loading bridge. Each train contains as many lorries as the ships loading length allows.

The ship is of the so-called pencil case type, which implies longitudinal loading over the transom of the ship. In principal, each loading "tube" corresponds with a destination and each train of platform cars contains boxes with identical destinations only.

Interesting though is that it is possible to re-arrange the destination mix of the trains in case lack of capacity requires to do so. On shore the resulting shifting operations can be carried out.

Part IV: Technological Solutions

This concept is not suitable because of the following disadvantages:

- * The train operations are basically a Sto-Ro type of handling method. If and only if on-shore shifting activities can be avoided there will be very few people required for the cargo handling process. However, as soon as the capacity of the destination bonded "loading tubes" is not sufficient the MBU's will have to be split and divisions of trains need accommodation in the other tubes. This is time and labour consuming and it takes away the power of the idea. The train carrier lacks the incorporation of group changing possibilities on board the ship.
- * The system requires a lot of rolling equipment. The total weight of the lorries has a negative influence on the payload of the ship. The platform cars will require repositioning.
- * The system is sensitive to failure. If dislocation of platform cars or other potential problems occur inside a tube it is not possible to continue the cargo handling process by means of a by-pass scenario.
- * The train arrangement site covers a large area, because there is no stacking of boxes on top of each other. The result is that the automated overhead cranes of the terminal have to cover long travelling distances and they will need a very wide span.
- * The loading bridges are either very large or technically complicated. The six-lane type is elevating only but that type of bridge is necessarily very wide. On the other hand, the smaller single-lane type has the technical difficulty that it has to swing to both sides, which introduces angles at places where smooth curves are required.

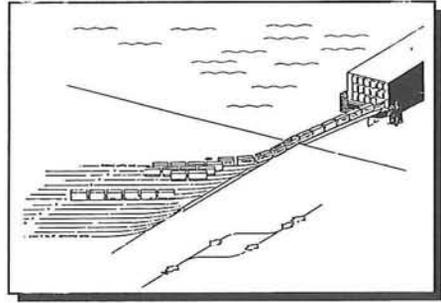


Figure 96: Train Carrier

The remaining two feasible concepts, the conveyor/elevatorloader and the trainloader will be discussed in the following chapters.

CHAPTER 14: CONVEYOR/ELEVATOR SHIP-TERMINAL TECHNOLOGY

Figure 97 shows an artist's impression of the ship. The ship is a four deck carrier specially suited only for the handling of non stackable cargo units based on the ISO 20' standard on lower corner castings. This means that she is able to carry all types of flats, containers or swapbodies following the ISO, DIN or CEN standard. The maximum size has been set to 8 m length, the width to 2.6 m and the height to 3 m over all. These figures have been chosen to make the ship capable of carrying all load carriers allowed for road transports.

Figure 98 and **Figure 99** show the ship's arrangement. The top deck of the ship is open in the aft part giving space for the carriage of dangerous cargo units. The inside of the ship comprises a steel bar structure on which the units are carried.

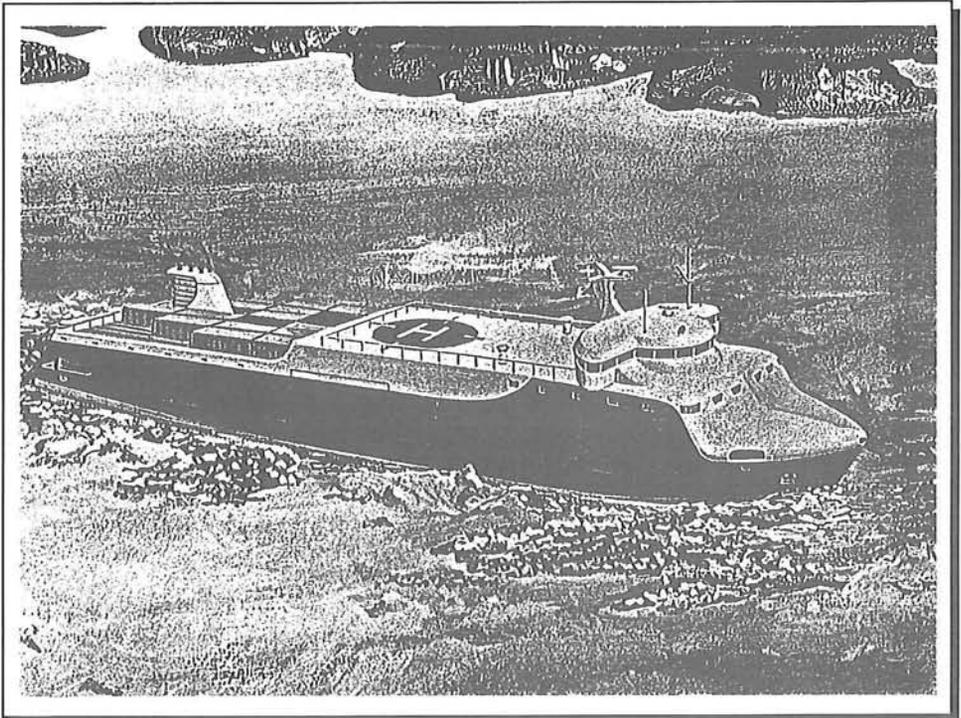


Figure 97: Artist impression

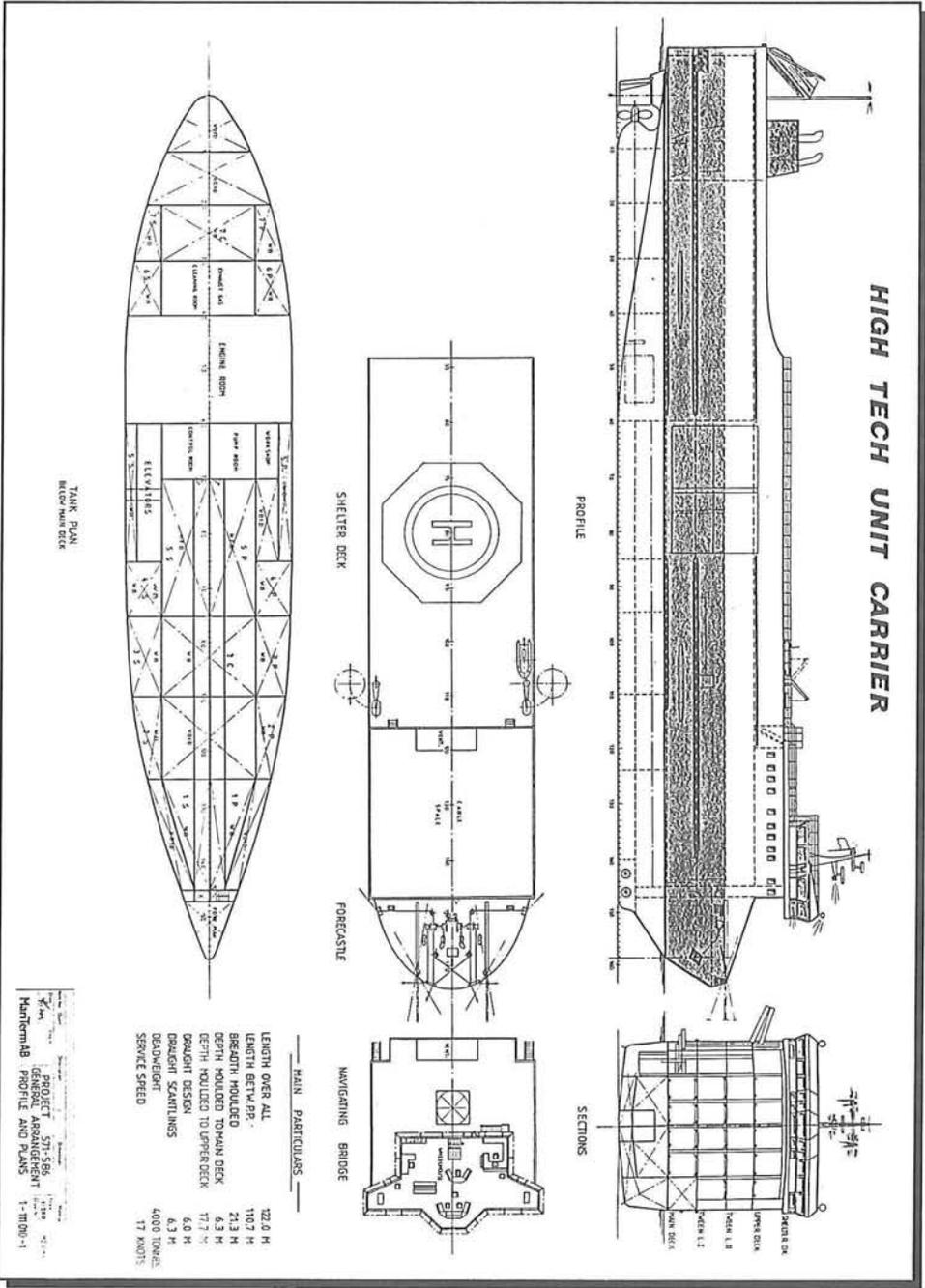


Figure 98 General Arrangement 1(2)

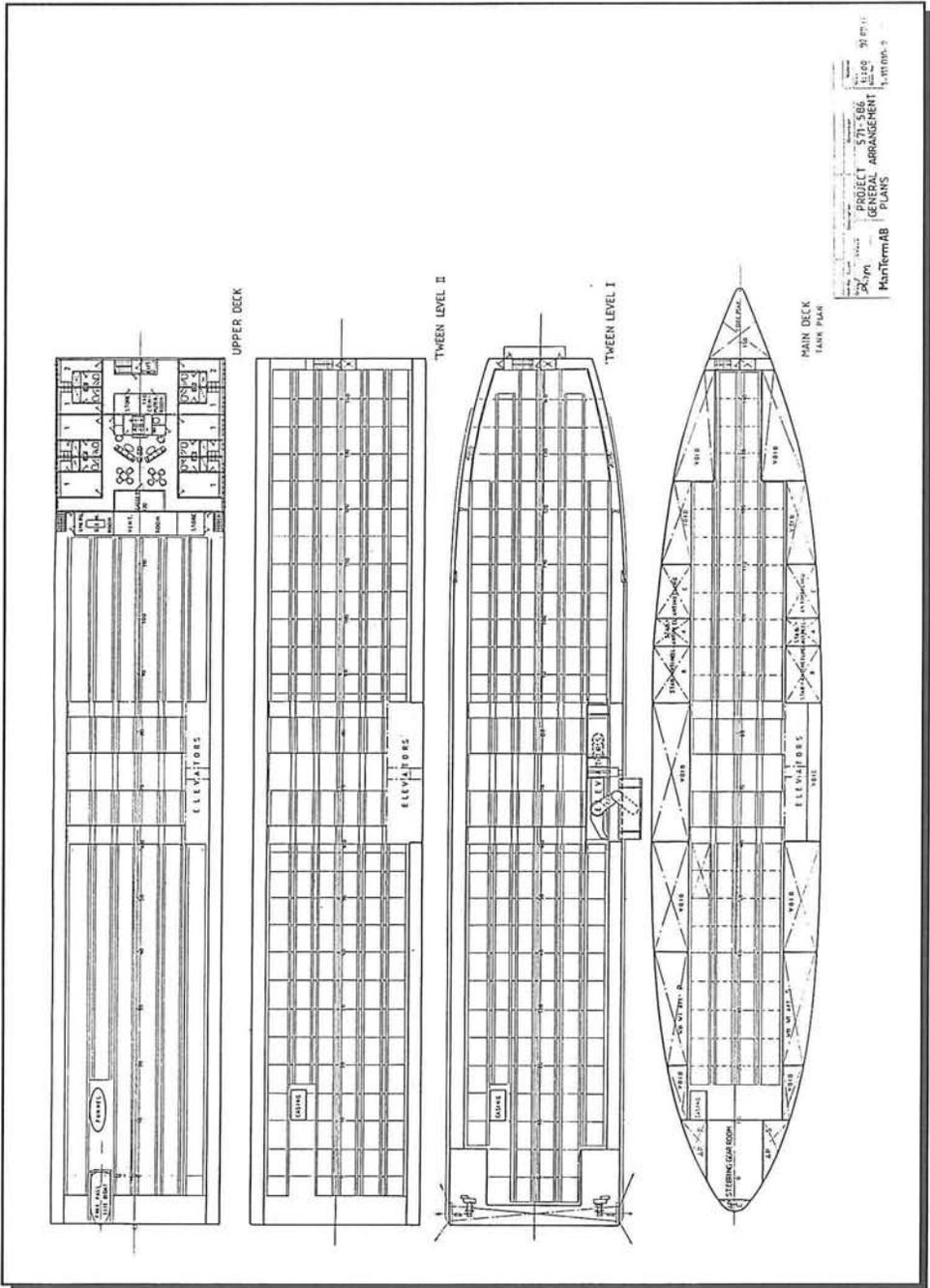


Figure 99: General Arrangement 2(2)

Part IV: Technological Solutions

The cargo handling is controlled by the onboard based computer. The manual-operation should be limited to a general survey of the operation. An extensive control desk is situated on the bridge containing all control functions needed for the survey and what ever actions are needed. The full automation is guaranteed through a system purpose built to be reliable. The central computer system is doubled with auto detect functions and second checks of the operation. The automation goes far beyond what is normal advanced ships' standard.

The crew is minimized to only four men. All are highly qualified and experienced seamen and technicians.

Among other functions the vessel features special equipment for the reception and connection of icebreaker controlled from the bridge without further manual assistance. Gangways and other needed equipment is to be remote controlled. The mooring system is mechanized and can be fully controlled from the bridge.

A double engine system provides for the possibility to operate and manoeuvre in case of a system breakdown of one engine. The ship will navigate in close coastal waters and can be routed using electronic sea charts arranged with free corridors for navigation.

Bow and stern anchor can be dropped in case of emergency and the ship will be equipped with a helicopter landing platform for manual assistance or evacuation if needed.

Some of the equipment used in the vessel has not been tested and is of a new design. However, all equipment has been enquired for and the feasibility and performance have been discussed with suppliers who have accepted to manufacture and deliver the equipment.

As a summary the ship will comprise the most modern and advanced features in ships technology.

CARGO HANDLING IN TERMINALS

This ship-loading/discharging is featuring a fully mechanical and automatic handling of cargo units. The units will be of the type swapbodies and ISO Containers preferably without any particular restriction. If priority has to be made between different types of units, the units are to follow the order of priority listed below (higher number means lower priority):

1. Swapbodies DIN standard
2. ISO 20' Container standard
3. Other types of swapbodies
4. ISO 40' Container standard

The main feature of the handling system is a system which handles non-stac-kable cargo units horizontally in the ship. For this reason the ship should be equipped with a type of conveyor that can move the units longitudinally in the ship.

The system will also feature a terminal system which allows the units to be handled on and off road vehicles. The terminal system will be an interface between road transport and ship. It must be suitable for intermediate storage of units waiting for the ship's arrival or being discharged by the ship waiting to be transported to the final destination. The operation between road vehicle and terminal can be assisted by the driver of the vehicle.

In the following a number of alternative technical solutions are outlined for a handling system that will meet the above criteria.

Handling by road vehicle

The technical conditions for positioning or picking up swapbodies or containers make it necessary to utilize an assisting device. By means of a roller frame it will be possible to position the units on a lane feeding the ship.

It is also possible to handle ISO-containers by means of this device. But to be able to reach the bottom of container and lift it up on to the vehicle, the lane must incorporate a recess which makes a clearance between the unit and the support of the roller frame, so that the frame can pass under the unit.

In order to position a container at the manufacturer's and to lock it to the frame of the vehicle, the same distance must be provided for under the unit. This is accomplished by applying corner pallets made of aluminium to the corner castings.

The corner pallets must be applied while the units stay in circulation during the cargo turnover ashore. The principal way of doing this is to apply the pallets in the terminal when the vehicle picks up the unit. The job can be done by the driver as he brings the pallets carried on the vehicle. When the pallets are mounted on the containers or swapbodies they can be handled in any way during the circulation in the commercial area around the terminal. Swapbodies must not necessarily have those units on if they can rest on their legs during the handling. Each position in the handling lane at the terminal will have a recess which allows the vehicle to position the unit in the lane.

The disadvantage of this flexibility is the high tare weight of the vehicle which reduces the loading capacity in comparison to an exclusive swapbody vehicle. The extra cost of the vehicle is estimated to be about 200 kSEK compared to a vehicle that needs lifting equipment to load or discharge it. In comparison to a pure swapbody vehicle the extra cost will be of about the same size. The advantage will be achieved by using a more flexible vehicle in comparison to the others. The more flexible unit can be used in a wider range of transport services.

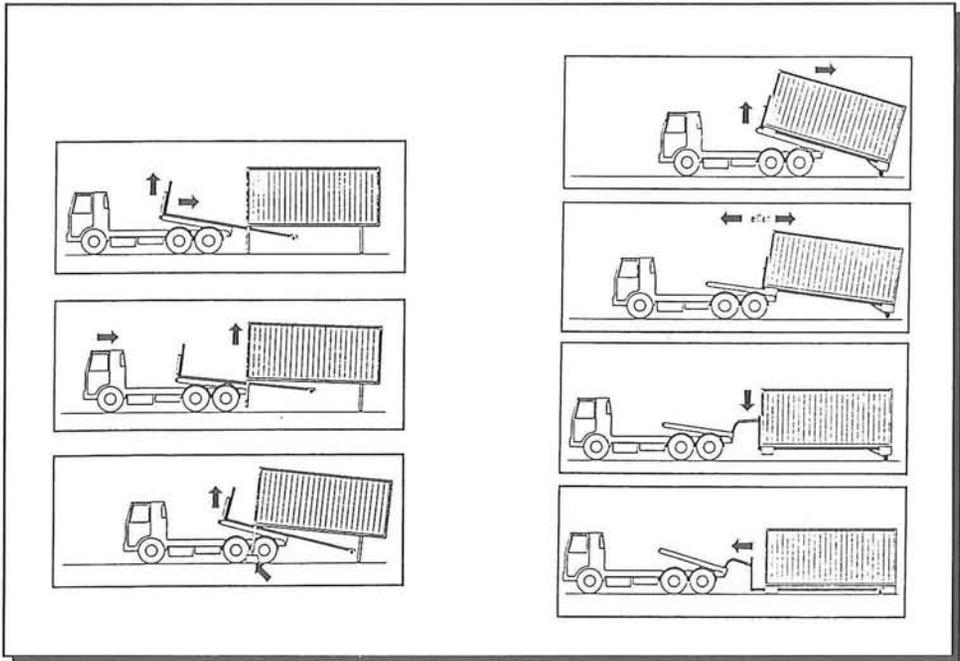


Figure 100: Handling of swapbodies and containers by means of roller frame

Swapbody vehicles of a standard design may transport both containers and swapbodies but the containers must be lifted on to the vehicle and the swapbodies must be standing on their legs to be loaded or discharged by the vehicle. If another type of operation is allowed, there must be some sort of docking station in the terminal. The docking station must be able to move so that a unit can be picked out from any position in the lane.

As that this type of operation may be complicated and vulnerable, it is proposed to make the vehicle more complex but also more flexible by utilising a roller frame handling system on the truck. This will allow the truck to operate in a number of other services and thus be utilized far more extensively.

Ship-to-shore handling system

The truck driver is to inform the system of the character of the unit. The information that the driver can feed into the terminal is :

- * type of unit delivered
- * transport code (identification code in the system)
- * guiding of the handling device in height and length to provide a safe loading of the unit into the terminal

The driver will discharge the unit in the terminal, give the terminal the information requested and activate the system.

The function of the terminal system is to receive and queue up the units awaiting ship's arrival. The system should not lift the units.

A unit fed into the terminal should be individually moved to queue up close to the preceding unit. There will be only one sorting of units in the terminal; northbound or southbound. The sorting can be achieved by feeding the units in the middle of the lane and the system will queue it up on one or the other side depending on the arrival of the first ship. (Figure 101).

The terminal must be able to receive incoming units from the ship. These units should preferably be possible to address and pick out individually by the vehicles coming to distribute the units.

A principal idea is to have two lanes entering the ship. One lane is for incoming units and one lane is for outgoing units. Each lane has a width of 8 m and will transfer the units transversely.

The automatic handling equipment in the terminal is designed as shown in Figure 102. The lanes are designed as steel platforms built on local concrete supports. The lanes shall be fully covered by a sheltering roof. The figure shows the principal arrangement where a space between the units and a support area for the roller frame allow the frame to be put under the unit as a drawer. The roller frame will hydraulically suspend the unit from the supports to be pulled on the vehicle. The truck driver will position the unit on to its position on the support when loading the unit on to the lane. The handling lane will be able to deliver any unit from any position on the lane. This gives full flexibility for picking out incoming units by the truck.

To position units on the lane some type of sorting priority is needed as the terminal must sort northbound and southbound units. The driver needs to know where his unit should be fed into the lane. The information can be given by a signal system informing where the northbound and the southbound units are stored.

The lanes are designed to allow a roller frame to enter the lane and position/pick up a unit. The roller frame must be equipped with a hydraulic roller. The roller will lift and lower the unit to the fixed position in the lane. Guiding attachments in the lane will centre the unit giving it an exact position. The positioning must be controlled by the driver feeding the unit into the terminal.

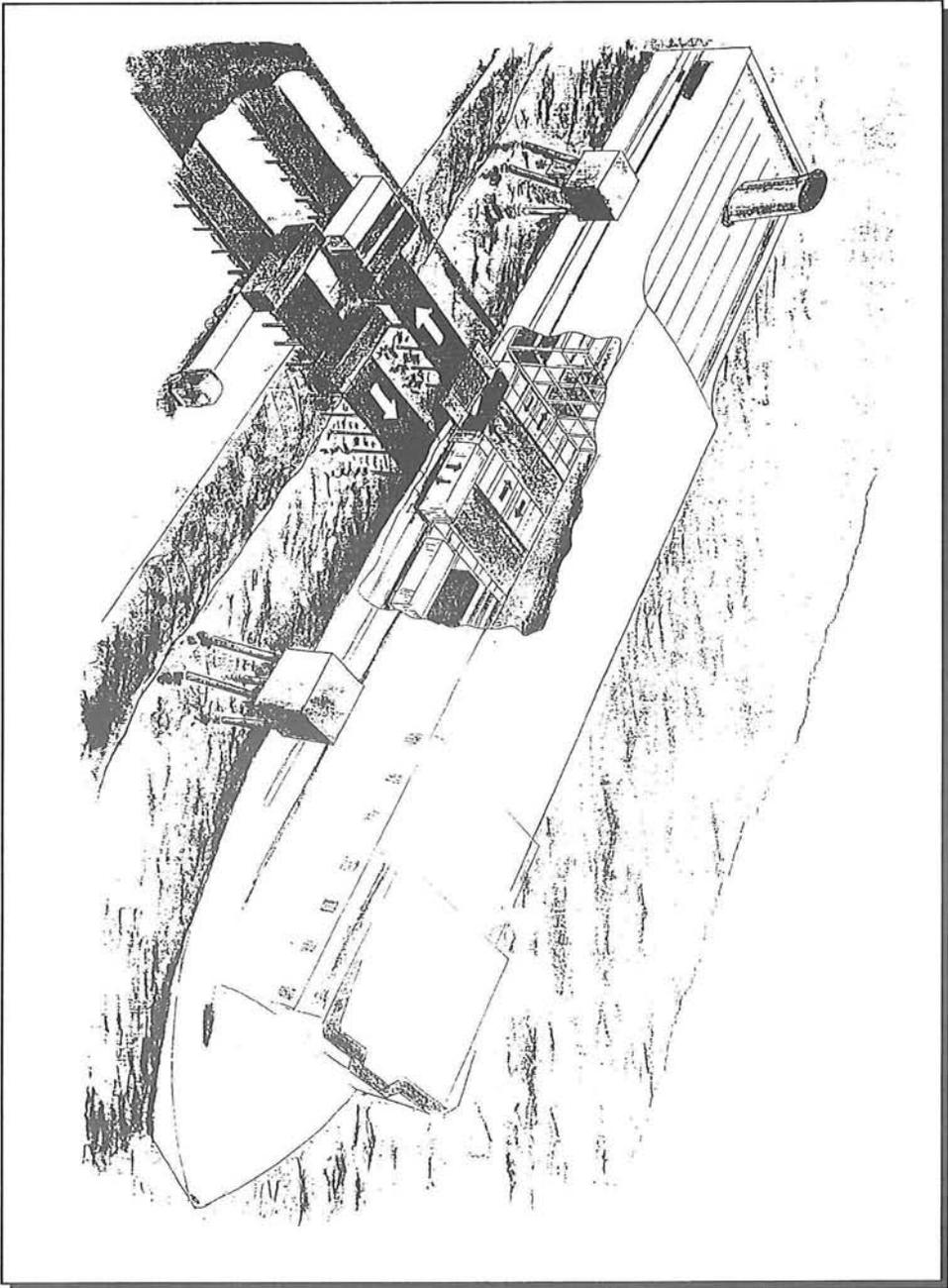


Figure 101: Principal arrangement of the terminal (1)

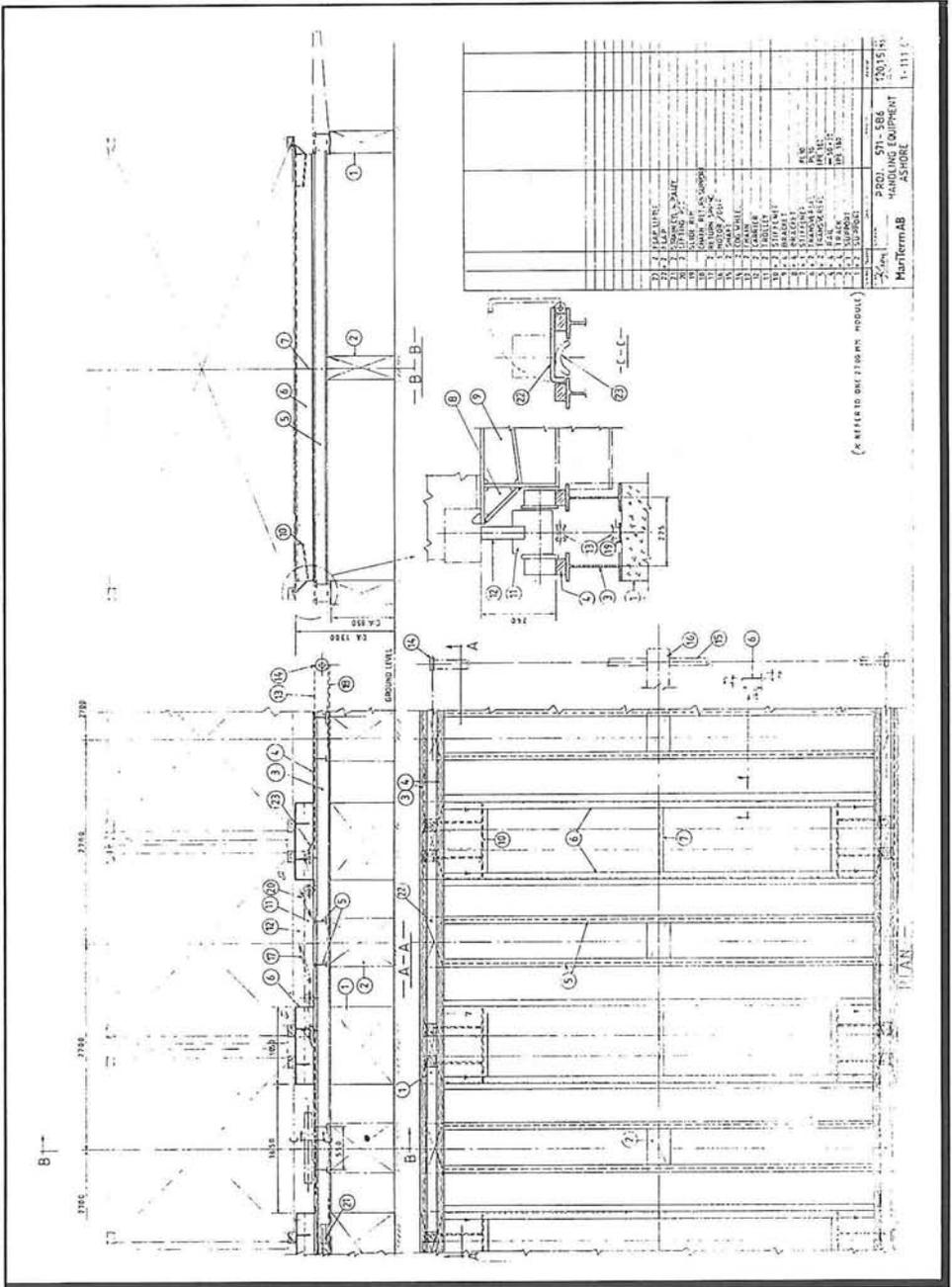


Figure 102: Principal arrangement of the terminal (2)

Part IV: Technological Solutions

The technique for moving the container or swapbodies on the lanes will preferably be a Trolley Conveyor System (TCS). This is a simple and technically reliable type of transport equipment earlier used in marine applications. The TCS system moves individual units up or down the lane. It is a railbound system which can also move the unit out of the lane itself, for example on to the lift platform at the sideport of the vessel.

Trolley conveyor system

In principle the trolley conveyor system consists of a carrier, a rope, a tensioning device and a rotating device. (Figure 102)

The system features the possibility of moving single units long distances while using very few mechanical components. This means that the device can move units all over a ship's length or the length of the terminal feeding track. The device can also pick out the individual unit and queue it up in a lane. When the unit is positioned it will stay on the friction of the supporting surface.

In a sense, the technique can be compared to a lifting system with the difference that the unit is never hooked on but only supported during the movement.

Mooring to allow for the handling operation

To allow for the operation between ship and quay facilities the ship must be kept in position within certain tolerances. Together with Trellex AB we, Mari-Term has developed an integrated fendering and mooring system capable of keeping the ship within the acceptable tolerances. The mooring system also features the possibility of keeping full control of the mooring from the bridge by means of the exact position at the berth and the mooring forces. The system is based on a patented part of the Trellex fender system and due to this a more detailed description, is not presented.

Integrated secondary transit facilities

Moving the units between the terminal and the ship's deck requires a facility which integrates the handling system onboard each ship's deck with the terminal. Forest product handling often uses an apron conveyor system to move products from the sideport elevating platform to deck or vice versa.

The shipowner Seatrans AS Norway has designed a complete handling system of forest products from warehouse to ship using a system based on apron conveyors and trolleys. The handling inside the vessel is done using a side port elevator that positions the cargo to the proper deck and delivers the cargo via the apron conveyor to the ship's deck.

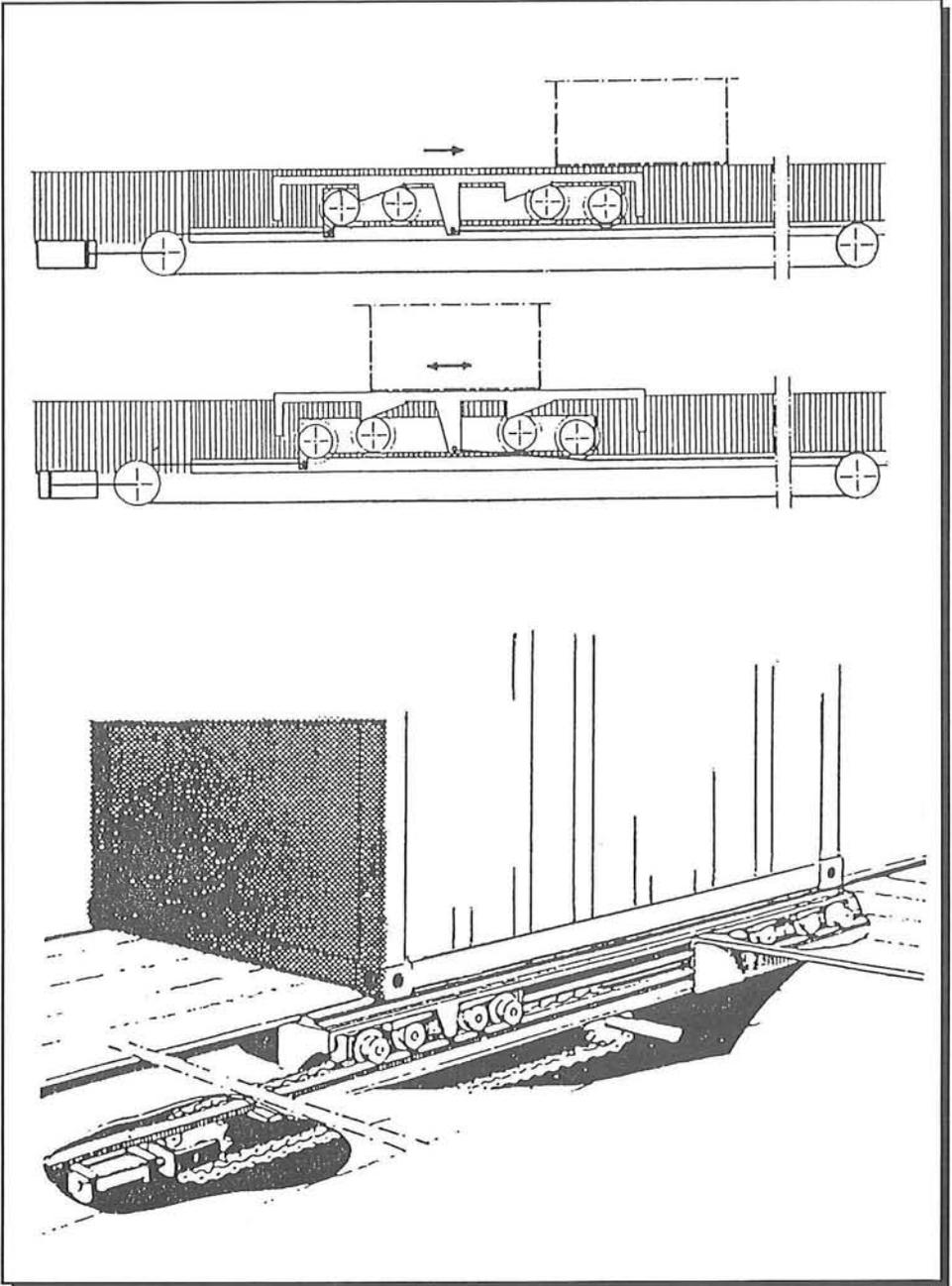


Figure 103:Trolley conveyor system

Part IV: Technological Solutions

This technique could also be used in this project. The ship is then to be equipped with a sideport elevator on which two tracks of apron conveyors are running, having the same spacing as the longitudinal spacing of 20' ISO container-corner castings. The sideport elevator will dock horizontally into the fixed bridge of the terminal. The container is moved on to the lift platform using the terminal TCS unit as feeder. There is nothing new in this technique. (Figure 104).

When the container is on the platform, this is retracted into the ship and moved to the proper deck. The units are then to be moved by the apron conveyor transversally to a meeting apron conveyor on the deck and further on the conveyor to the proper transversal position.

Instead of an apron conveyor which is space-consuming and containing of a large number of components, we have designed an air cushion system. This system lifts up the cargo and moves it by means of gear wheels acting on a rack on the air suspended platform.

Transfer from lane to ship

In this design the TCS unit positions the cargo unit on the lift platform. The platform is a part of the side loading lift system arranged on the ship. A docking position will be arranged at the end of the lane where the platform can be docked and guided into a fixed position. The platform will be kept into position so that it will stay fixed independent of the ship's movement at quay side.

The TCS conveyor has tracks running out on the platform and the platform will then be loaded by using the TCS to position the unit on the platform. Then the platform will be retracted and transferred by the lift to the proper deck where it docks. The transfer of the unit from the platform to the deck must be made by a device that does not interfere with the TCS running longitudinally on ship's deck. The transfer can be made by an air suspended platform which goes under the unit and lifts it to move it to the proper position transversally on the ship's deck. (Figure 105)

Ship's conveying system

Units to be positioned in the ship will be transferred to the proper transverse position by the assistance of the air cushion platform until it is in position to be picked up by a longitudinally running TCS unit. This unit runs in the full longitudinal length of the ship's hold and will move the unit to its final position in the vessel. Once the units are put down in position they will rest on the supporting steel bars. (Figure 106).

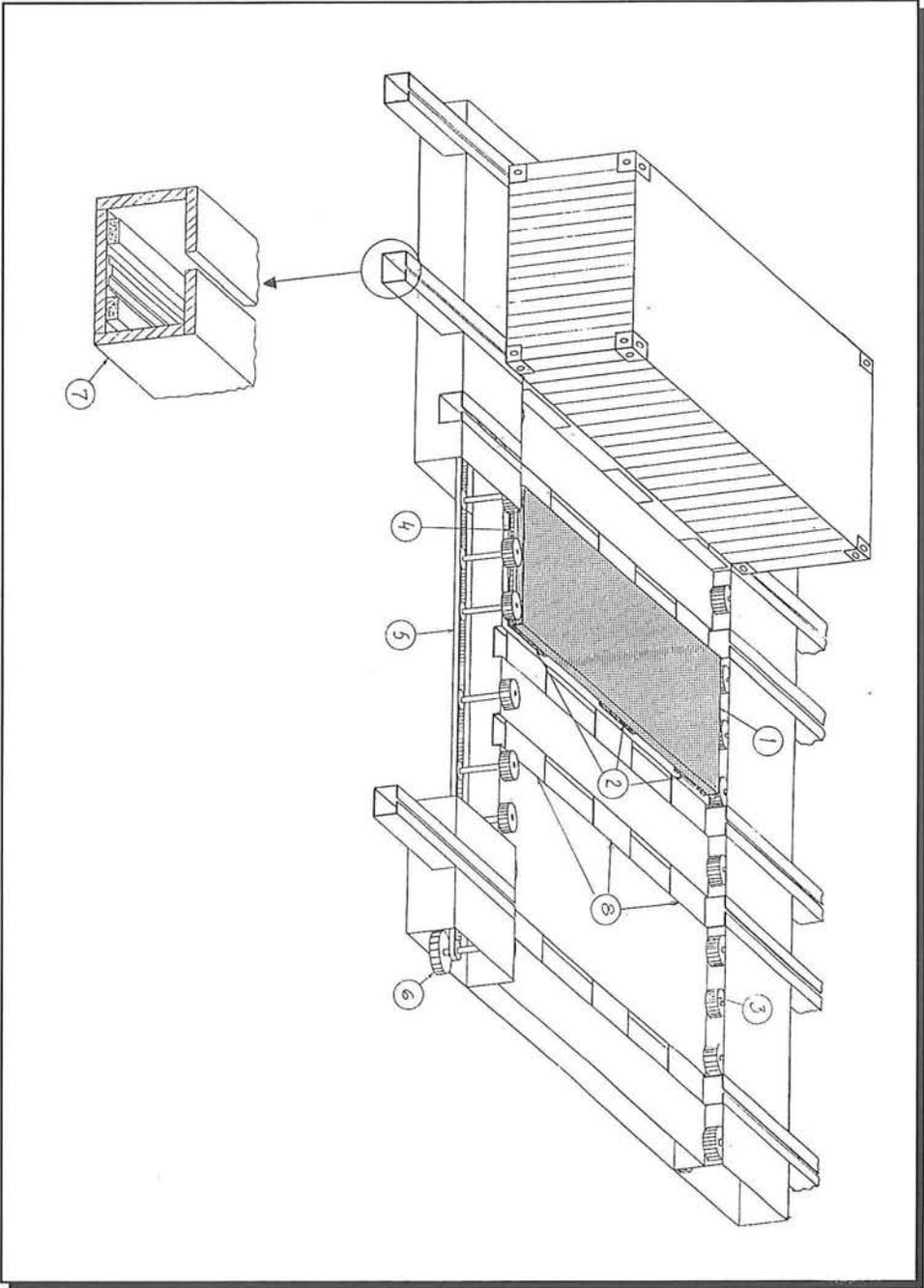


Figure 105: Transverse moving equipment on each deck of the vessel

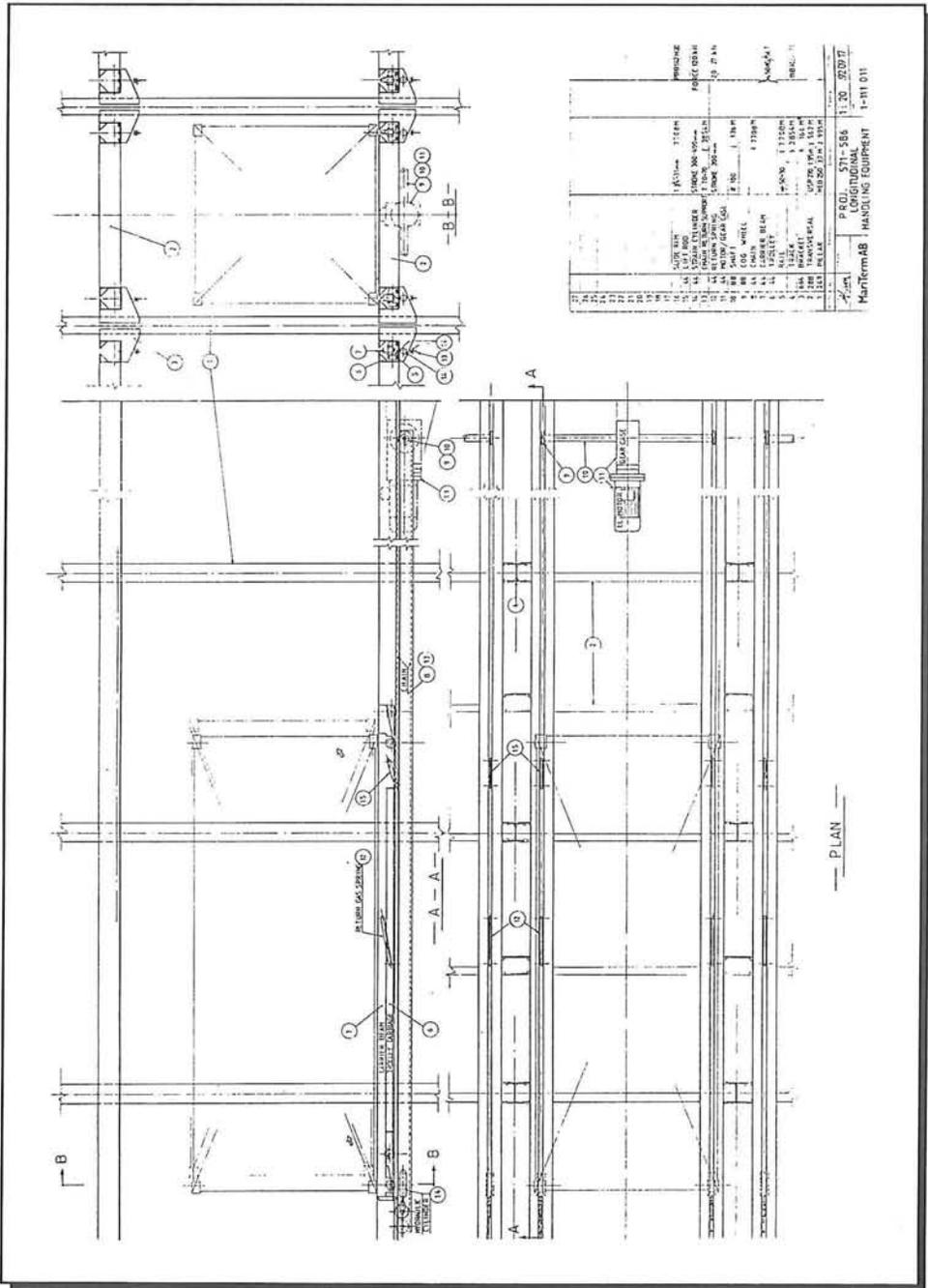


Figure 106: Principal arrangement of the conveying equipment on the vessel

Part IV: Technological Solutions

As the units are standardised and fixed in size it is possible to lock them in position onboard the vessel, thus eliminating the need for further securing in the vessel. In the longitudinal direction the securing is assured by the friction given by the material used as supporting material. In the transversal direction the supporting bars are equipped with a steel structure that prevents the unit from sliding transversally. The cargo in the units has to be sufficiently secured for the road transport. This means that there will be no risk of the units tipping so it is sufficient to prevent the units from sliding. In case of an accident resulting in an extensive heel of the ship, the units will be prevented from shifting because of the small clearance in the lanes to the ship's steel structure.

Most of the equipment forming the handling system is and has been in operation for several years. The technique based on an air cushion system where the air cushion provides for both the lifting and the carrying of the cargo is rather new in this type of service. The operation can be achieved by means of other solutions. The platform can for example be equipped with rail wheels in such a number that it is possible for the platform to bridge over the longitudinal rail tracks. Evaluating this it is judged that the air cushion system gives a number of advantages compared to other systems. One weak point in the air cushion concept is that it will lift the units under the bottom of the unit. Using a bar system it could be possible to reach for a part of the bottom corner of the unit for the lift operation thus keeping up the flexibility of the system.

CHAPTER 15: TRAIN LOADER SHIP-TERMINAL TECHNOLOGY

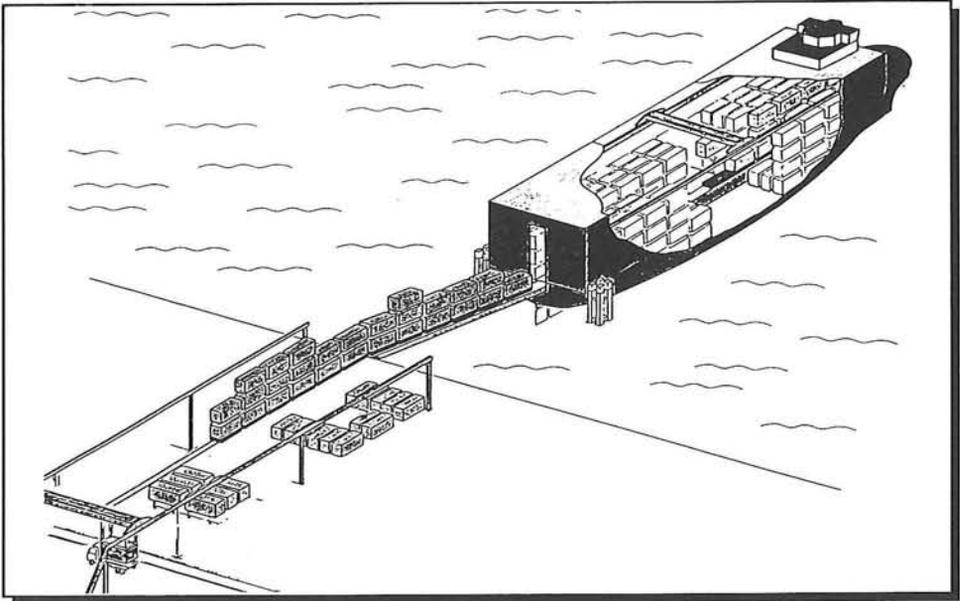


Figure 107: Train Loader

The Super Pallet Carrier had the disadvantage of not being suitable for a multi port shuttle system. The Super Pallet Loader solved that problem by offering internal distribution facilities.

The semi-sub/sea-lift technology, typical for the super pallet concepts, has operational disadvantages; time consuming method, repositioning of the ship, excessive trim and unprotected cargo.

The Train Loader concept was borne out of the problem solving process regarding the operational disadvantages of the Super Pallet Loader.

Instead of using the heavy lift technology for loading a super pallet this concept is based on a MBU in the form of a triple stack train, consisting of platform cars. The triple stack train is able to carry as many boxes as three times the loading length of the ship could allow and can be loaded onto the ships internal cells via the loading bridge.

As soon as the train of triple stacked cars is loaded and properly positioned, the on-board distribution system can start unpacking the MBU and distributing the individual boxes over the stowage area. This can be done at any convenient moment; at the berthing place, during slow steaming while leaving or entering a

Part IV: Technological Solutions

port or perhaps even while sailing on open sea. Especially the latter as well as the slow steaming option would allow a remarkable reduction in turnaround time.

On some container terminals the multi-trailer concept has been adopted. A stacking crane delivers containers from their stack position to a multi-trailer system. One terminal tractor leads a train of for example 5 rubber tyred terminal chassis to the container crane (Figure 108, ECT, Rotterdam). The container crane hoists the boxes from these vehicles and lowers them into the vertical cellular holds of a container vessel.

The terminal train of the Train Loader concept does not bring the boxes to the quayside and under the landborne container crane but goes directly into the ship where it is serviced by the ships internal container and swapbody distribution cranes (Unmanned, automated guided vehicle and stacking crane, Figure 109, ECT, Rotterdam).

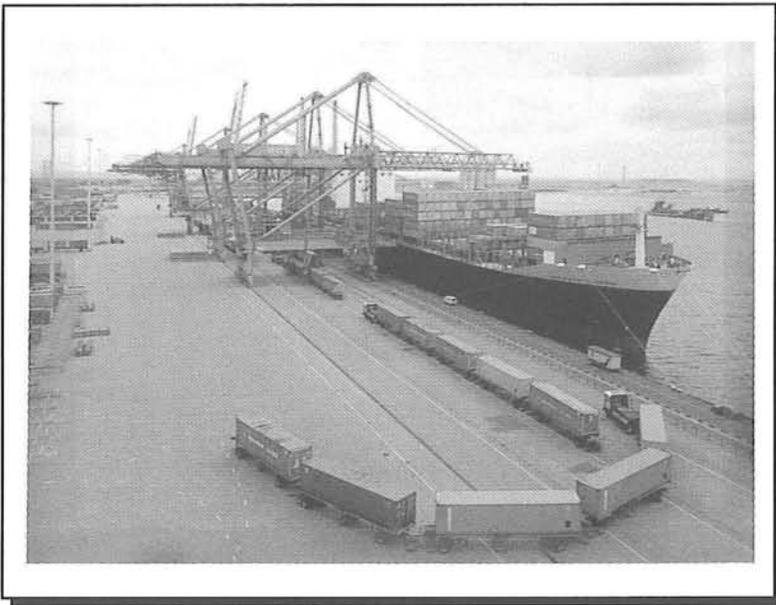


Figure 108

Existing technology for loading bridges, trains and internal overhead cranes can be used for this concept.



Figure 109

The advantages of the Train Loader are:

- * A considerable gain in turn around time can be achieved by taking advantage from the MBU principle. The first lot of boxes which is discharged goes ashore in a very short average handling time. The full capacity of the train is discharged within few minutes. Similarly, the last lot of boxes which is loaded onto the ship does not add to the ships turnaround time; the ship can leave port and finish the distributing process while at sea.
- * The boxes on the train can be brought very close to their final positions in the ships stowage area. The travelling path of the internal distribution system can be minimized by placing the boxes on the train on positions which correspond with the distribution plan of the cellular stowage area.
Despite the fact that an overhead crane onboard a ship has moderate performance parameters, it is still possible to set short average box handling times for the distribution system, as a result of the minimum path effect.

Part IV: Technological Solutions

- * An MBU in the form of a train covers the entire loading length of the ships stowage area. This allows for the use of two or three simultaneously operating overhead cranes, which improves the performance of the distribution system by a factor of little less than two or three. This is possible if and only if the set-up of the train is well-prepared and corresponds with the distribution plan.
- * The distributing cranes work in series mode. Failure of one crane does not affect a complete section of the ship. The other cranes can take over, resulting in a performance reduction only.
- * The cargo is fully protected inside the loading space of the ship, which is an important issue in regard to the Swedish winter conditions.
- * The weight of the MBU is distributed over the full loading length of the ship. Excessive trim is not likely to occur, although changes in trim can be expected during the loading or discharging operation itself when the train is passing the loading bridge. In the end situation, however, there will be no large trim moments thanks to the improved weight distribution.
- * The technology for triple stack trains can be developed from the existing experience with double stack trains.
- * The loading bridge technology also is available from the shelf.

A disadvantage of the train loader is:

- * A feature of the train-loader is the limited cargo handling at sea, which creates the time advantages of this concept. Cargo handling at sea requires the development of cranes which are designed for working under circumstances of a rolling and pitching vessel (heave compensation). Average handling times will increase when cargo handling at sea is not possible due to the sea conditions. This has to be considered when comparative calculations are done.

GENERAL ARRANGEMENT

Figure 110 shows a general arrangement of the train unitloader, with a capacity of approximately 380 TEU, of which 90 TEU on the two triple-stack trains. Figure 111 shows a typical cross-section and a perspective of the entire ship. The access of the trains via the stern of the ship to and from the terminal, makes it necessary to create a void space of approximately 3000 cubic metres, which can be used to transport clean petroleum products along the coast of Sweden. This may create additional revenue. The potential (one way, northbound

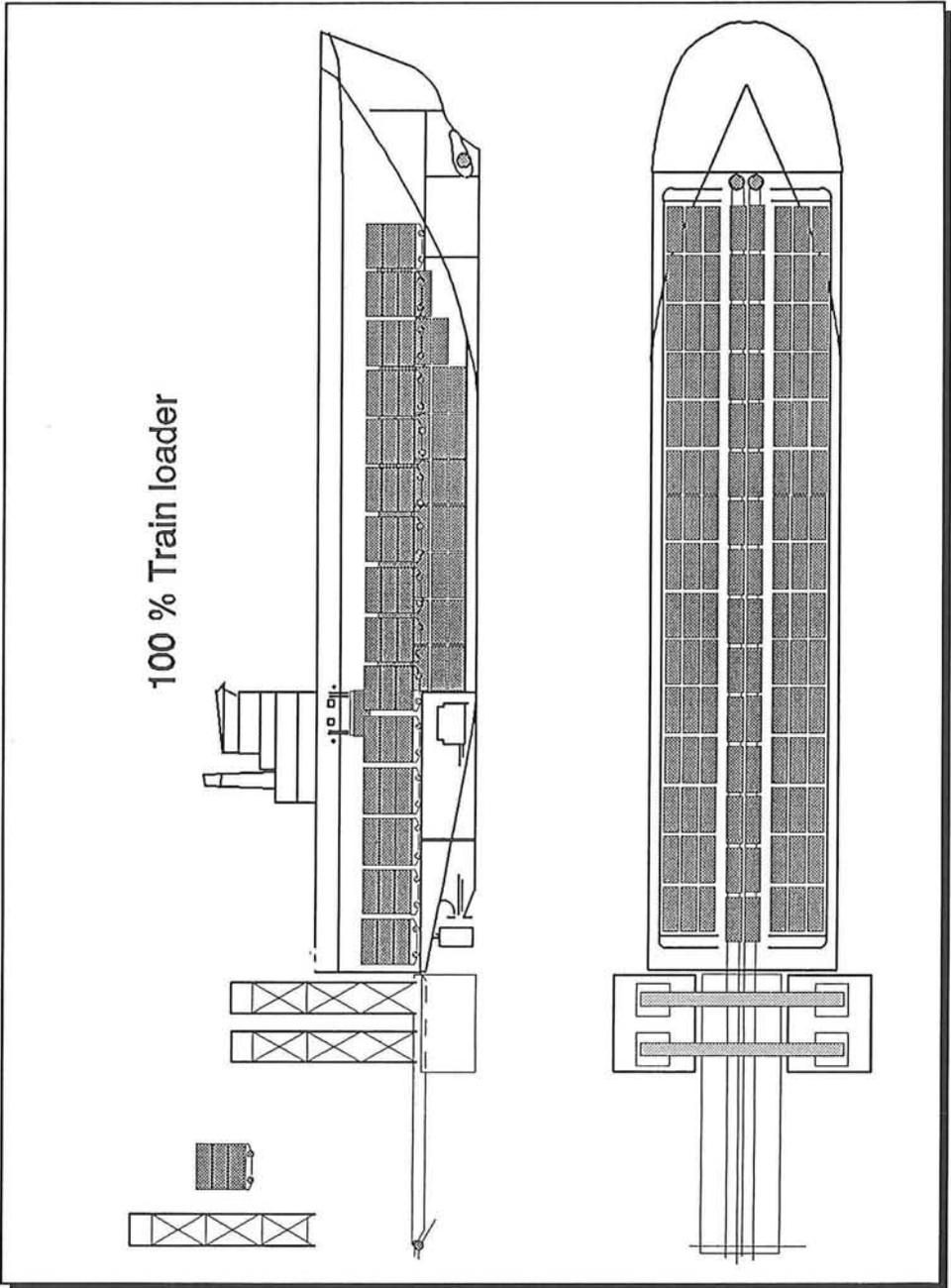


Figure 110

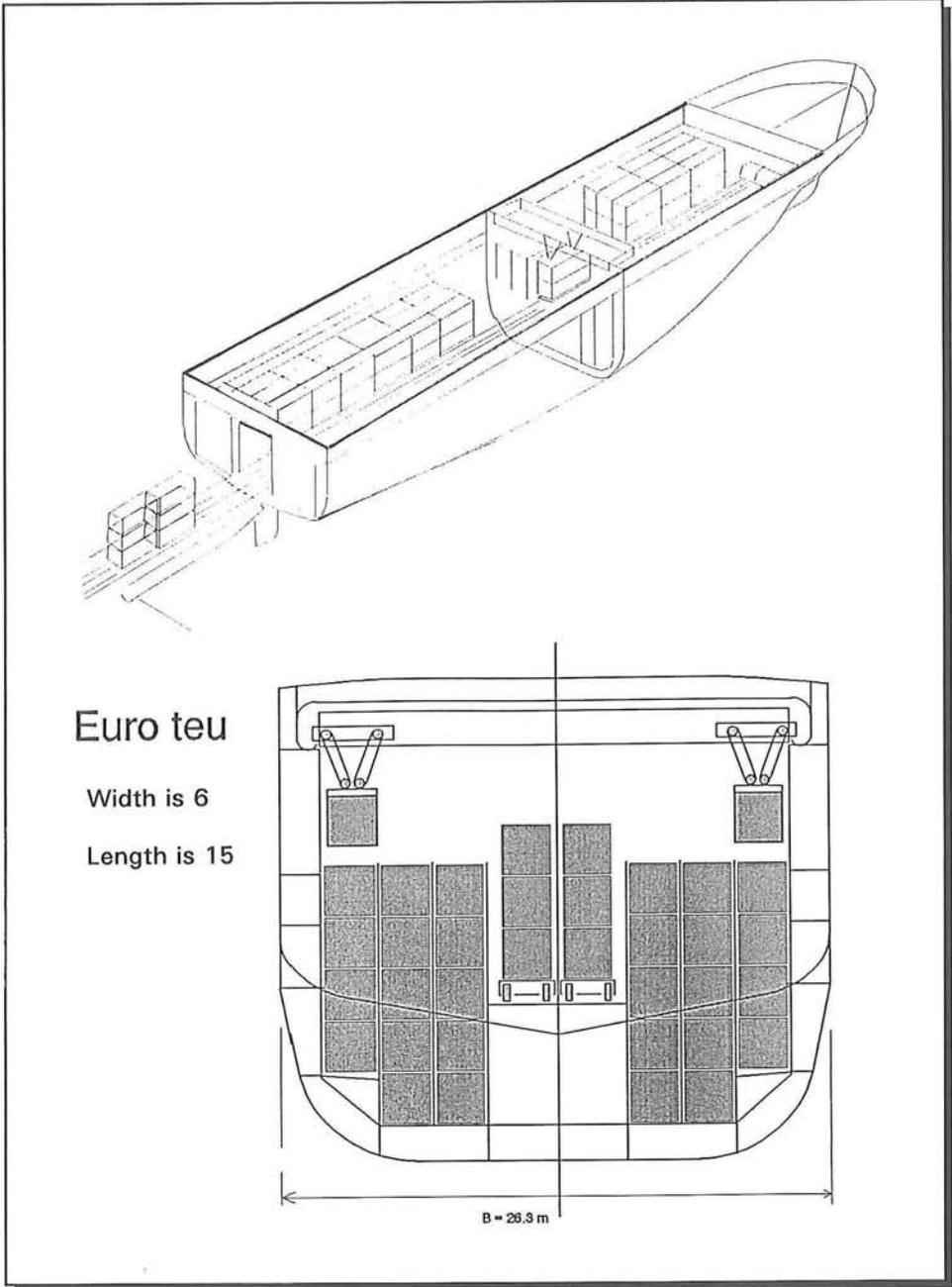


Figure 111

only) carrying capacity is $365 * 3000 \text{ m}^3 \approx 1.1 \text{ mln m}^3$.

There exist presently different versions of the design, based on three types of units: the maritime container of 20 ft, the pallet-wide container (2.5m), and the stackable swapbody (7,15m). The final design could be even a combination of the above. The cell-guides will be made in such a way that the dimensions can be adjusted, depending on changing requirements of the market.

OPERATIONS

The operations at the terminal are shown in **Figure 112**. The ship moors with the stern perpendicular on the quay, via a linkspan. The ship is wedged firm by means of a fender system aft and via a spud pole on the front. This operation does not require any manual assistance.

Next, the stern door is lowered onto the loading bridge, and the height is adjusted to the draught of the ship and tide. The ship is equipped with double winches. The cable on the winch is connected on one end to the train, while a cable on the terminal/bridge is connected on the other side of the train. This way an endless cable is created.

The ship's winch pulls the train on the terminal. The 750 tons platform train, with 45 units is winched in 5 minutes on land. The pull-power is rather limited as the ship's rails are flush with the terminal/bridge. The trim of the ship during the operation has been calculated and is rather limited.

The reverse process is carried out to pull the train, pre-stacked with 45 units, on board the vessels, and so on...

The details of the design of all the equipment are presently being developed. The system is technically feasible, and it uses existing, robust technology.

It requires a rather large space on the terminal and in the port. However, space is ample available in Sweden, while the use of the port is very limited (1 hour per call).

The trainloader concept can be based on the use of one or two trains inside the ship. Smaller ships might use one. In the following paragraph the performance of this one-train concept is evaluated.

PERFORMANCE CALCULATION TRAIN LOADER (ONE TRAIN)

The calculation method

The calculation of the loading and discharging performance of the Train Loader shows discontinuities, which was the intention of introducing the MBU philosophy.

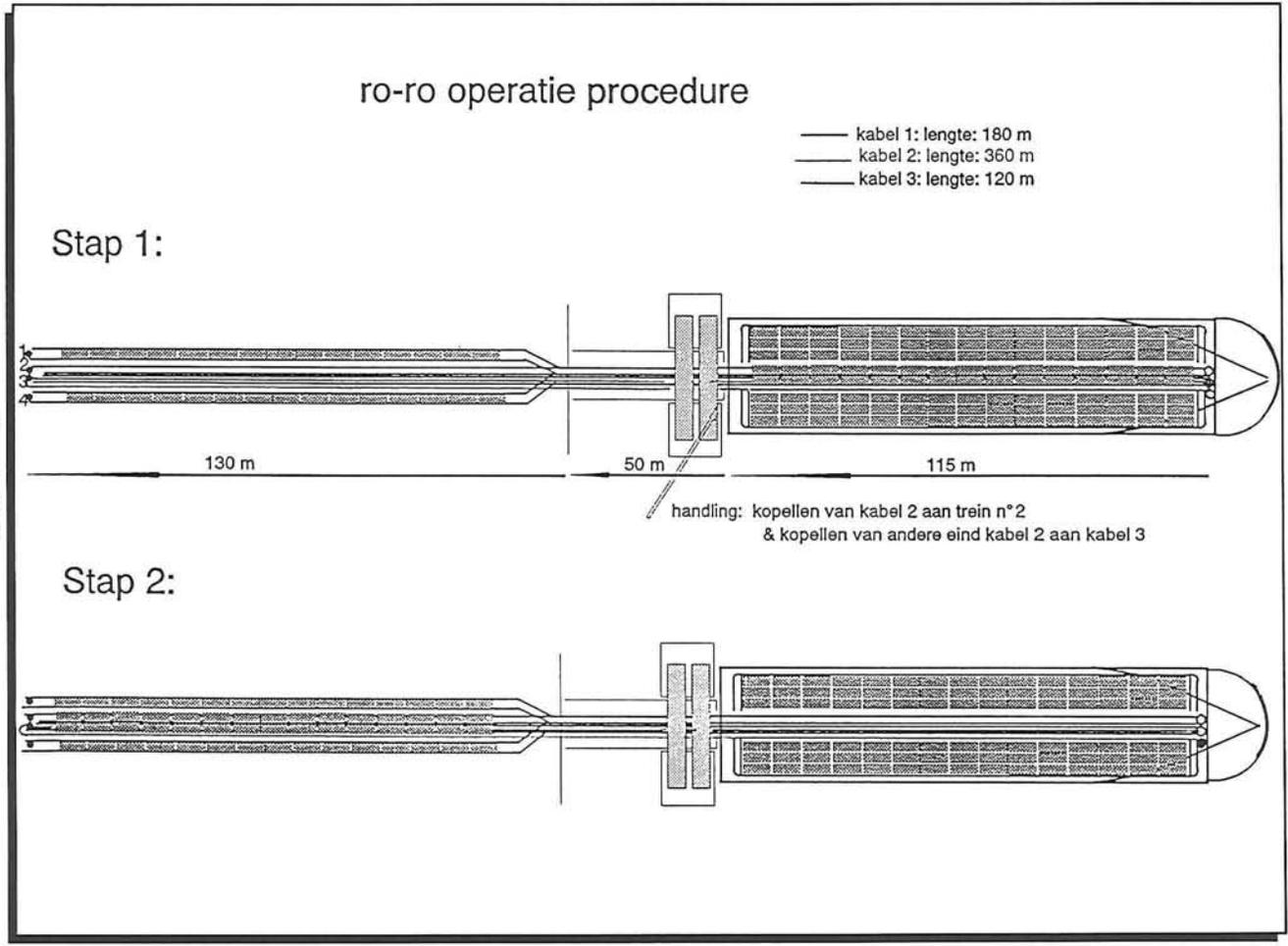


Figure 112

The calculation will be split in setting an average internal distribution performance figure and in the calculation of effective handling times incorporating the influence of the MBU capacity, MBU transfer speeds and the discontinuities. An average handling figure for an infinite number of boxes will be given as well. The results will be presented in the form of graphs and time tables.

The average path of the distribution cranes

The average crane path of the train loader is shown in **Figure 113**. The cranes of the Train Loader have a transverse trolley move in their path. With 3 cranes in operation each of them covers 5 box length's which results in 30 meters average crane travelling distance. The crane path includes crane travelling, trolley travelling and hoisting/lowering.

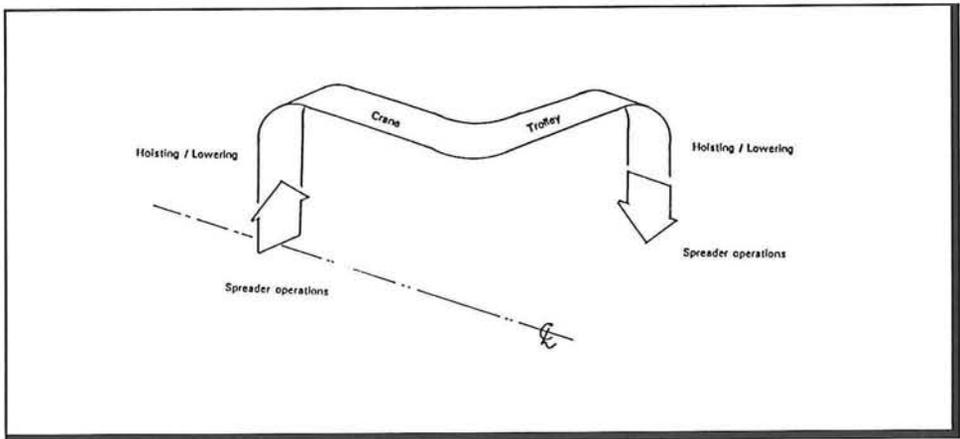


Figure 113: Average path of the distribution cranes

The average internal distribution time

The calculation of the average internal distribution time is reflected in **Table XXXVI**.

Time consumption of train moves

The Train Loader uses an MBU to load and discharge packages of boxes.

The MBU, the train of platform cars, has the same length as the loading length of the ship. It travels the free length to the quay side, across the loading bridge and into the ship, (**Figure 114**)

	TRAINLOADER		
	(sec/m)	meters	seconds
Hoisting/Lowering	2.5	22	55
Spreader operations			20
Trolley	1.5	12	18
Crane	1	30	30
Average per crane		(1 crane)	123
Effective average per box		(3 cranes)	46

(3 cranes correspond with approximately 2,7 effective)

Table XXXVI

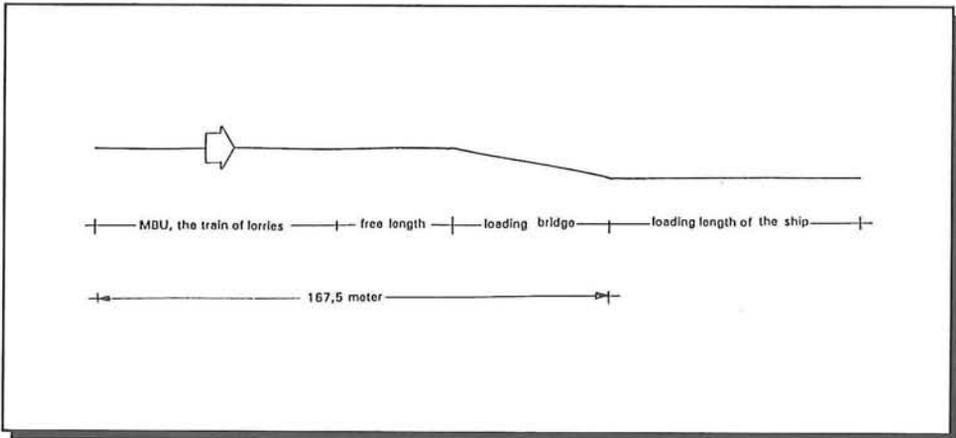


Figure 114: Path of the triple stack train

The train speed is determined by the maximum speed on the bridge or by the maximum speed when passing an interchange. During the entire move there will be parts of the train on the bridge or above an interchange. As a consequence the maximum speed of a loaded train is 30 meters per minute. An empty one will do approximately 40 meters per minute.

This results in the figures as given in Table XXXVII.

TRAIN MOVES				
	(meters)	(meters/- min)	(sec/meter)	(seconds)
Loaded triple stack train	167.5	30	2	335
Empty triple stack train	167.5	40	1.5	251

Table XXXVII

Handling characteristics train loader

One of the key elements of the MBU philosophy is reduction of the number of ship/shore moves. The introduction of the Multiple Box Unit allows that a large number of boxes can be loaded or discharged in one single loading or discharging operation. The strength of the MBU principal in the technical appearance of the Train Loader, will be explained by high lighting some typical phenomena in the loading and discharging processes. The discontinuous behaviour in time will be explained.

Preparing discharging operation at sea

On its way from the preceding port to the next port of call the discharging operation can be partially prepared. In the calculation examples the capacity of the triple stack train equals 45 boxes. As soon as the loading bridge is available the first package of 45 boxes can go ashore. The train move has a time span of 335 seconds which means that the first 45 boxes had an average discharging time of approximately 7 seconds per box, see Figures 115 and Figure 116.

Discharging more than 45 boxes requires an empty train to be returned to the ship. This consumes 251 seconds. Each next box can be put on the train against the rate of 46 seconds per box, which is the internal handling time per box. Once the loading of boxes onto the train has been completed, the entire lot can be transferred to shore in 335 seconds.

Completing the loading operation at sea

Once the discharging operations are finished the loading can begin. The loading operation is the reverse operation of discharging and it shows the same discontinuous behaviour.

Part IV: Technological Solutions

In advance of the ships arrival all boxes which will be loaded onto the ship are put on the necessary number of triple stack trains .

The first trainload of maximum 45 boxes is transferred on to the ship within 335 second. If not more than 45 boxes are loaded in that port then the ship can unmoore and leave directly after the train is on board and the loading bridge removed. In that case the turnaround time and the average handling time per box has the behaviour of the first part of the curves in **Figures 115** and **Figure 116**.

When loading more than 45 boxes the surplus of boxes requires additional train moves and direct distribution over the stowage space unless a double train system is used. Each next box exceeding the maximum train capacity of 45 boxes will add 46 seconds, which equals the average internal distribution time, to the ships turnaround time apart from its share in the 586 seconds which cover the additional moves of full and empty trains.

At a rate of 46 seconds per box the distribution time of a full triple stack train will total 2070 seconds, which is equal to 34½ minutes.

In order to take the maximum advantage of the cargo handling at sea the last triple stack train going onboard should be a full one.

The effect of cargo handling at sea on the turnaround time

Figure 115 shows the turnaround time of the Train Loader with and without cargo handling at sea.

When cargo handling at sea is not or can not be applied the turnaround time follows the grey pattern. On each interval of 45 boxes the slope of the inclined line pieces equals the average handling time per box while the vertical steps correspond with the time consumption of the train moves.

The black pattern reflects the improved turnaround time figures when cargo handling at sea is applied. The entire figure has been moved to the right along the X-axis, which shows the number of boxes. Any number of boxes not exceeding the maximum capacity of the train can be loaded or discharged within 335 seconds. The horizontal part indicates that the minimum turnaround time has a positive value of 335 seconds, which corresponds with the transfer of one non-empty train. In case more than 45 boxes are handled the turnaround time has the same slope and vertical steps as in the situation without cargo handling at sea.

The trailing average handling time

The trailing average handling time depends on the number of boxes and shows discontinuities in its behaviour (**Figure 116**).

The more boxes are handled the less the time saving effects of preparing or completing the cargo transfer operation at sea can be traced in the final values

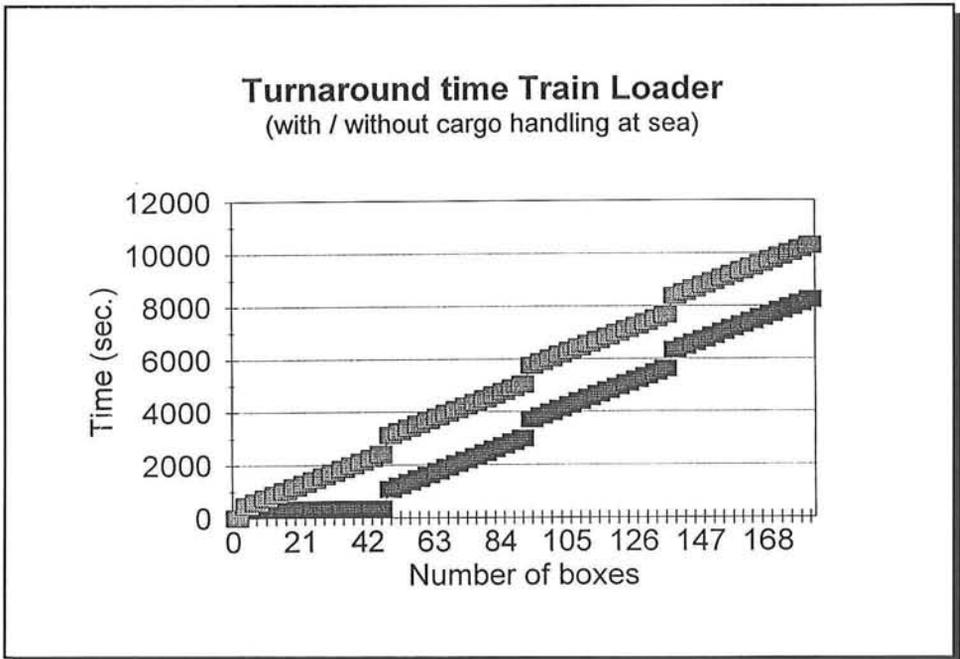


Figure 115: Turnaround time with and without cargo handling at sea

of the effective average handling time per box.

The 45th box has the lowest average handling time. In one single operation 45 boxes are loaded requiring just 335 seconds. This corresponds with an average handling time, at 45 boxes, of approximately 7½ seconds for each box.

Besides its own internal handling time, the 46th box requires additional time for train moves which is accounted to just one extra box. This causes the relatively large difference in average handling time between the 45th and the 46th box. Each next box causes the average handling time to increase although the slope of the growth decreases because the additional time for train moves can be apportioned to a growing number of boxes.

The discontinuities occur at each plural of 45 boxes.

Loading or discharging an infinite number of boxes

If very large numbers of boxes are handled the trailing average is hardly affected anymore by the time-gain resulting from MBU principal. In that situation the MBU transfers are part of the final figure for the average handling time. The final figure is the sum of the average time per box spend on MBU moves and the average internal handling time per box.

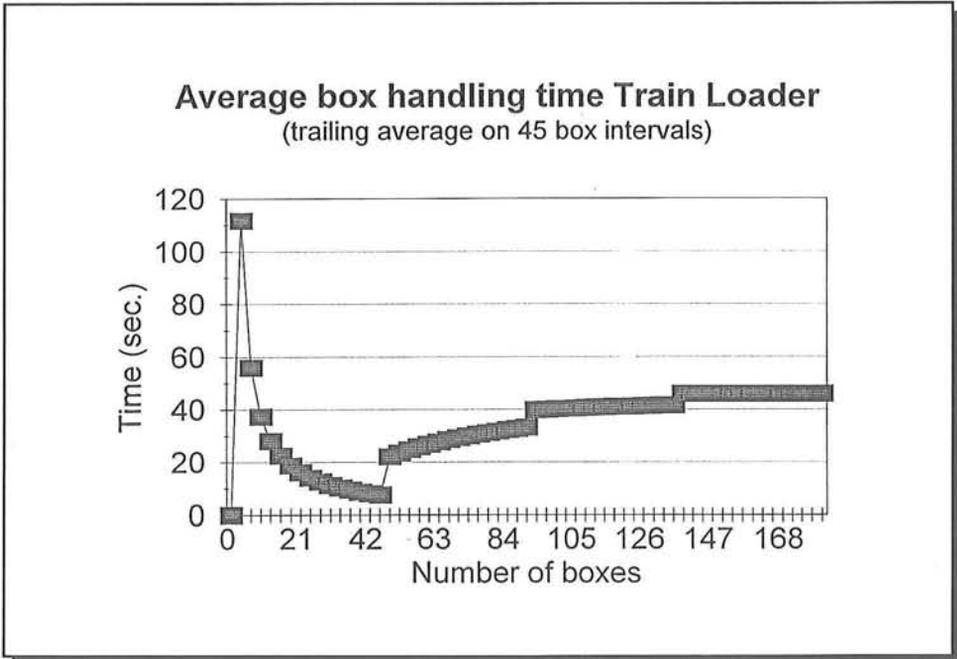


Figure 116: Average handling time (cargo handling at sea)

Figure 117 indicates that the average box handling time, ABHT, embraces an end value of 59 seconds. This satisfies the following equation:

$$ABHT_{(Infinite\ number\ of\ boxes)} \approx \frac{335+251}{45} + 46 = 59\ seconds$$

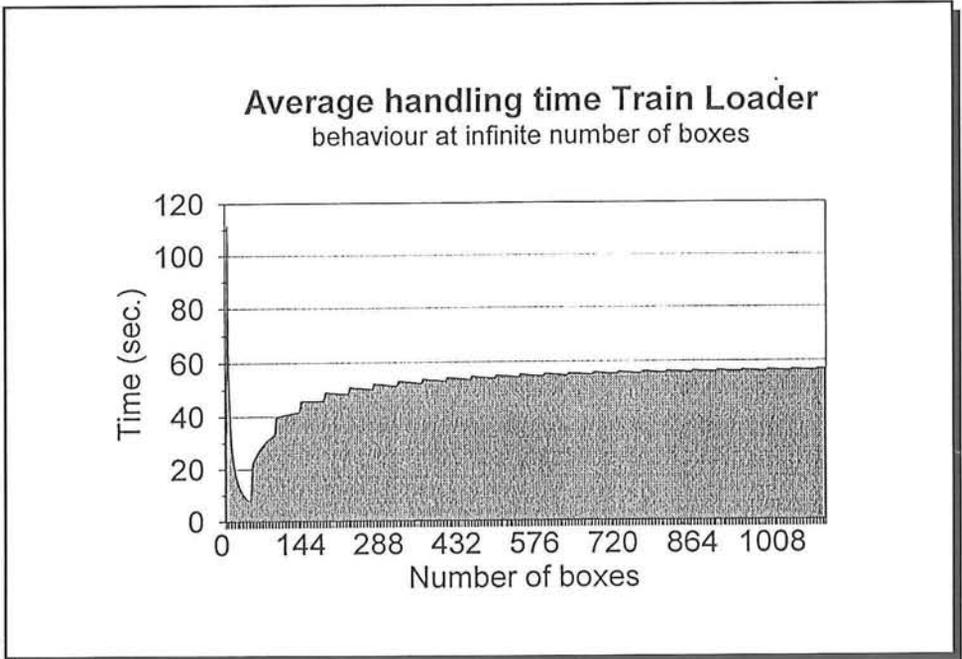


Figure 117: Behaviour at infinite number of boxes

PART V - FEASIBILITY OF THE CONCEPTS

The feasibility of the self-loading and unloading unitload ship systems can be assessed in economic, commercial, operational, technical and environmental terms.

For both conveyor and train loader concepts, different evaluation formats have been used and in both cases the evaluations are only indicative. The concepts are too new and there are too many "loose ends" to present them in this stage of the project as authoritative.

However, the conclusions of both feasibility studies is that the ship systems are feasible, in terms of critical success factors (price, transittime, frequency, and quality), and certainly in environmental terms. Although the technology in this project is of great importance, it is not a critical factor.

The only real uncertain but decisive factor is the cargo-base.

A new concept has to be implemented full scale, in order to offer the sailing frequency, which is required to compete with the existing modes. This start-up phase will be discussed in Chapter 18.

CHAPTER 16: CONVEYOR/ELEVATOR LOADER

The basis for these calculations is the assumption that there is a shipping system consisting of seven ships trading the east coast of Sweden. The number of port calls is set to 14. The port calls are, as the size of the terminals, dependent on the turnover in each terminal. In the sea transport system it is considered that there is one terminal with the capacity of the full size of vessel (400 units in turnover), one terminal of an average turnover capacity of 200 units, three terminals with an average capacity of 100 units per call, four with a capacity of 50 units and five with 50 units in average capacity. The stay in the ports is based on the full capacity turnover in each terminal which will be maximum four hours.

RUNNING COSTS: CREW

Maintenance and technical service onboard the ships are intended to be performed by shore-based personnel according to a planned maintenance system. It is quite difficult to estimate the number of needed technicians in a system. As the ships are to have a high technical standard, the need for what is known as normal maintenance such as painting etc, will be kept to a minimum.

The policy of the shipping operation will be that the crew onboard a ship should only carry out the operational tasks, such as navigation and cargo care. Safety is of course included. The crew should also have the capacity to carry out repairs which cannot wait. As the operation shall be based on planned maintenance, repairs will be extraordinary duties and not normal duty.

Part V: Feasibility of the Concepts

In order to achieve this, the crew must be highly qualified and compensated for the extra training and working hours. The salary for a master is estimated to be 30 000 SEK per month.

The total onboard crew is to be composed of four persons, two masters and two for technical support.

Two crews are needed for each ship. The working period onboard is expected to be four weeks. Consequently, four weeks will be leave.

There is no need for a watch-free master. Two nautical officers can take watches and alternate in the position of master. Systems like this already exist on one ferry trade between Sweden and Denmark in Öresund.

"Watch One" is a must for a ship with such a small crew. Until now, no such ship has been sailing under Swedish flag. However, there are spoken indications from the Swedish National Maritime Administration that this can be feasible. A number of vessels under other national flags, such as German and Norwegian, are practising this type of ships operation.

The watch for a two-man schedule should not be fixed. One solution to this can be a system based on 4 - 5 - 6 hours watches. The purpose is to do a rotation of the watches over the full 24 hour day.

Estimating crew costs today (1992) under Swedish flag is extremely difficult as there is a great uncertainty about the new shipping policy expected from the government.

The upper limit for what is generally named social costs is a factor of 1.4, i.e. 40 per cent on top of the salary.

The Table XXXVIII shows salary per month for one person and total cost per year for the position. The total cost includes travel expenses and social costs.

Position	No of	Salary	Cost
		SEK/month	SEK/year
Master	2	30,000	2,193,000
Technician	2	20,000	1,521,000

Table XXXVIII

Since historical times the ship has constituted a small isolated society. Everything within the society to make it run had to be taken care of by the crew members themselves. This created the needs for different and multiple skills among the seafarers. As time has passed, many functions have disappeared and

some new have developed. Overall, however, with the technical development it is no longer necessary for all these skills to be available on board, and the number of crew members has been decimated accordingly.

The manning of ships has traditionally been based on the fact that operation and most of the maintenance must be carried out by the crew. Legislation and agreements between shipowners and onboard representatives have been based on this situation.

The boundaries between different categories onboard have also been strict. Deck, engine and galley departments are the main groups in modern times.

Progress in communication technology has has been dramatic during the past decade. This has not only led to reduced crews, but also to cargo planning on many dry-cargo ships being carried out by shore-based personnel.

Integration between engine and deck has also increased with the latest development in computer technique. On-line systems with engine and deck monitoring on the bridge are common on advanced modern coastal tankers. The manning on those ships is still conventional even though the number of crew members is minimized according to agreements existing today.

The following example of a coastal tanker illustrates this.

A coastal trading tanker of 8 800 tons DWT with a minimum crew has ten men in crew all told, which is consequently two below what is generally meant by a minimum crew, in Sweden. The basis for this size of crew is still that the main maintenance is to be carried out onboard the ship.

On this tanker the crew is configured as show in Table XXXIX.

As a tanker is on an irregular trade it is not feasible to have a strict operational crew.

Another example is the Lake Vänern shuttle.

On more scheduled coastal or short distance routes, the crews can be minimized from an operational point of view.

The Vänern shuttles are an example of this. Two vessels trade between Gothenburg and Lake Vänern. The route takes about 20 hours and consists of Trollhätte canal with some locks and Lake Vänern. The vessels always alternate between the same harbours.

The crew consists of four persons. Captain, nautical officer and two men on deck. The two officers share the watches. One extra man is shared between the two vessels and assists with maintenance.

Position	No of
Captain	1
Nautical officers	2
AB:s	3
Chief engineer	1
1:st engineer	1
Oiler	1
Cook	1
Total	10

Table XXXIX: Crew list

International agreements are the basis for the Swedish legislation regarding the captain's position onboard the ship. However, legislation concerning the working hours is entirely based on national law.

The most common system is three watch-keeping officers and one captain, resulting in a normal working week of 56 hours. This system normally requires, like all others, that the captain is free from watch.

However, there is nothing in the law to state that the captain must be free from watch. This question is more related to negotiations with the officers' organisation. Nor is there anything that states that the position of captain cannot alter during sea passage. Or, expressed in a different way: let the officer in charge of the watch also serve as captain.

The strict rule interpretation of the manning resulted in a number of very strange developments. For example, at one time there was an intensive development of tug-barge concepts due to the fact that the crew was based on the size of the tug instead of the whole transported unit. This led to a ship unit consisting of tug plus barge where the size of the crew could be half of that on a ship of the same size.

The number of crew members has been a matter of competition between the national flags. The rules for measurement of ships have been given different interpretations in various countries so that the size of the vessel could be increased using the same manning.

The situation has led to a new international way of measuring the gross tonnage of the vessels. The reaction from the national authorities has gradually changed from strictly using the measurement of the ship size to determine the size of the crew by means of an individual evaluation of each vessel. This has led to a negotiable size of manning where the national authority evaluates the vessel out of safety aspects.

The new way to look at the manning has led to further rationalisation of the vessels now on the base of the technical development. A number of experimental projects have been presented and put into operation. The most famous is the Lauritzen reefer vessels, where the manning was reduced to 6 men in an international trade. This type of high tech vessel has been developed to meet the competition from the internationally flagged vessels manned by crews from the Third World.

RUNNING COSTS: MAINTENANCE

According to the policy of technical support all maintenance is to be planned maintenance. Some minor maintenance and repairs must be carried out by the crew. Repairs and more extensive work is taken care of by shore-based personnel.

Maintenance carried out onboard should be minimized. This can be achieved by having exchange systems for as many items as possible. Auxiliary engines together with generators can be mounted on platforms which are lifted ashore for planned overhaul.

A system like this can in fact lead to lower maintenance costs than a traditional system where all service is done onboard. The reason is that the service is carried out under better conditions and at lower labour costs as all work is done during normal working hours. The installation of exchange systems is of course more expensive, but experience from ships in operation shows that the lower maintenance costs are in some cases of greater significance. An important item is of course that the vessel shall be built for the type of service making the most of the service system.

The average situation for the shore personnel is to carry out their work at port calls. As the port calls are to be very short, it is some times necessary for them to follow the ship on a sea voyage. This will evidently lead to higher working costs due to overtime compensation and travel expenses.

The following calculations are based on a number of shore-based technicians varying from three up to seven (3 - 7). The average time spent at sea is about 40 days per year. Each voyage is expected to last two days in average. Travel costs and overtime compensation is taken into consideration.

Part V: Feasibility of the Concepts

Maintenance costs depend on a number of variables. The easiest ones to identify are of course salaries and direct procurement. Others are more hidden. Especially, the cost for not doing maintenance is hard to estimate. Lay time costs, the difference in selling price between a well-kept ship and one with a lower degree of maintenance are never known exactly. Therefore it is often up to the owner which philosophy to follow.

TOTAL RUNNING COSTS

The conveyor loader is a ship with a high degree of technology which increases capital costs to a level which is higher than normal, but comparatively low crew costs. In general, ships exclusively equipped for automation and low demand for maintenance, high tech ships, will need a smaller crew. From a cargo handling point of view, they are normally built to be much more efficient than low tech ships.

The total investment cost of the ship will be dependent on the total life time of the ship. The rest value is important and has been the major profit from the shipping service for many shipowners.

The ship's concept of operation is also vital for the second hand value. This can work both ways. If the ship is still attractive on the market when she is due to be sold, then there is the risk that she will go out on a market competing in the same trade. The same situation applies for special ships in special trades. Higher sophistication gives a technological protection of the service. The service cannot be entered by low cost ships provided that the high-tech concept gives lower total costs. The total running costs are shown in **Figure 118**.

CAPITAL COSTS

To obtain a correct price for the ships, three shipyards have been asked to deliver an offer regarding the cost for newbuildings. Their offers are based on a complete specification and the GA plan. Consequently, the prices offered include all technical arrangements such as cargo handling equipment and exhaust gas reduction.

The prices differ between 155 MSEK (dec 1992) for the construction of each ship to a price of approximately 240 MSEK. Although we have tried to give as substantial information as possible to the yards enabling them to do a serious calculation, there was not enough time or information for the yards to make the complete calculation.

There are differences in the quotes with regard to capital costs, which explains some of the discrepancies in price. The prices are to be regarded as first offers and therefore the prices could be changed if more close discussions were to commence. However, the price indications are within our own estimations and

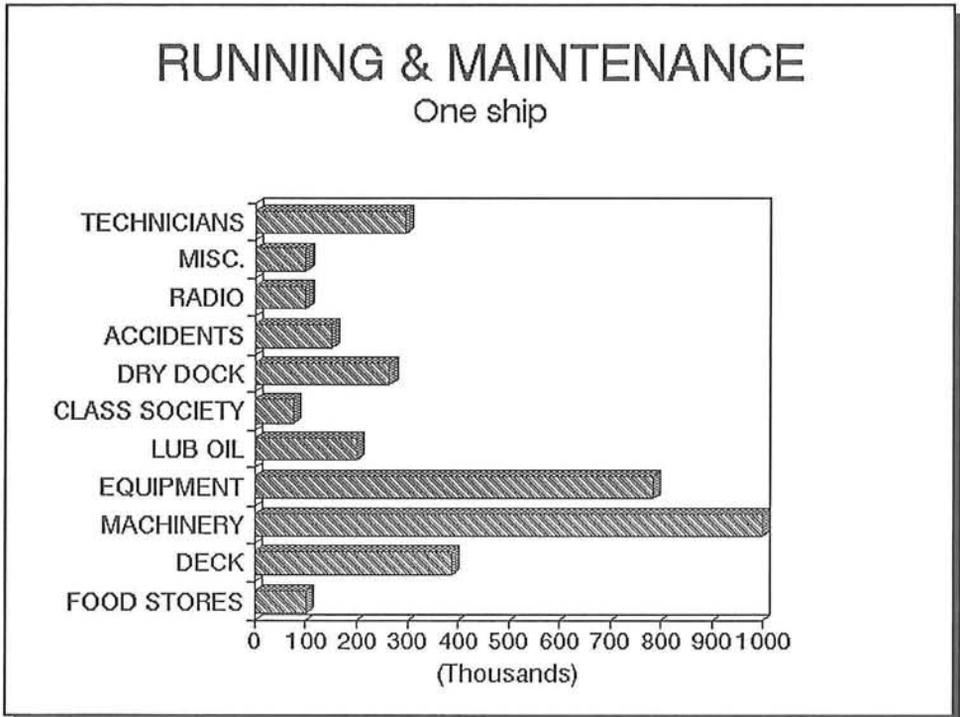


Figure 118: Running and maintenance costs for one ship

having discussed the subject further with the yards as regards a relevant price indication we have come to the conclusion that 160 MSEK is a fair cost assumption adding a capital cost of 8 MSEK during construction.

For the entire system we have calculated with a depreciation time of 15 years and an interest rate of 12 percent. Capital cost is calculated as an annuity cost.

The cost distribution for one ship in a system consisting of seven ships is shown in the following chart. Compared to many other ships, the capital costs are the most significant. For the first year the share will be abt 74 percent. After a 15 year period it will have decreased to approximately 58 percent if the running costs are expected to increase by five percent annually. These figures are very significant when comparing the total system with cost of land transport modes. The daily cost for one ship will be about 84,700 SEK. with the cost distribution given in Figure 119.

Figure 120 shows the cost in absolute amounts.

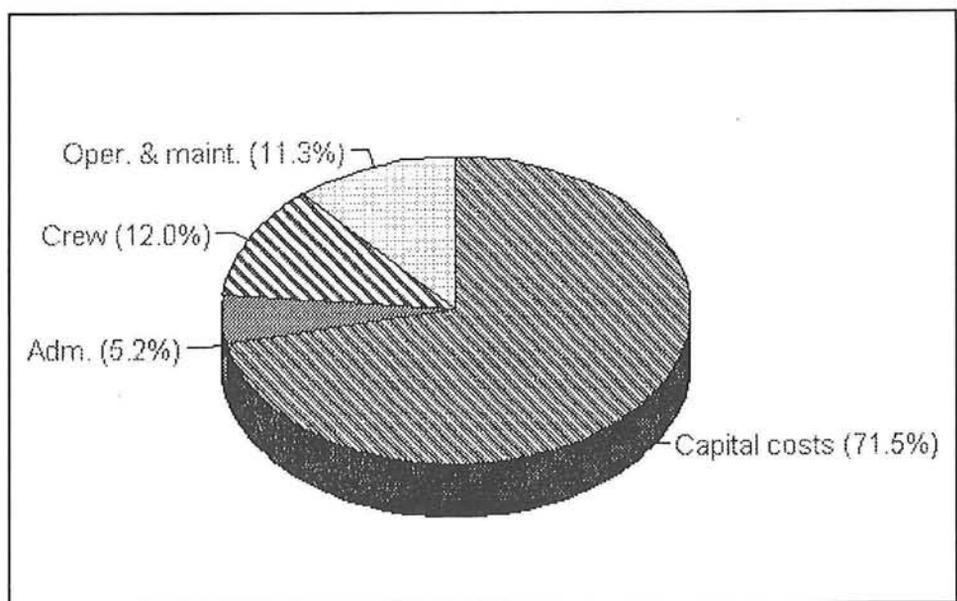


Figure 119: Cost distribution for one ship

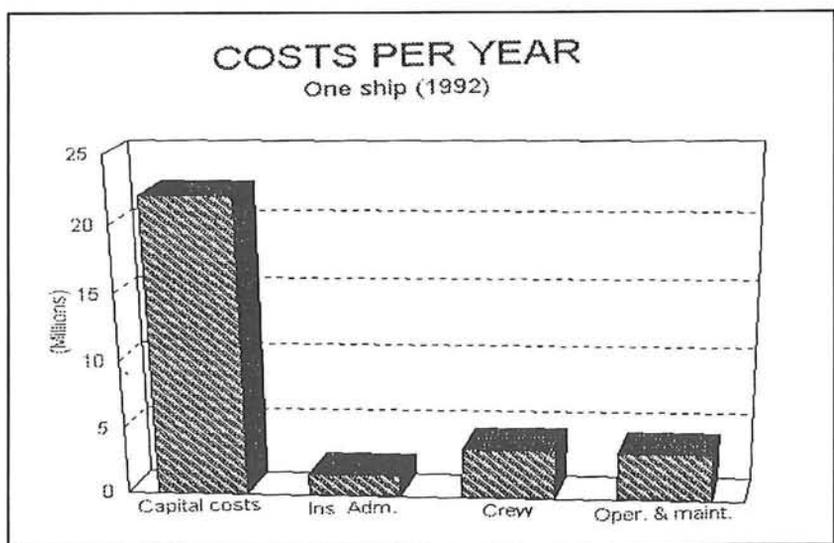


Figure 120: Total amounts for one ship, calculated in 1992

Cost for the handling equipment in the ship

The project has included a complete design of the handling system onboard the ship and in the terminal. The design is presented in enclosures 7 and 8. All major parts of the handling equipment have been specified and quoted by suppliers. The quotations and specification have then been given to the yards and Kværner Ships Equipment for the cost analysis. The total cost of the handling equipment inside the vessel has been calculated to 13.5 MSEK for the sideport equipment installed in the vessel and 10 MSEK for the total handling equipment inside the vessel. As a comparison, a ship gantry crane of low sophistication is calculated at a cost of about 10 MSEK.

The figures give a cost per TEU carrying capacity of abt 37 000 SEK for the handling equipment onboard the vessel (excluding the sideport arrangement which can be considered as a fixed cost independent of the size of the ship as long as it covers four ship's decks).

COST EVALUATION OF AUTOMATIC HANDLING IN TERMINAL

During the last few years a clear liberalization has taken place with regards to the possibility of closing stevedoring contracts for regular shipping services. It must be stated that the possibility of service differs very much between ports in Sweden. The most flexible organisations today offering a liberal view of working hours will be found in the Gulf of Botnia area.

In order to evaluate the cost benefit of automatic cargo handling, a cost comparison must be made with a manual handling system.

Manual handling system

A number of assumptions must be made in a general calculation of a manual handling system. The result is that two models have been created. The first model is based on an evaluation of the normal manning to give service to the ship. In the second model we allocate a manual resource which is comparable to the handling capacity of the automatic handling system, in order to give the same prerequisites as for the automatic handling.

The manual handling is based on the following case. Costs include the total cost, i.e. administration and other overhead.

Part V: Feasibility of the Concepts

Manhour cost	300	SEK/H
Running cost vehicles	100	SEK/H
Investment of 30 tons forklift	3	MSEK
Investment of truck + trailer	0.8	MSEK
Time of depreciation	10	years
Interest rate annuity	15	%

The total time is the sum of the time of reporting 2 x 1.5 H plus the time of the ship's handling in port.

The handling is assumed to be performed by one or more gangs. Each gang comprises three men; one driver of the forklift, one driver of the terminal trailer and one ground assistant. The incoming truck is assumed to have parked the unit on its legs in the terminal parking area. The special terminal trailer picks up the unit and is assisted by the ground man to fold the legs. The ground man also assists in checking that the forklift has grabbed the unit properly. This operation is to be performed at the quay side. The assistant will also do the tally work. The forklift lifts up the unit and positions it on the sideport elevator platform, releases the unit, folds the legs and pulls it away from the elevator platform to grab the next unit.

The productivity per gang hour is estimated to 15 units. This means that each gang can perform 15 handling operations as described above in one hour.

For a turnover of up to 20 units one gang will be enough. The time of operation will then be up to 1 h 20 min for the handling. For a higher turnover the handling capacity will be increased by one gang.

In Tables XL and XLI the total cost per handled unit is given as a function of the total annual hours of utilisation of machines. In the case that the machines will be exclusively utilized for the operation (the availability required is to be 100%) the cost of the machines must be based on the actual utilisation.

It is of course difficult to have the exact fixed cost for the type of operation especially as here we are only looking at the cost of handling. No cost for the parking area or other port duties are considered. One aspect is that it should be practically possible to operate with a 4 gang system per ship in order to arrive at the assumed high productivity. We are familiar with this fact but we are here taking the liberty of performing this test case and assuming that it will be practically possible.

Every delay in handling causes a delay of the ship which also will generate cost. The cost of the ship will be about 3 500 SEK/h. Further, the loss of time will create a loss of turnaround capacity which will generate new costs etc.

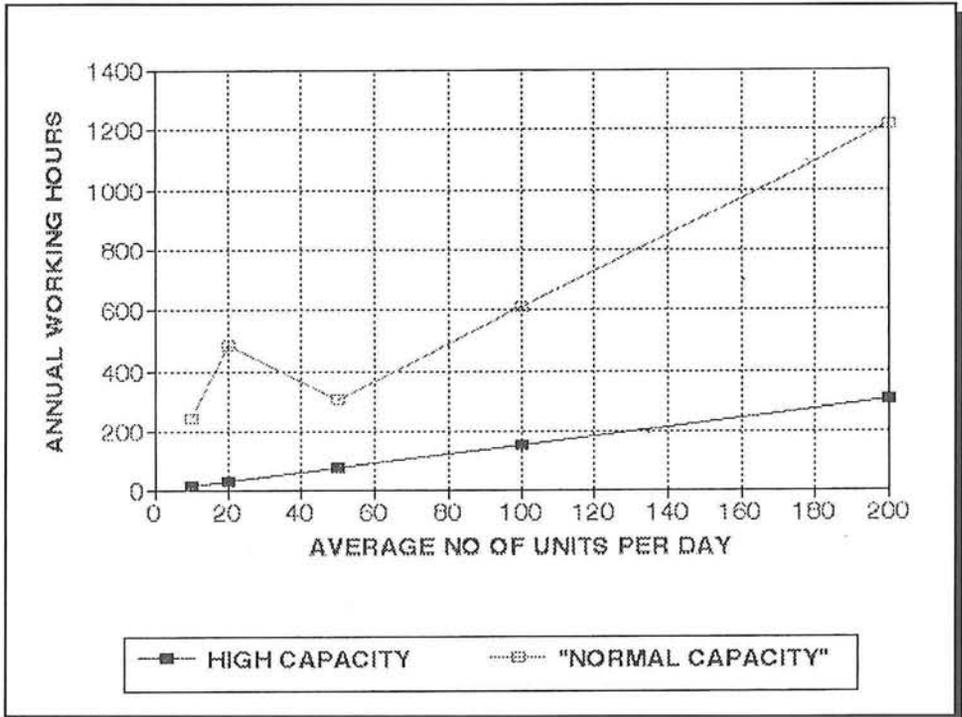


Figure 121: Utilization of vehicles in a terminal with daily calls

Cost for the handling in an automatic service station

For manual handling it will always be the net cost for the number of units handled which is to be calculated. In the automatic operation the capacity in the terminal has been calculated to be 150% of the average handled number of units. In our calculation we also include the cost for the erection of the whole terminal including dolphins, handling lanes, cover etc. It is of course a drawback for the automatic terminal that it must be designed and carry the investment of the maximum number of units expected to arrive in to the terminal. But the investment cost per unit is the smaller part of the total cost of investment.

It is difficult to go too far into details of what is included in the calculation but a list is presented for the understanding of the total quantity.

Table XLII is a printout from the spreadsheet calculation of the total cost.

It can be noted that all currency is Swedish kronor SEK. The calculation includes both the support per unit which consists of steel bars and the cover plus a preparation of the tarmacs in the terminal.

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<u>Units/call</u> <u>Hours/year</u>		20	50	100	200
No of gangs	1	1	2	2	2
500	531	396	317	263	210
1,000	456	321	257	203	157
1,500	430	295	236	182	139
2,000	418	283	226	172	131

Table XL: Cost of manual handling in SEK per unit in or out of port for normal productivity 15-30 units/h

<u>Units/call</u> <u>Hours/year</u>	10	20	50	100	200
No of gangs	4	4	4	4	4
500	2,126	1,063	425	317	263
1,000	1,823	911	365	257	203
1,500	1,722	861	344	236	182
2,000	1,671	836	334	226	172

Table XLI: Cost of manual handling in SEK per unit in or out of port for a high capacity

All units are assumed to be handled exclusively by the automatic system as described in this report.

Investment

In principle the cost for an automatic handling system is fixed in time. The running cost for the terminal will be very small. The fixed cost consists of the interest and depreciation of the investment. Ordinary manning cost is running cost which follows the general cost increase.

Cost of automatic terminal		SEK	Time of depreciation	10 years
COSTS	SOFTWARE	100 000		SEK/pos
	DRIVE UNIT	250 000	chains	3 869
	DOLPHINS	3 000 000	support	12 750
	RAMP	2 500 000	equipment	1 000
TOTAL FIXED INVESTMENTS		5 850 000	ground + cover	15 180
		INVEST/CONT POS TOTAL		32 799
Daily	automatic syst			
Turnover	SEK/Unit	Investment		
10	268	6 833 964	Overcapacity	1.50
20	159	7 817 928		
50	100	11 269 820		
100	81	17 189 640		
200	71	29 029 280		

Table XLII: Cost for the automatic handling

The automatic terminal cost is calculated on the base of quotations from suppliers of equipment plus general cost calculations for additional equipment. The investments are shown in Table XLII. In this calculation the investment includes both equipment and what is needed in the terminal for the construction of the berth. The main fixed cost for this is the dolphins. In addition there is the cost for the preparation of the tarmac etc. These are costs that are normally covered by the port overhead cost which is paid as port duties. If we reduce the cost by these investments we come to a cost which is more similar to the traditional cost scenario. The principal investment costs are shown in Figure 122. It should be noted that the maximum capacity is 1.5 times the one presented on the X axis.

Cost comparison

A cost comparison between the systems is given in Figure 123. The comparison is based on the automatic handling system as per above. The "normal" manual capacity is 25 - 50% of the capacity for the automatic system. In the "Manual

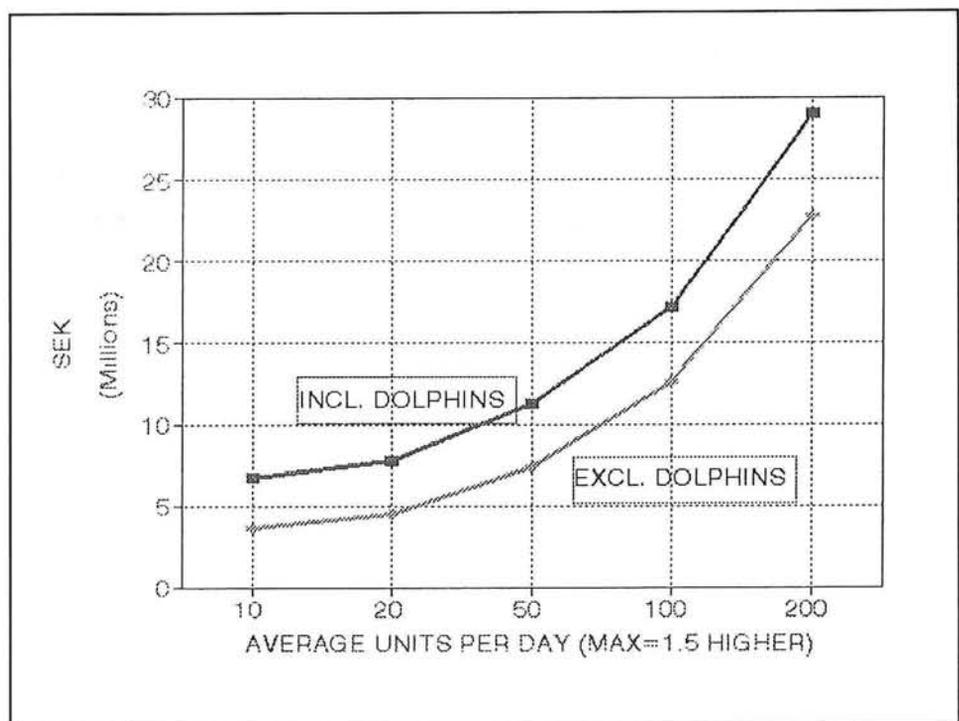


Figure 122: Investment per unit capacity for an automatic terminal

high capacity" diagram the manual capacity will be of the same size as the automatic handling capacity. However, it is not realistic to call in a work force representing a capacity of 2 x 60 units per hour to move 20 units, which is why we present both curves as a high and a low cost level for the manual handling.

All machine cost figures are based on a total annual utilization of machines of 1 500 hours. This is an other practical problem as regards earlier shown times of utilisation, as we also demand 100% availability. Using the material in the tables above it is possible to draw one's own conclusions of realistic values.

It is interesting to find that it is more profitable to invest in an automatic system even if the quantities are small. We expected the contrary and anticipated finding a level of turnover where it is interesting to go from a manual to an automatic system which is a more traditional way of planning for development.

The cost of manual handling is based on the same capacity as for an automatic system. This is the base for the comparison. If the capacity is reduced and/or the ship should wait until normal working hours the ship's costs should be added to the handling calculations. This cost is about 3500 SEK/h. On top of

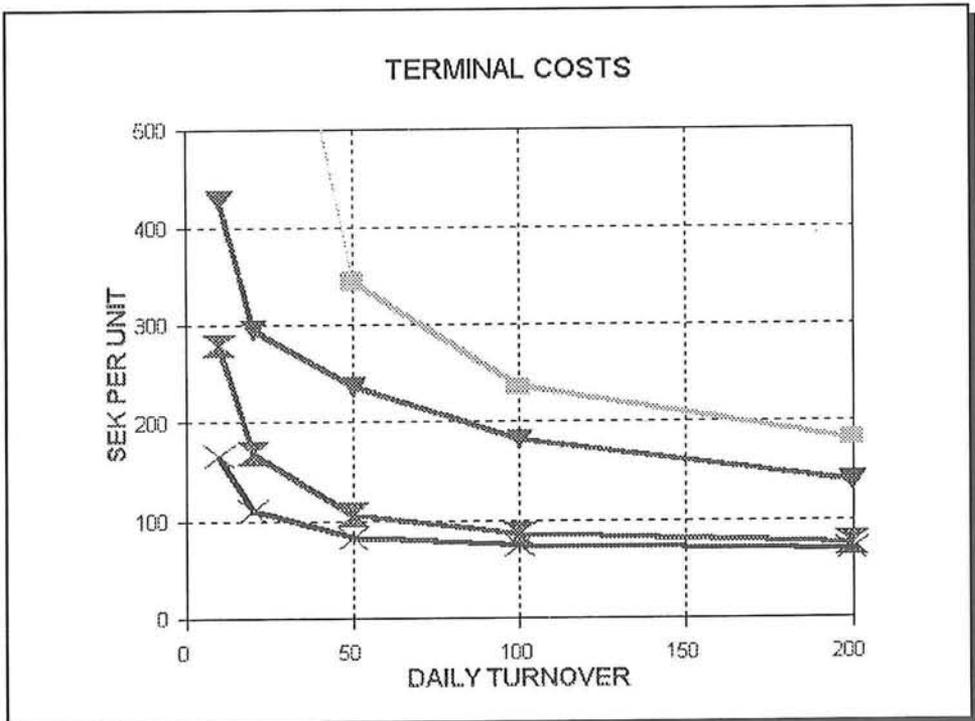


Figure 123: Cost comparison manual and automatic handling

this there is a marginal cost in loss of productivity (lower service level etc). This will give different effects on the total cost depending on the utilization of the total system. If the utilization is at an optimum, the marginal effect of the cost will be many times higher per hour than just the ship's cost as it causes a demand to increase the operating capacity which in total will give lower productivity and efficiency.

There are of course other ways of analyzing the total concept. However, the analysis must not be seen from a pure individual ship's or port operation point of view, which is the most common way of making cost analyses in shipping today. The cost analysis must be made viewing the total logistic chain and the cost for the complete system.

Distribution cost

The total cost includes the cost for transporting the cargo all the way from door to door. In a domestic shipping service we have considered the average distance to the sea terminal to be 50 km. The cost of a multipurpose vehicle suitable for the transport of units is given by one of the trucking companies participating in

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the study. The tariff for the type of vehicle in question is 375 SEK/h and the normal calculated speed for a vehicle in distribution traffic is set to 20 km/h. If half of the transports are considered as return transports the total transported distance will be $1.5 \times 30 \text{ km} = 45 \text{ km}$. The total time consumed will then be $45 \text{ km} / 20 \text{ km/h} = 2.25 \text{ hs}$. The cost for each handled unit will in this case be $2.25 \text{ hs} \times 375 \text{ SEK/h} = 845 \text{ SEK}$, or if the average cargo weight is set to 12 tons the cost per ton equals abt 70 SEK.

As in all other transports savings are obtained by increasing the utilization. The vehicles can be operated in two or three shift systems, thus reducing the total cost as the capital cost of the vehicle can be reduced if the vehicle is utilized extensively.

If the distance for the transport is longer, the average speed of the vehicle will be higher. A pure cost calculation based on the cost per km running vehicle will give a cost reduction to abt half of the above level. This means that the distance is not all that important. The operation will not be further analyzed here but it may be noted that the cost of transport to and from the sea terminal is of vital importance for the total cost level.

TOTAL COST CALCULATION

The ambition of the project is to show whether we can design a logistic system which will meet the demands of transports in such a way that the ship system will be competitive in the future. In the pre-study a total cost calculation was made based on estimates of costs. The capital cost of the ship was estimated to abt 100 MSEK plus the expenses of the extra equipment, in total abt 150 MSEK. The extra equipment is first of all the SCR cleaning equipment reducing the exhaust NOx emissions to 5 % of normal plus the handling equipment.

The yards estimating the cost of the vessel calculated the handling devices inside of the ship to abt 10 MSEK which we consider to be a fair figure. The sideport system was calculated to abt 14 MSEK and other sophisticating features to abt 10 MSEK.

We can see that the major part of the cost calculation is still valid although it has to be upgraded with new quotations. As per above we have calculated the ship's construction cost to 160 MSEK and added 5% of that value for financing during construction.

The time in terminal and terminal cost have also been optimized making the total productivity somewhat higher than expected in the first calculation. The total cost level is still valid and the speed is optimized for the lowest cost. Still, in the result of the calculation the cost does not turn upwards after 17 knots (**Figure 124**). There are two reasons for this. The first is that we have now put in the investment as fixed per ship (not dependent on the speed). The second is that

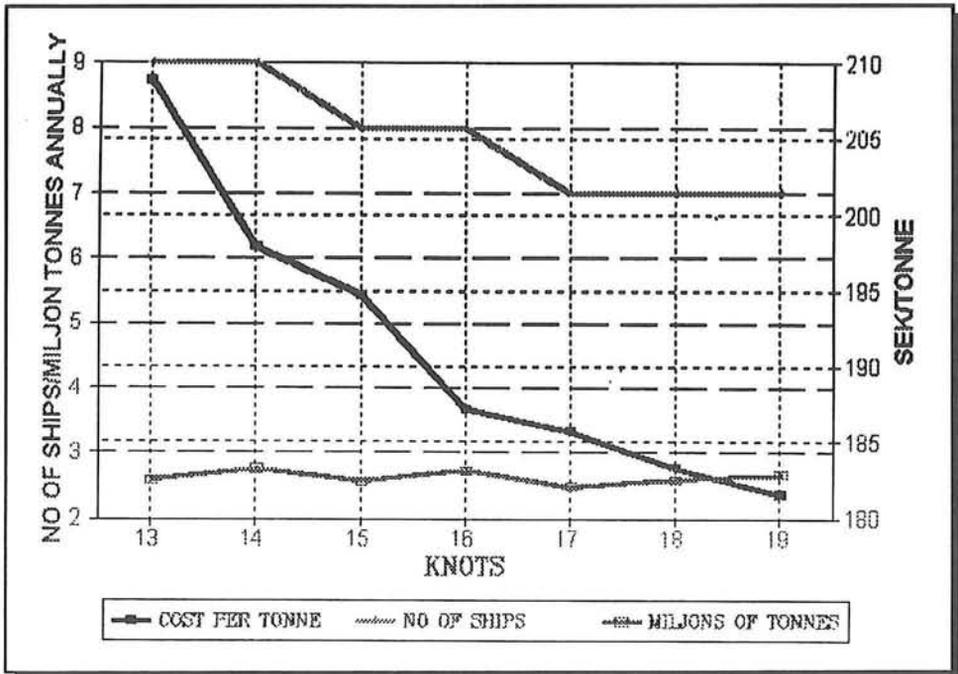


Figure 124: Cost as a function of speed

the transport system changes from 8 to 7 ships if the speed increases due to higher productivity.

It should be noted that this result is given for 7 calls in each direction per week in every port. It represents the cost from Luleå to Sassnitz (Figure 125) which is a distance of 1,045 NM. The shipping system includes 14 ports.

The total cost is to be considered as very low and in the region of what a normal FIO shipment would cost for forest industry products at this distance. In this case we have included the costs of the terminals and the handling in the terminals.

The capital cost of the terminals is taken as the expected size of each installation. The ship's call to the port is also based on the expected turnover in each port. In the calculation each port is called during the round trip.

The calculation shown is also based on a utilization of 60 % of the system. In one respect this figure may look high. On the other hand there are a number of transports in the coastal shipments giving tons in part shipments. This will add the turnover rate in tons, giving a cost effect taken into account of in the total capacity.

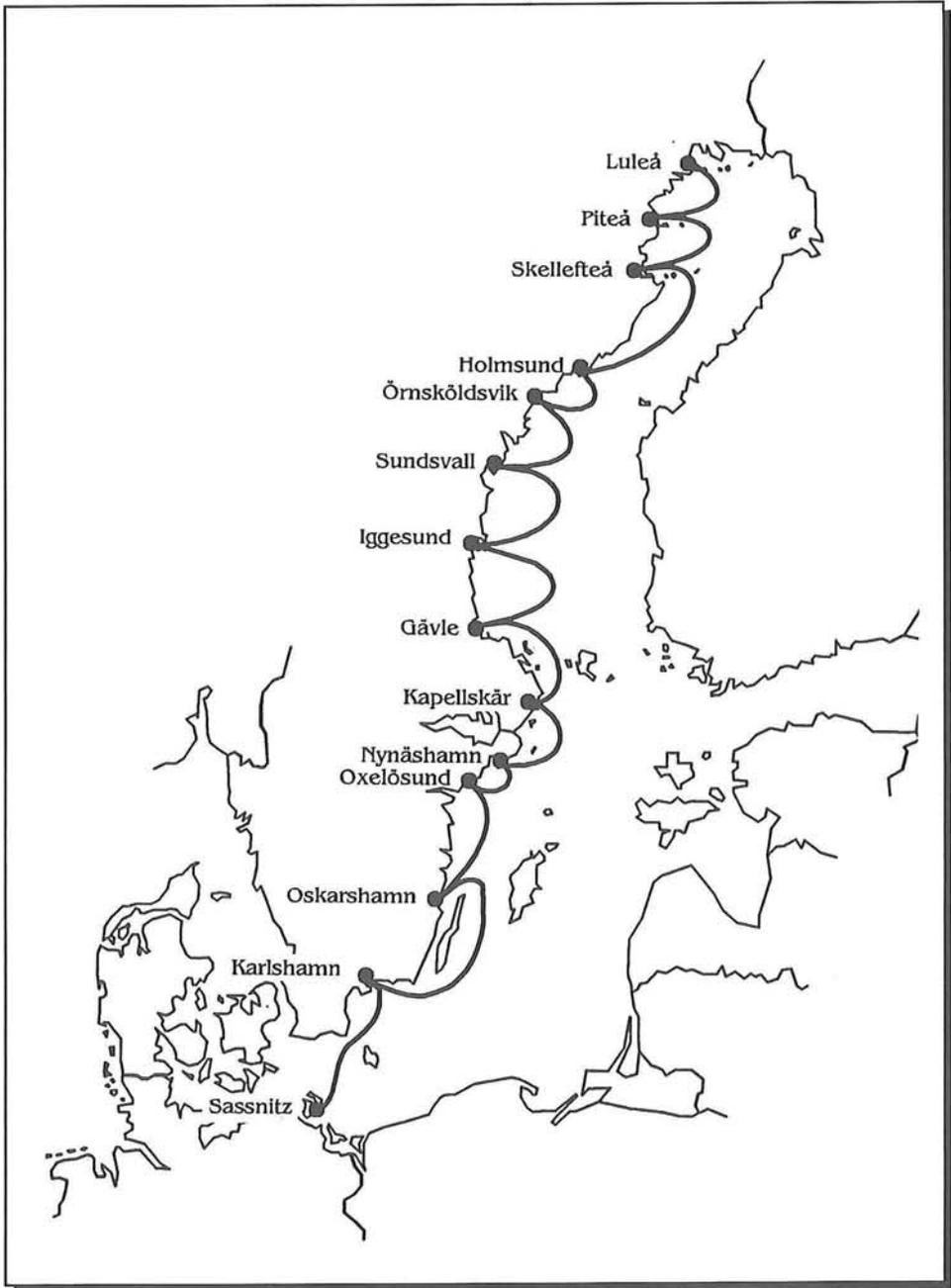


Figure 125

We regard the total cost level as very low and about half of the total cost for a similar shipping system. The level is probably half of the cost for a rail transport and 25% of a road transport on a semitrailer.

The cost distribution is given in Figure 126 and in this figure we find that the major cost element is the ship's cost. In the graph the cost of the load carrier has been included. The relation between the costs gives a better proportion in relation to the transport work than what is normal in a sea transport system. The small part of port duties depends on the fact that all the investments in the port are included in the shipping system. The port fee is set as 2.50 SEK/ton and should cover the infrastructural cost for the port operation. Further analysis of the coverage of port cost for the system has not been made in this study.

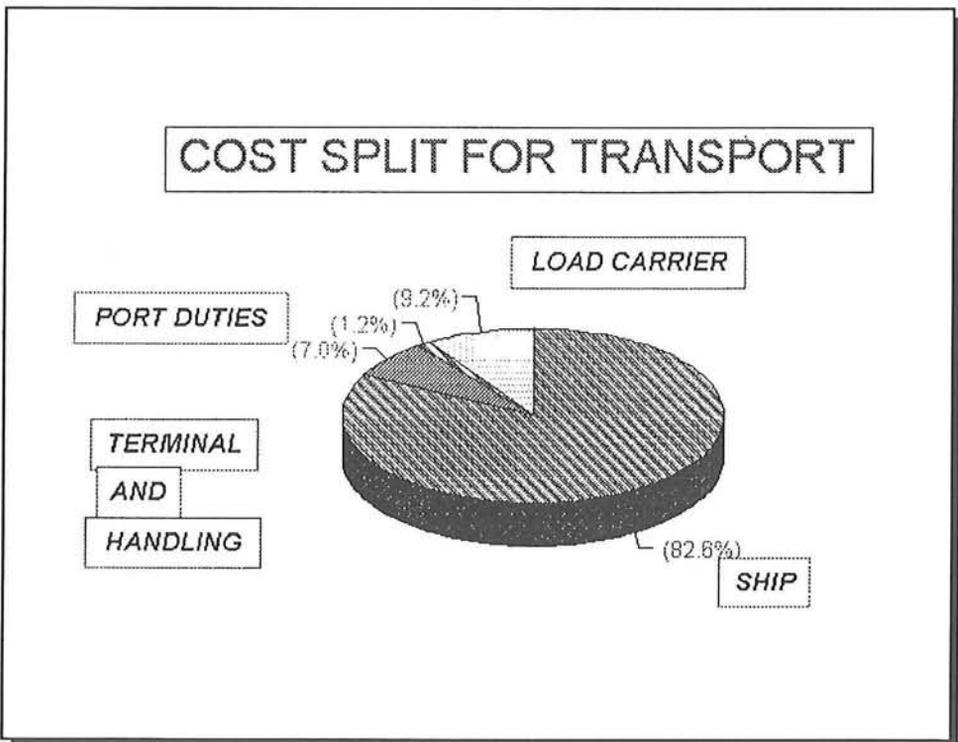


Figure 126: Cost distribution for the shipping system

Another cost factor is also missing in the total cost figure, i.e. the administration cost for controlling the cargo by means of booking and other information systems for the cargo software service. The hardware in the form of the computers in the terminal and onboard the vessels is included as well as the software

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onboard the ship. The central administrative computer and software system have not been included, nor have commissions for the brokers. However, the cost of this can be estimated to about 2% of the cost per ton.

For calculation purposes we have chosen to calculate a 7 day per week service. This will give a two way cargo capacity of about 2 475 000 tons annually. We have estimated this to be the volume of domestic cargo shipped between the Baltic sea districts in Sweden. Still we know that the major volumes of cargo are made up by the cargoes shipped between Sweden and the continent.

A cost analysis should also include the transport service from the sea terminal to the shipper/consignee in domestic transports. According to above this will give a cost of 2 x 70 SEK/ton. The total amount will be added to FIO 111 + Terminal 29 + Port 5 + Land transport 140 SEK/ton totally 285 SEK/ton from door to door for a transport of 1 000 km based on 60% utilization of the shipping system. This corresponds to a total cost of 0.28 SEK/tonkm. This cost is within the region of what a bulk transport by rail will sum up to if the railway could perform a door-to-door transport.

ENVIRONMENT AND ENERGY

The ship has been designed and equipped to secure an environment-friendly operation. All known technology to minimise the impact on the environment from the ship and consequently its costs have been considered in the ship operation.

It is necessary to distinguish between costs for environment-friendly operation and fees for environmental impact. Today there are no fees for pollution. This means that there are no actual environmental costs for a "normal" type of operation. A number of ship owners, especially ferry operators, have voluntarily tried to minimise the pollution. The primary objective is to reduce air emissions contributing to acidification. The most common way to do this is to run the ships on a fuel with a low content of sulphur. The cost for the different qualities varies in time and between the qualities. Figure 127 shows the current cost situation for different fuel oils. The cost varies in time independently between the qualities. In this report we consider the environmental cost as the additional cost for a more environment-friendly operation compared to "normal" operation.

The environmental costs for the operation presented in this report can be divided into the following parts:

- * capital costs for investments in equipment onboard the vessel for the reduction of pollution
- * running costs for the consumption of additives in the operation to reduce pollution

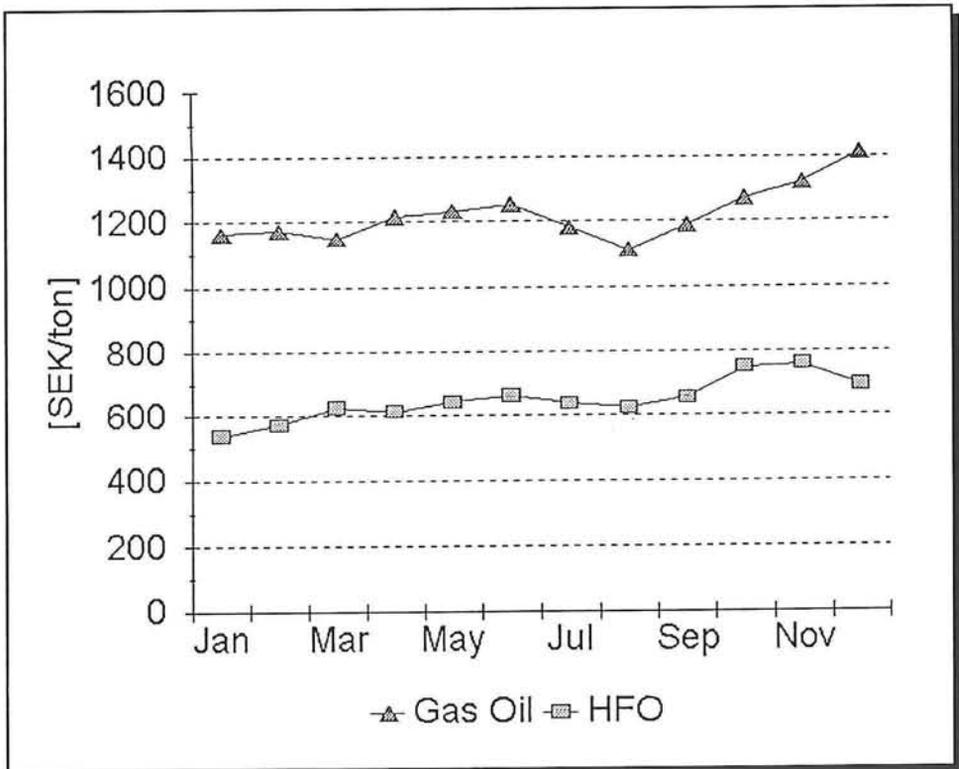


Figure 127: Current cost situation January 1993 for fuels of different sulphur content

- * running and maintenance cost for the running of the extra equipment for reduction of pollution
- * extra cost for using special quality fuel to reduce the pollution

If there would have been environmental fees or other duties, we would have considered them as costs. But as for the situation of today we can only compare the different types of operation in the view of a discussed level of fees.

Nitrogen oxides (NO_x)

There are no actual environmental fees fixed to ships' exhaust emissions, nor are there any proposals for fees. IMO (International Maritime Organization) has set up a goal of reducing the NO_x by 30% for the ship transports before year 2000. In order to achieve this goal there will probably be some kind of legislation on ship emissions which will involve some kind of duties. We have used the

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fee for the NO_x emissions on stationary land-based installations as a guideline. The fee of 40 SEK/kg is to be paid for every kg of NO_x let out to the air.

To reduce NO_x emissions an SCR catalyst is installed. In order to fulfill the IMO goal less sophisticated methods can be used. One example is to inject water into the cylinders together with the fuel.

For this ship the cost deriving from an environmental fee on remaining NO_x emissions would be 1,7 SEK/ton (calculated at 80 % utilization) transported cargo for a transport from Luleå to Sassnitz. This can be compared to 44 SEK/ton without reduction.

The fixed cost for the SCR exhaust cleaning equipment is about 6.90 SEK/ton transported cargo. On top of that comes the cost for urea consumption, which is estimated to 1.00 SEK/ton.

A lower ambition level regarding NO_x emissions, as can be achieved with an emission optimized engine without SCR, would result in an environmental cost of 29 SEK/ton.

Sulphur

Sulphur emissions depend on the sulphur content in the fuel. Low sulphur fuel oils are more expensive than oils with high sulphur content and fuel oil prices also vary a lot which is commonly known (Figure 128)

As these ships are to have an SCR catalyst installed it is necessary, not only from a strict environmental point of view, but also for the operation of the SCR, that a high quality fuel oil with low sulphur content is used.

These ships are therefore to use fuel oils with a sulphur content not exceeding 0.1 percent.

The previous diagrams display price variations for an oil with low sulphur content and for a heavy fuel oil with higher sulphur content.

Greenhouse gases (CO₂)

The emission of greenhouse gases is a topical subject, especially in the view of closing down the nuclear power plants. The fact, as concerns these gases, is that it is strictly related to the energy consumption. Low energy per transported ton goods gives low emission of greenhouse gases. The transport sector will be given priority in using the fossil fuels as these are the most powerful energy sources per weight carried energy. The target will thus be to optimise the energy utilisation.

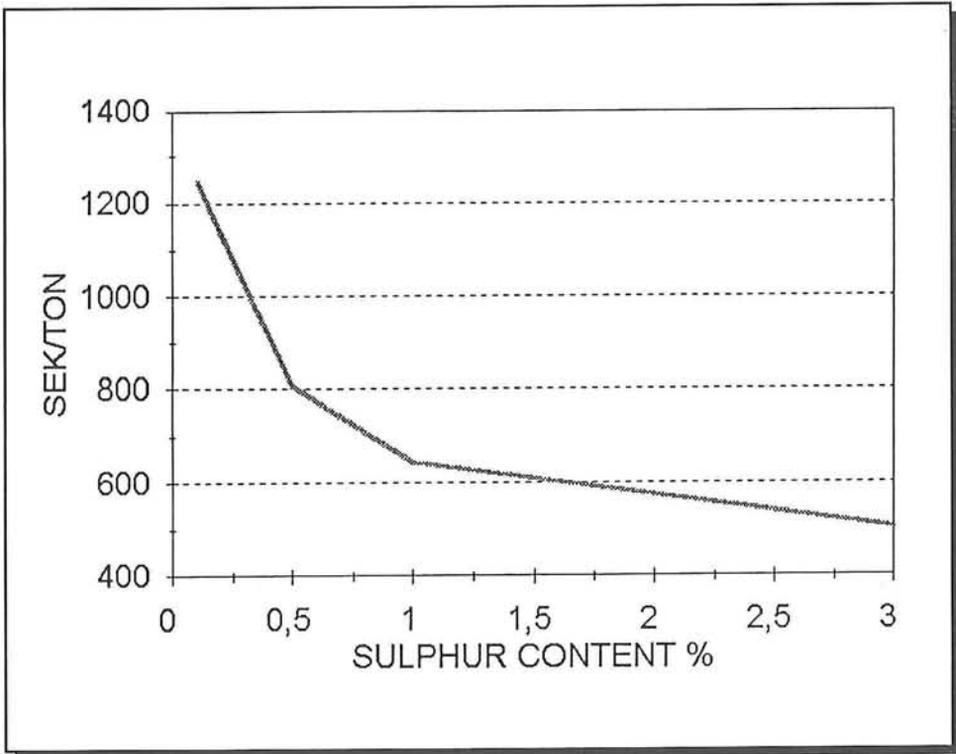


Figure 128: The cost level for fuels of different sulphur content in early 1993

Energy consumption

Low energy consumption is a key to an environment-friendly operation. The usual way to measure and compare energy consumption is to find the energy used per transported ton and km. Among others, the load factor for this is of significant importance.

The energy equivalent for one ship varies between 0.06 and 0.08 kWh/tonkm with load factors spanning from 80 to 60 percent. For train transports, the average primary energy equivalent is about 0,13 kWh/tonkm and for transports by truck it varies between 0,14 and 0,19 kWh/tonk (Figure 129). Transferring goods from land transports will consequently lead to less impact on the environment.

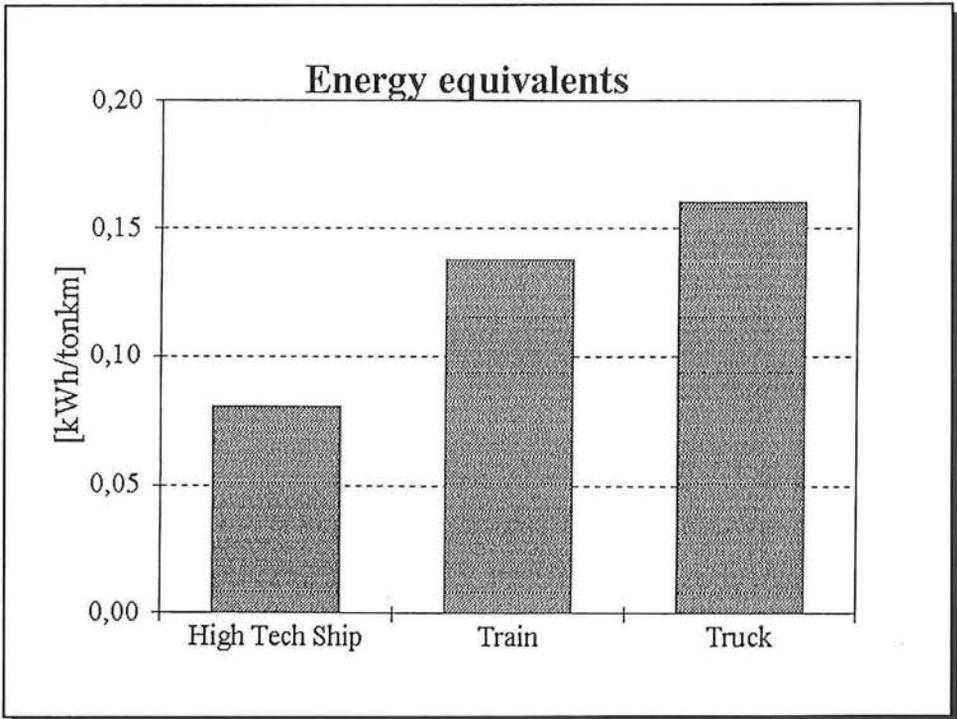


Figure 129: Energy equivalents for different means of transportation

SUMMARY AND CONCLUSIONS

The technical study and design of the vessel and transport system have confirmed that it is feasible to design and construct a High Tech shipping system that will give very low total transportation costs. The key to this is a fast handling operation and low terminal costs. The ship's cost, and especially the daily cost, is very high in comparison to existing ships. The daily cost is about twice as high as an ordinary box-shaped, comparatively new vessel of the same cargo capacity. The cost per tonkm will be higher but due to the very high productivity the total cost will be kept down.

However, the major cost benefit is gained from the low cost handling in the terminals and the fast turnaround of the vessel in the terminal.

The design work and the number of suppliers of equipment shows that this is not science fiction but reality.

The major problem of creating a shipping system is probably the scale factor of the total system. This will be the future problem for the society in order to

optimise the resources of transportation. The problem does not only concern the shipping service but also other transport services. For rail and road this has been overcome by the natural step from the society to supply the infrastructure. This demand for infrastructure seems to be without any limitations, a fact which has been very obvious on the continent where the road and rail transports have grown out of control and caused what has been called traffic infarctus.

Within the EC this has been noted and measures have been taken to develop ships' systems to relieve the land transports.

When infrastructural investments are to be made it should be natural to investigate possible alternative solutions of transport investments. This will be done in the EC in future. The calculation shows that for an investment of 1.54 billion SEK a daily shipping service for cargo can be acquired along the Swedish east coast with a capacity of 2,47 million annual tons. The shipping system will have a cost level that can be compared to transport costs for large quantities of staple products shipped in bulk.

It is interesting to see what the total cost for a ships system, giving daily calls in each direction to a large port system along the Swedish East coast, will be.

The ship's daily cost is 84 400 SEK. Seven ships and 365 days a year gives a total of 216 million SEK. If bunker, terminals and port duties are added the corresponding total annual cost to operate a complete system would be 314 million SEK, which is very low compared to any other transport mode.

CHAPTER 17: TRAINLOADER

The goal of this economic evaluation is not to present one optimum roundtrip configuration but to develop insight in the effects of changes in the transit time, number of ports and ship sizes. For reference purposes a box rate for a north south transport has been determined. A box rate index has been set up in order to compare the various configurations with one standard configuration which has been adopted as a calculation example.

BOX RATE AS REFERENCE FIGURE

This economic evaluation of the trainloader ship configurations is meant as a 'decision making' tool. It is expressly stated that the obtained cost indications should not be considered to be the true cost.

To satisfy the need for a reference figure a cost indicator has been developed and each roundtrip configuration has been extended with information concerning cost aspects and with a box rate reflecting the port to port costs for a north to south transport.

The box rate in US\$/box consists of:

- * Sea Leg Cost, the cost involved with transporting a box terminal to terminal
- * Terminal Handling Cost, the cost involved with transporting the box from the land transport mode onto the Multiple Box Unit and vice versa
- * Land Transport Cost, the cost involved bringing the boxes from the shipper to the terminal and from the terminal to the receiver,

Land transport cost

The land transport cost depends on:

- * Mode of land transport, truck or train
- * Length of land transport leg

It is not the aim of this study to produce exact figures on the additional hinterland transport cost which are always involved with sea transportation systems. An example will be given of the cost equivalent distance land transport can cover when compared to respectively the port to port and the terminal to terminal box rates of a sea transport by the shuttle service.

Terminal handling cost

The kind of terminals which will be used by the shuttle service are different from present terminal types in a way that the terminal is part of a total transport system. This means that the cargo handling costs of a box on a new terminal are included in the total system costs. Therefore the tariffs set by traditional terminal operators can not be used as reference figures when the terminal to terminal rates are determined for a transport.

Calculating the true handling cost of a box on an automated MBU terminal, is not the aim of this study. For comparison purposes the costs of a terminal move will be estimated. In order to keep the box rate as accurate as possible, the terminal handling cost are left out the calculation and only a port to port box rate will be given.

Sea leg cost

The sea transport cost depends of the configuration of the service. The running cost and the voyage cost are mainly determined by the number of ships, the ship size and the sailing speed. Calling interval, number of ports, port to port transit time (on a complete North South transport) and box capacity of the ships provide sufficient information to define a configuration.

SEA LEG COST CALCULATION

Running cost

The indication of the running cost is based on time charter rates. The time charter rates are chosen as bases of the running cost because these rates incorporate all uncertain cost factors like crew costs, interest rates, depreciation, maintenance etc.

The time charter rates include:

- * Capital Cost, depending of price of the ship, interest rate and depreciation period
- * Operating cost, consisting of the following cost factors: crew, insurance, administration, repair, maintenance, stores and lubricants

Figure 130, shows the time charter rates from 1983 to 1992 for cellular containerships.

The time charter rates in **Table XLIII** can be obtained from this figure.

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Box Capacity	Rate US\$/TEU	Rate US\$/Ship
250	22	5500
300	20	6000
350	18	6300
400	16	6400

Table XLIII

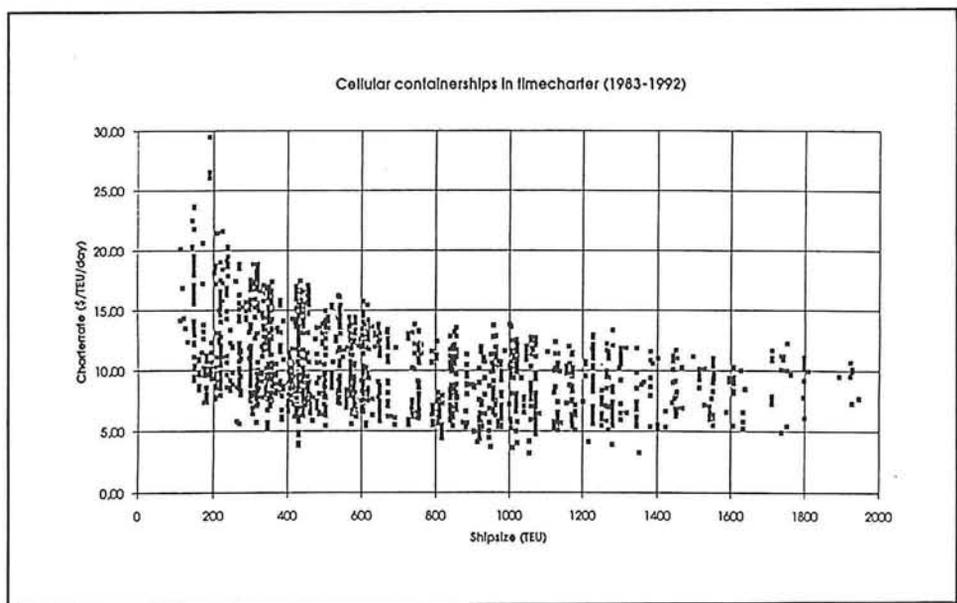


Figure 130: Time Charter Rates (1983/1992)

The figure clearly shows the effects of economies of scale. Small vessels are relatively expensive which can be related to the declining growth of the time charter rates by increasing TEU capacities.

The time charter rates, which are used in the box rate calculation, are chosen in the upper part of the graph, which stands for the high time charter rates, anticipating the fact that the shuttle ship needs ice-class. From a practical point of view it is safe to avoid being too optimistic about the time charter rates especi-

ally when these figures are used in comparison calculations with other transport modes. The use of the TEU capacity of a container ship as a reference figure for the BOX capacity of a train loader vessel is based on the idea that the deadweight of both vessels will be the same despite the fact that a train loader vessel will be larger in terms of loading space volume. The unit cargo of train loader consists of a mixture of 20 foot containers and the longer C715 STL swapbodies. However, the average weight of both units equals 12,5 tons when loaded.

Voyage cost

The voyage cost mainly consist of fuel cost. Cost factors like pilotage and towage are not taken into account.

Mooring of the ship does not require assistance from tug boats or from shore because of the excellent manoeuvrability of the ship, spud-pole and shore based mooring facility.

The fuel cost are directly related to the fuel consumption of the ships. The fuel consumption of a ship is considered to be dependent on two parameters:

- * sailing speed
- * ship size

Sailing Speed

The relationship between speed and fuel consumption is shown in **Figure 131**. The mathematical relationship can be expressed as follows:

$$\text{Fuel Consumption} = C_1 * \text{Speed}^3$$

Ship Size

The relationship between ship size and the fuel consumption is shown in **Figure 132**. In the deadweight class up to 10000 tons these relations show linear behaviour which justifies the following linearized mathematical expression:

$$\text{Fuel Consumption} = C_2 * \text{Ship Size}$$

Part V: Feasibility of the Concepts

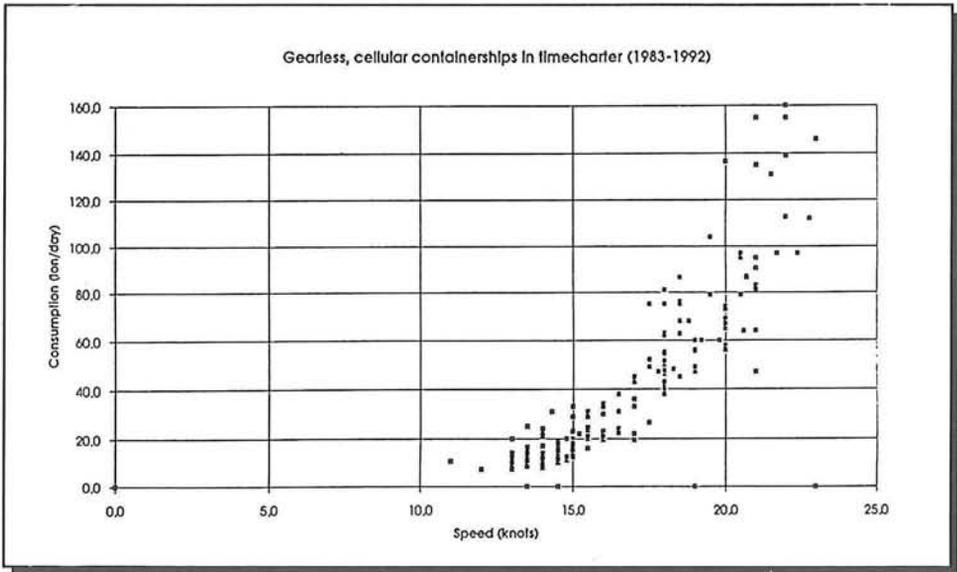


Figure 131: Relationship between Fuel Consumption and Speed

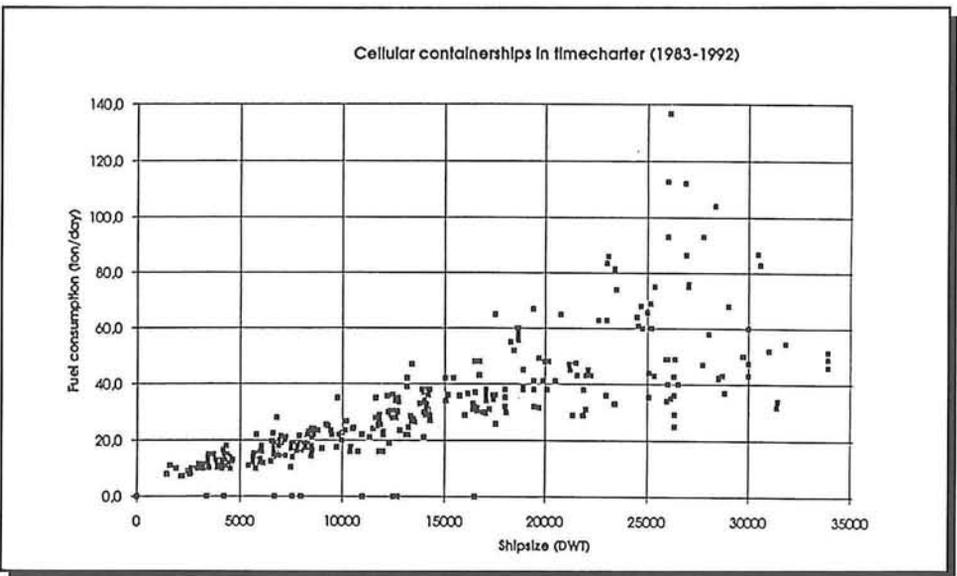


Figure 132: Relationship between Fuel Consumption and Shipsize

Regression Analysis

The fuel consumption can be expressed as follows:

$$Fuel\ Consumption = X_1 * Speed^3 + X_2 * Ship\ Size$$

If the two coefficients, mentioned in the formula above are known, the fuel consumption can be calculated.

A database containing a total of 837 time charter fixtures provides figures on the fuel consumption at the TEU capacity (ranging from 113 to 486 TEU) and at the deadweight of the ships.

With these fixtures it is possible to perform a regression analysis in order to calculate the coefficients X_1 and X_2 .

<i>Regression Statistics</i>			
Multiple R	0,718898349		
R Square	0,516814837		
Adjusted R Square	0,515038567		
Standard Error	3,499892315		
Observations	837		
<i>Analysis of Variance</i>			
	<i>df</i>	<i>Sum of Squares</i>	<i>Mean Square</i>
Regression	2	10939,9975	5469,998748
Residual	835	10228,12059	12,24924622
Total	837	21168,11809	
<i>Coefficients</i>			
		<i>Standard Error</i>	<i>t Statistic</i>
Intercept	0	#N/A	#N/A
x1	0,003215374	0,000110951	28,98004627
x2	0,000775095	5,50306E-05	14,08481404

Table XLIV: Results Regression Analysis

The results of this analysis are given in Table XLIV and correspond with the following values of the required coefficients:

* $X_1 = 0.003215374$

* $X_2 = 0.000775095$

Part V: Feasibility of the Concepts

Standard Error Test:

If the standard error is smaller than half the numerical value of the parameter estimate then the estimate is statistically significant. Table XLIV shows that both coefficients are highly significant.

The fuel consumption can now be calculated for the several ship sizes and sailing speeds.

The fuel cost are based on a fuel price of 85 US\$/ton.

USING THE BOX RATE AS REFERENCE FIGURE

General remarks

After the scenario selection process presented in a previous chapter, there remained 42 configurations which will be evaluated on their economic merits. The projected box rates will be used as reference figure in order to describe the effects of changes in port to port transit time, number of ships, number of ports and ship sizes. The figures are provisional and at this stage they should not be considered to be the true costs.

Daily sailings and servicing 10 ports with a 300 BOX ship which can cover the north south distance in three days has been used as a reference configuration. This configuration will also be used as an example of the final roundtrip calculations.

In Table XLV the results of the box rate calculation are shown. Not only the box rate in \$/tonmile is calculated but also the North-South rate in \$/box.

The North-South rate provides a better indication of the competitiveness and the tariffs than the box rate based on miles. The total sailing distance depends on how many ports are called at.

All configurations have a box rate index figure which shows their cost level relative to the reference configuration.

INTERPRETATION OF RESULTS

Sailing Speed

The example of a final roundtrip calculation which is discussed hereafter, explains the reduction in ship's speed which will occur in most cases when final calculations are made. These final calculations do no longer use the average handling time of 45 seconds per box but they refer to the actual total handling time, which are based on the actual numbers of boxes which are handled in each port. This speed reduction has an influence on the final box rate.

In this chapter the box rate indication will be used for reference purposes only.

Number Ports	Calling Pattern	Box Capacity	Market Share	Perform % 10e7/box	Port to Port Time	Average Time	Speed	Number Ships	Sailing Time	Time Charter	Fuel Cost	Total Cost	Time Charter	Fuel Cost	Sea Port Cost	Box Rate	N-S Rate	Index
6	24	250	24.8	7.32	2	45	25.7	4	19.11	5500	3992	9492	22000	15968	37968	0.187	157.0	100.5
7	24	250	25.0	7.28	2	45	26.7	4	19.00	5500	4414	9914	22000	17657	39657	0.196	165.1	105.7
8	24	250	24.0	8.02	2	45	28.2	4	18.66	5500	5056	10556	22000	20226	42226	0.190	165.5	105.9
9	24	250	24.8	7.32	2.5	45	18.8	5	20.09	5500	1833	7333	27500	9167	36667	0.180	151.7	97.0
10	24	250	25.0	7.28	2.5	45	20.3	5	20.03	5500	1952	7452	27500	9759	37259	0.184	155.1	99.3
11	24	250	24.0	8.02	2.5	45	21.6	5	19.57	5500	2169	7669	27500	10847	38347	0.172	150.3	96.1
12	24	250	23.4	8.35	2.5	45	22.5	5	18.73	5500	2473	7973	27500	12366	39866	0.172	156.8	100.3
13	24	250	23.4	8.06	2.5	45	23.7	5	18.75	5500	2724	8224	27500	14122	41122	0.184	170.1	108.8
14	24	250	23.4	8.22	2.5	45	24.9	5	18.39	5500	3075	8575	27500	15375	42875	0.191	182.1	116.5
15	24	250	23.4	8.33	2.5	45	26.0	5	17.94	5500	3466	8966	27500	17330	44830	0.196	191.6	122.6
16	24	250	23.4	8.34	2.5	45	27.0	5	17.85	5500	3870	9370	27500	19349	46849	0.202	211.3	128.8
17	24	250	24.8	7.28	3	45	14.8	6	20.77	5500	1091	6591	33000	21406	48906	0.211	212.0	135.6
18	24	250	25.0	7.28	3	45	15.1	6	20.73	5500	1136	6636	33000	6815	39815	0.197	165.8	106.1
19	24	250	24.0	8.02	3	45	15.9	6	20.13	5500	1235	6735	33000	7411	40411	0.181	158.4	101.3
20	24	250	23.4	8.35	3	45	16.8	6	19.42	5500	1348	6858	33000	8149	41149	0.177	161.8	103.5
21	24	250	23.4	8.06	3	45	17.4	6	19.28	5500	1457	6957	33000	8741	41741	0.186	172.6	110.5
22	24	250	23.4	8.07	3	45	18.2	6	18.90	5500	1592	7092	33000	9553	42553	0.190	180.7	115.6
23	24	250	23.4	8.22	3	45	19.1	6	18.51	5500	1757	7257	33000	10543	43543	0.191	186.1	119.1
24	24	250	23.4	8.33	3	45	19.8	6	18.32	5500	1905	7405	33000	11432	44432	0.192	190.9	122.1
25	24	300	29.7	8.79	2	45	20.4	4	18.10	6000	2048	7548	33000	12287	45287	0.195	196.3	125.6
26	24	300	30.0	8.73	2	45	21.4	4	18.06	6000	5010	11010	24000	18159	42159	0.173	145.2	92.9
27	24	300	28.8	9.63	2	45	28.4	4	17.77	6000	5748	11758	24000	20040	44040	0.182	152.9	97.3
28	24	300	28.8	9.63	2.5	45	30.0	4	17.77	6000	5748	11758	24000	20040	44040	0.176	153.9	98.2
29	24	300	29.7	8.79	2.5	45	19.7	5	19.28	6000	1999	7999	30000	6992	39992	0.164	137.7	88.1
30	24	300	30.0	8.73	2.5	45	20.2	5	19.23	6000	2127	8127	30000	10655	40655	0.168	141.1	90.3
31	24	300	28.8	9.63	2.5	45	21.3	5	18.79	6000	2360	8360	30000	11901	41901	0.157	138.7	87.5
32	24	300	28.0	10.00	2.5	45	22.6	5	18.28	6000	2707	8707	30000	13536	43536	0.157	142.9	91.5
33	24	300	28.0	9.67	2.5	45	23.5	5	18.11	6000	2978	8978	30000	14990	44990	0.167	154.8	99.0
34	24	300	28.0	9.69	2.5	45	24.8	5	17.76	6000	3381	9381	30000	16903	46903	0.174	165.9	106.1
35	24	300	28.0	9.87	2.5	45	26.1	5	17.49	6000	3831	9831	30000	19157	49157	0.179	175.0	112.0
36	24	300	28.0	10.00	2.5	45	27.3	5	17.32	6000	4301	10301	30000	21506	51506	0.185	184.3	117.9
37	24	300	28.0	10.00	2.5	45	28.4	5	17.25	6000	4785	10785	30000	23924	53924	0.194	194.9	124.7
38	24	300	29.7	8.79	3	45	15.4	6	20.04	6000	1166	7166	36000	6997	42997	0.176	148.1	94.8
39	24	300	28.8	9.63	3	45	16.5	6	20.02	6000	1215	7215	36000	7289	43289	0.179	150.3	96.2
40	24	300	28.0	10.00	3	45	17.4	6	19.49	6000	1451	7321	36000	7924	43924	0.164	143.3	91.7
41	24	300	28.0	10.00	3	45	18.9	6	18.94	6000	1451	7321	36000	8707	44707	0.161	146.8	93.9
42	24	300	28.0	9.67	3	45	18.0	6	18.74	6000	1556	7556	36000	9335	45335	0.169	156.3	100.0
43	24	300	28.0	9.69	3	45	18.9	6	18.33	6000	1714	7714	36000	10283	46283	0.172	163.7	104.7
44	24	300	28.0	9.87	3	45	19.8	6	17.99	6000	1889	7889	36000	11335	47335	0.173	168.5	107.8
45	24	300	28.0	10.00	3	45	20.5	6	17.84	6000	2047	8047	36000	12260	48260	0.174	172.8	110.5
46	24	300	28.0	10.00	3	45	21.2	6	17.72	6000	2217	8217	36000	13304	49304	0.177	178.2	114.0

Table XLV: Box Rate Calculation

Cost Level

Looking at the provisional figures the competitiveness of sea transport clearly shows. Even if the final figures end up being higher than those presented in **Table XLV** transportation by the shuttle will be very attractive in terms of transport costs, on a port to port basis.

The savings which can be achieved by having a sea transportation system taking care of the long distance transport work will leave enough budget to allow for the additional terminal handlings, the hinterland transport and various other costs.

Number of Ships

Short transit times require high sailing speeds. At a transit time of just 2 days 8 ports or less can be serviced if speeds are kept within reasonable limits. Although the required sailing speeds as projected in **Table XLV** exceed the natural hull length speed barrier of 25 knots, for displacement ships with a waterline length less than 150 meters, these solutions are mentioned here to show that despite the high voyage costs per ship the total system costs are still acceptable because of the fact that there are less ships in operation. When a limited number of ports is serviced the actual number of boxes in each port will be relatively high, which means that in the final round trip calculations the required sailing speed will indeed end up in the 25 knots range.

In case of the reference configuration, reducing the transit time from three days to 2½ days, on a North South port to port basis, results in an increase in speed and higher voyage costs per ship. The costs increase, however, is entirely compensated by the fact that only 5 vessels are required instead of 6. One ship less results in a remarkable reduction of the total running costs of the system. The index figure even drops 1 point. The downside is that less ports can be serviced, high sailing speeds are environmental unfriendly due to increased exhaust emission levels and sailing schedules themselves become very tight, which means that short delays can hardly be compensated for.

Number of Ports

In **Figure 133** the N-S rates are shown at different numbers of ports. The higher N-S rates for increasing numbers of ports can clearly be noticed.

Market research should indicate what the trade off will be between higher service level or higher freight rates. However, even if the more expensive configurations, at the maximum number of ports, are chosen, the shuttle transports will still be significantly cheaper than the present land transports.

Calling at one additional port will require more port manoeuvring time and additional sailing distance. Consequently, the required sailing speeds will increase which results in higher transport costs. The index figure increases 4,7 points.

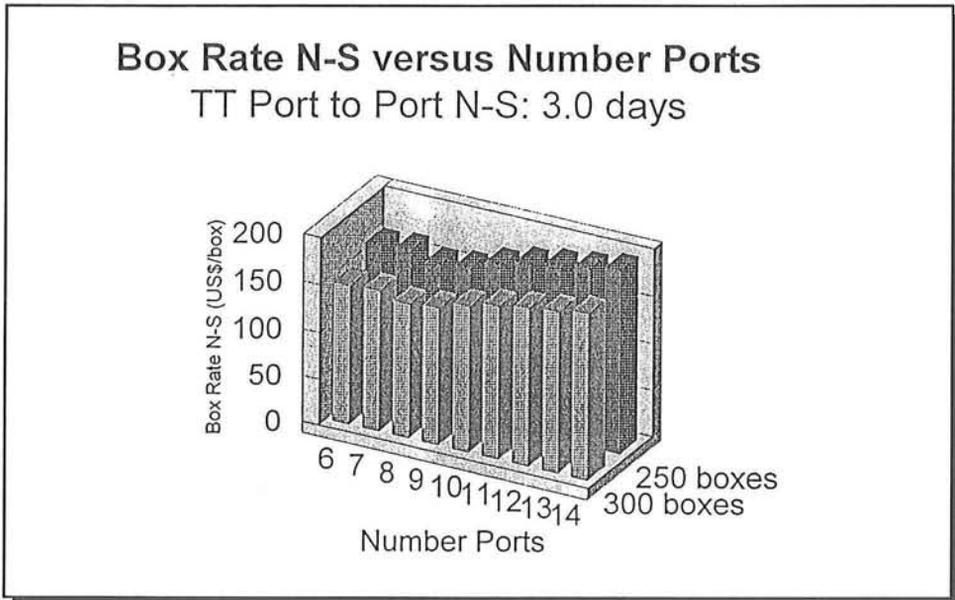


Figure 133: Box Rate N-S versus Number Ports

Economies of Scale

Also the effects of economies of scale appears again in **Figure 133**. The box rate index, **Figure 132**, shows an increase of 10.5 points, when comparing the reference configuration with the corresponding configuration with a smaller box capacity of 250 boxes. The smaller vessels are relatively expensive.

A disadvantage for larger box capacities is that the ships operate at higher sailing speeds. In some cases these ships with larger box capacities can not be used with regards to the natural limitations to the maximum speed of displacement ships referring to the hull length speed barrier at a Froude number of 0,35. At a transit time of 2½ days the 300 box vessels can not service more than 11 ports because at twelve ports or more the increased cargo handling time adds too much to the turnaround time in port leaving too little available sailing time to allow for speeds less than 25 knots.

CRITICAL REMARKS REGARDING COSTS

The projected box rate has been used for reference purposes only. The true costs are hard to quantify and many costs factors which should contribute to an exact cost indication have been left out of the box rate calculation.

The running costs, which are provisionally based on the time charter rates of container vessels, can be significantly higher due to the following reasons:

Part V: Feasibility of the Concepts

- * The shuttle vessels are more complicated than a container vessel because of their internal cargo handling and distribution system. The capital costs as well as the maintenance costs will be relatively high.
- * The systems on board a shuttle vessel require additional power supply.
- * The internal cargo handling and distribution system requires additional crew, despite the fact that the systems have a high degree of automation.
- * The shuttle service calls at many ports which requires additional crew, despite the fact that the ship has excellent manoeuvrability and shore based mooring equipment.
- * Considering the sailing schedule and the short turnaround times it might be necessary to operate with a double crew on board the shuttle ships.

The commercial policy of the shuttle organisation will require a substantial budget especially in the introduction phase.

A successful and quick introduction might require containers and stackable swapbodies which are owned by the shipping line. The boxes can be made available to the shippers by the shuttle equipment management which allows for some means of control with regards to the expensive relocation of empty units. The equipment will represent high capital and maintenance costs. Effective equipment management can be a way to avoid excessive relocation costs.

In the end situation, with sufficient acceptance of the stackable swapbody, the idea of a common carrier might appeal more although the repositioning of empty units can become a problem due to the flow imbalances between north bound and south bound.

INVESTMENT LEVEL

The aim of this project is to study the technical and commercial feasibility of a sea transportation system. At this stage an exact projection on the investment level is very hard to give considering the fact the particulars of the ships and terminals are available in a conceptual stage only.

Estimations can hardly be given because the shuttle vessels and terminals can not be compared to any other existing ship or terminal concepts.

EXAMPLE OF SHUTTLE ROUNDTRIP CALCULATION

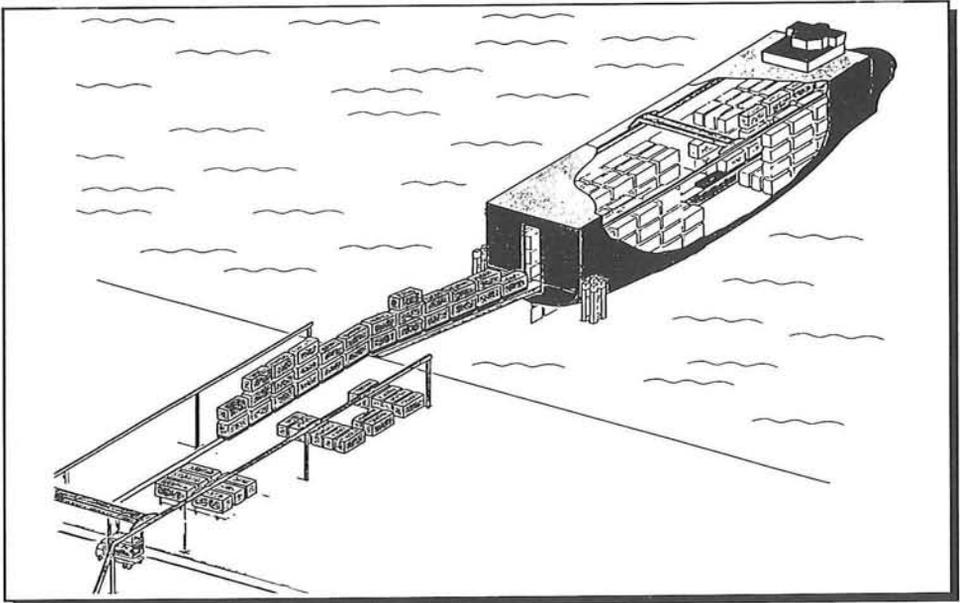


Figure 134: Train loader

Description chosen roundtrip scenario

The following round trip scenario is chosen as an example from the 42 selected scenarios. The reasons why this roundtrip scenario has been chosen as an example can be explained as follows:

- * 10 ports of call gives a proper service to the customer, providing short land transport legs
- * Calling interval of 24 hours provides a uncomplicated daily calling schedule
- * Box capacity of 300 boxes corresponds with a deadweight of approximately 3800 tons ensuring good performance in ice-conditions. Following the economies of scale larger ships are preferable.
- * Port to port time N-S of 3 days makes the shuttle system competitive with land transport
- * Number of ships is a direct result of the calling interval and the port to port time N-S.

ROUNDRIP	DESCRIPTION
Number Ports	10 ports
Calling Interval	24 hours
Box Capacity	300 boxes
Port to Port Time N-S	3 days
Number of Ships	6 ships
Market Share	28 %
Performance	9.67 10^7 boxmiles/year
Required Sailing Speed	18.0 knots
Box Rate N-S	156 US\$

Table XLVI

- * Market share has a linear relationship with the number of ships and the ships size. This configuration has an acceptable marketshare.
- * Required sailing speed depends on the calling interval and the turnaround time in port. Taking the same roundtrip scenario with a calling interval of 2.5 days requires a sailing speed of 23.5 instead of 18 knots.
- * The box rate is determined by the number of ships and the sailing speed. Some scenarios require one ship less at higher sailing speeds. Economically this is feasible but from an environmental point of view it should be discouraged

Actual turnaround time in port

The exact loading and discharging times for each number of boxes has been used to calculate the actual turnaround time in port. With the actual turnaround time in port it is also possible to calculate the actual required sailing speed. Table XLVII shows the calculation of the actual turnaround time in port. The corrected average box handling time is 31.5 seconds. With small amounts of boxes the turnaround in port can be very short as, only one train has to be discharged and loaded.

Part V: Feasibility of the Concepts

NUMBER PORTS	CALLING PATTERN	BOX CAPACITY	MARKET SHARE	PERFORM	PORT TO PORT TIM	NUMBER SHIPS
10	24	300	28.03	9.67	3	6
	hours	boxes	%	10e7*box miles/year	days	

PORTS:	DISTANCE LOADING:			DISCHARGING:			
	miles	%	boxes	time	%	boxes	time
NORTHBOUND:							
YSTAD	0	24.7	74	2242	0.0	0	0
OSKARSHAMN	170	4.4	13	335	2.7	8	335
VISBY	65	69.1	207	10059	1.2	4	335
OXELOSUND	72	22.0	66	1878	16.4	49	1103
NYNASHAMN	22	9.5	29	335	21.4	64	1786
KAPPELSKAR	115	7.9	24	335	44.3	133	5519
VALLVIK	106	5.0	15	335	17.3	52	1239
SUNDSVALL	112	6.1	18	335	8.4	25	335
UMEA	125	7.3	22	335	19.8	59	1559
LULEA	139	0.0	0	0	24.6	74	2238
SOUTHBOUND:							
LULEA	0	40.2	121	4969	0.0	0	0
UMEA	139	11.1	33	335	1.5	5	335
SUNDSVALL	125	2.8	8	335	3.8	11	335
VALLVIK	112	2.9	9	335	4.2	13	335
KAPPELSKAR	106	27.8	83	2652	14.0	42	335
NYNASHAMN	115	26.8	80	2515	12.5	38	335
OXELOSUND	22	14.7	44	335	31.4	94	3740
VISBY	72	10.2	31	335	16.5	50	1149
OSKARSHAMN	65	4.1	12	335	10.4	31	335
YSTAD	170	0.0	0	0	46.2	139	6377
TOTALS:	1852	296.6	890	28335	296.6	890	27725
Average BH Time (seconds):				31.8			31.2

REQUIRED SAILING SPEED CALCULATION:			BOX RATE CALCULATION:	
Total BH Time	15.57 hours		Time Charter Rate	6000.00 US\$/shipday
Port I&O Time	19.00 hours		Fuel Cost	1461.32 US\$/shipday
	+			+
Turnaround Time	34.57 hours		Sea Leg Cost	7461.32 US\$/shipday
Roundtrip Time	144.00 hours		BASS Cost	44767.9 US\$/day
	-			/
Remaining Sailing Time	109.43 hours		Box Rate	0.167 US\$/boxmile
Sailing Distance	1852 miles		North-South Rate	154.3 US\$/box
	/			
Required Sailing Speed	16.55 knots			

Table XLVII: Actual Sailing Speed and Box Rate Calculation

Part V: Feasibility of the Concepts

Actual required sailing speed and box rate

The saving in turnaround time leaves more remaining sailing time. This results in a reduction of required sailing speed from 18.0 knots to 16.55 knots.

The lower sailing speed is followed by a lower fuel consumption. The fuel consumption has an impact on the box rate, so also this figure has to be recalculated. With knowledge about the exact figures for the sailing time the fuel cost can be calculated very accurately (Table XLVII).

THE SHUTTLE SERVICE IN COMPARISON WITH LAND TRANSPORT

Transport rates in US\$

The comparison of the roundtrip scenario against land transport is based on box rates. The box rate in US\$/boxmile is an indication figure which should not be considered to be the true cost.

Before comparison with land transport is possible, a box rate in US\$/boxkm for trucking is needed. It is very difficult to obtain exact figures for trucking so a range of box rates is used to calculate the land transport costs.

Table XLVIII shows the port to port rates for the shuttle and for land transport.

The distance port to port differ for land and sea transport:

- * for the shuttle, the sailing distance between the ports keeping in mind the ports of call configuration
- * for trucking, the road distance port to port

The transport rates which are obtained in this way are principally different. The shuttle rates are port to port only. The hinterland transports of a sea transportation system can be recognized as separate, additional transport legs.

The trucking rates are also calculated port to port. However a truck does not have hinterland transport because it travels directly from shipper to receiver. A ports of call configuration of 10 ports assumes a service area radius for each port of 150 kilometer. The calculated port to port rates are valid for all customers and receivers within the service area radius of the ports. With the given distances the trucks can transport the boxes door to door and when swapbodies are used even floor to floor.

Interpretation of the transport rates

In order to know whether the shuttle is competitive with land transport on the various transport legs the following calculations have been made (Table XLIX):

DISTANCE PORT TO PORT TO BE PERFORMED in MILES:										
	YETAD	DEKARSHAMN	YSBY	OXELOENFJØ	NYNABHAMN	KAPPELBJØR	VALLVÆ	BUNDEVALL	LMEA	LULEÅ
YETAD	0	170	235	307	329	444	550	662	787	926
RATE (PORT TO PORT) in US\$:										
US\$/BOXMILE:										
0.167	0.0	28.3	39.2	51.2	54.8	74.0	91.7	110.3	131.2	154.3
EQUIVALENT DISTANCE TO BE PERFORMED BY LAND TRANSPORT in KM:										
	YETAD	DEKARSHAMN	YSBY	OXELOENFJØ	NYNABHAMN	KAPPELBJØR	VALLVÆ	BUNDEVALL	LMEA	LULEÅ
YETAD	0	334	not possible	583	803	954	1209	1372	1667	1974
LAND TRANSPORT RATE (PORT TO PORT) in US\$:										
US\$/BOXKM:										
0.10	0.0	33.4	not possible	58.3	80.3	95.4	120.9	137.2	166.7	197.4
0.15	0.0	50.1	not possible	87.5	120.5	143.1	181.4	205.8	250.1	296.1
0.20	0.0	66.8	not possible	116.6	160.6	190.8	241.8	274.4	333.4	394.8
0.25	0.0	83.5	not possible	145.8	200.8	238.5	302.3	343.0	416.8	493.5
0.30	0.0	100.2	not possible	174.9	240.9	286.2	362.7	411.6	500.1	592.2
0.35	0.0	116.9	not possible	204.1	281.1	333.9	423.2	480.2	583.5	690.9
0.40	0.0	133.6	not possible	233.2	321.2	381.6	483.6	548.8	666.8	789.6
0.45	0.0	150.3	not possible	262.4	361.4	429.3	544.1	617.4	750.2	888.3
0.50	0.0	167.0	not possible	291.5	401.5	477.0	604.5	686.0	833.5	987.0
0.55	0.0	183.7	not possible	320.7	441.7	524.7	665.0	754.6	916.9	1085.7
0.60	0.0	200.4	not possible	349.8	481.8	572.4	725.4	823.2	1000.2	1184.4
0.65	0.0	217.1	not possible	379.0	522.0	620.1	785.9	891.8	1083.6	1283.1
0.70	0.0	233.8	not possible	408.1	562.1	667.8	846.3	960.4	1166.9	1381.8
0.75	0.0	250.5	not possible	437.3	602.3	715.5	906.8	1029.0	1250.3	1480.5

Table XLVIII: The shuttle in Comparison with Land Transport

Part V: Feasibility of the Concepts

- * Box rates port to port are subtracted from the land transport rates port to port. The difference between these rates corresponds with the amount of money that will be saved when using the shuttle instead of land transport.
- * Taking only the difference between the box rates is not a fair comparison. Landtransport goes door to door whilst the shuttle goes port to port. For better comparison two terminal handlings of 50 US\$/move are included in the box rates. The box rates calculated in this way are the terminal to terminal rates.
- * terminal to terminal box rates still differ from the land transport rates in the transport cost from shippers to the terminal and from the terminal to the receiver. The locations of the shippers and the receivers are hard to quantify in exact distances. At a given landtransport rate, however, reversing the problem will produce a distance which can be covered by land transport. This allows for a radius around each port which can be serviced.

The results of these calculations are given in Table XLIX. It can be seen that even on very short distances the shuttle is competitive with land transport.

A more accurate land transport box rate in US\$/boxkm estimation can be made with the following information:

1.0 US\$/40ft*km (Western Europe trucking price levels), comparable with 0.5 US\$/boxkm, a box is a 20ft container or a C715 swapbody

Considering these truck prices and the indication figures for the BASS box rates, it can be stated that shuttle's door to door prices are highly competitive. After port to port N-S transportation twice a land leg of more than 700 km is feasible.

ROUNDRIP TIME SCHEDULE

The roundtrip time schedules Northbound and Southbound are shown in respective Table LI and LII.

A traveling schedule of a truck (with one driver, two drivers is too expensive) can be estimated with the following information (based on official working hours and road regulations):

- * Maximum allowed driving hours: 9 hours/day
- * Average speed of 75 km/hour. This is valid for empty roads and long distances otherwise the average drops to 60 km/hour
- * Box rate 0.5 US\$/boxkm

TRUCK		TIME		SCHEDULE	
From Ystad to:	Distance km	Driving Time hh:mm:ss	Total Time d:hh:mm:ss	Box Rate US\$/box	
Oskarshamn	334	04:27:12	0:04:27:12	167.0	
Oxelosund	583	07:46:24	0:07:46:24	291.5	
Nynashamn	803	10:42:24	1:01:42:24	401.5	
Kappelskar	954	12:43:12	1:03:43:12	477.0	
Vallvik	1209	16:07:12	1:07:07:12	604.5	
Sundsvall	1372	18:17:36	2:00:17:36	686.0	
Umea	1667	22:13:36	2:04:13:36	833.5	
Lulea	1974	26:19:12	2:08:19:12	987.0	

Table XLIX

Part V: Feasibility of the Concepts

ROUNDRIP TIME SCHEDULE						
NORTHBOUND (10 ports, 24 hours, 300 boxes, 3 days and 6 ships)						
PLACE	TIME				BOX RATE between ports US\$/box	ACTIVITY
	days	hours	minutes	seconds		
Ystad	0	0	0	0	0.0	Entering Port
	0	0	30	0		Start Discharging
	0	0	30	0		Start Loading
	0	1	7	22		Leaving Port
						Sailing to Next Port
Oskarshamn	0	11	53	31	28.3	Entering Port
	0	12	23	31		Start Discharging
	0	12	29	6		Start Loading
	0	12	34	41		Leaving Port
						Sailing to Next Port
Visby	0	17	0	16	10.9	Entering Port
	0	17	30	16		Start Discharging
	0	17	35	51		Start Loading
	0	20	23	30		Leaving Port
						Sailing to Next Port
Oxelosund	1	1	14	28	12.0	Entering Port
	1	1	44	28		Start Discharging
	1	2	2	51		Start Loading
	1	2	34	9		Leaving Port
						Sailing to Next Port
Nynashamn	1	4	23	53	3.6	Entering Port
	1	4	53	53		Start Discharging
	1	5	23	39		Start Loading
	1	5	29	14		Leaving Port
						Sailing to Next Port
Kappelskar	1	12	56	2	19.2	Entering Port
	1	13	26	2		Start Discharging
	1	14	58	1		Start Loading
	1	15	3	36		Leaving Port
						Sailing to Next Port
Vallvik	1	21	57	48	17.7	Entering Port
	1	22	27	48		Start Discharging
	1	22	48	27		Start Loading
	1	22	54	2		Leaving Port
						Sailing to Next Port
Sundsvall	2	6	9	58	18.6	Entering Port
	2	6	39	58		Start Discharging
	2	6	45	33		Start Loading
	2	6	51	8		Leaving Port
						Sailing to Next Port
Umea	2	14	54	11	20.9	Entering Port
	2	15	24	11		Start Discharging
	2	15	50	10		Start Loading
	2	15	55	45		Leaving Port
						Sailing to Next Port
Lulea	3	0	19	32	23.1	Entering Port
	3	0	49	32		Start Discharging
	3	1	26	54		Start Loading
	3	1	26	54		Leaving Port
						Sailing to Next Port
					154.3	RATE S-N

Table L: Roundtrip Time Schedule Northbound

ROUNDRIP TIME SCHEDULE						
SOUTHBOUND (10 ports, 24 hours, 300 boxes, 3 days and 6 ships)						
PLACE	TIME				BOX RATE	ACTIVITY
	days	hours	minutes	seconds	between ports US\$/box	
Lulea	0	0	0	0	0.0	Entering Port
	0	0	30	0		Start Discharging
	0	0	30	0		Start Loading
	0	1	52	49		Leaving Port
						Sailing to Next Port
Umea	0	10	46	37	23.1	Entering Port
	0	11	16	37		Start Discharging
	0	11	22	12		Start Loading
	0	11	27	47		Leaving Port
						Sailing to Next Port
Sundsvall	0	19	30	50	20.9	Entering Port
	0	20	0	50		Start Discharging
	0	20	6	25		Start Loading
	0	20	11	60		Leaving Port
						Sailing to Next Port
Vallvik	1	3	27	56	18.6	Entering Port
	1	3	57	56		Start Discharging
	1	4	3	31		Start Loading
	1	4	9	6		Leaving Port
						Sailing to Next Port
Kappelskar	1	11	3	17	17.7	Entering Port
	1	11	33	17		Start Discharging
	1	11	38	52		Start Loading
	1	12	23	4		Leaving Port
						Sailing to Next Port
Nynashamn	1	19	49	52	19.2	Entering Port
	1	20	19	52		Start Discharging
	1	20	25	27		Start Loading
	1	21	7	22		Leaving Port
						Sailing to Next Port
Oxelosund	1	22	57	7	3.6	Entering Port
	1	23	27	7		Start Discharging
	2	0	29	27		Start Loading
	2	0	35	2		Leaving Port
						Sailing to Next Port
Visby	2	5	25	59	12.0	Entering Port
	2	5	55	59		Start Discharging
	2	6	15	8		Start Loading
	2	6	20	43		Leaving Port
						Sailing to Next Port
Oskarshamn	2	10	46	18	10.9	Entering Port
	2	11	16	18		Start Discharging
	2	11	21	53		Start Loading
	2	11	27	28		Leaving Port
						Sailing to Next Port
Ystad	2	21	43	37	28.3	Entering Port
	2	22	13	37		Start Discharging
	3	0	0	0		Start Loading
	3	0	0	0		Leaving Port
					154.3	RATE N-S

Table LI: Roundtrip Time Schedule Southbound

CHAPTER 18: EVALUATION AND OPPORTUNITIES

REDUCING COMPLEXITY

The previous chapters have drawn up a picture of the complexity of shortsea shipping of unitloads in Europe. A complexity, caused by commercial considerations, such as transittime, frequency of departures, transport-cost, competition from other modes, and the choice of standardized cargo units, such as the maritime containers or the land-based swapbody, softtop and stackable. The operational and technical solutions presented in this book also depend on local conditions, such as the route, number of ports of call, cargo-base/number of units and so on.

There are presently too many variables with "loose-ends", which makes it almost impossible to design a system. Therefore, the first task has to be to reduce the complexity by making clear choices, such as:

- * the cargo unit in the system will be the maritime 20ft container and the soft-top swapbody and/or the stackable swapbody.
- * the route length and number of ports will be such that the transit-time is X hours.

The important answers from the technological side, such as, the ship- and terminal configuration, are dependant, endogenous variables of the system. The same as the financial and economic evaluation. These variables are determined via the assumptions about the exogenous variables, mentioned before.

CREATING A NETWORK

The exogenous and endogenous variables have to be defined by many parties involved in the transportchain, such as the shippers and receivers, the shipowners/operators, the port/terminal operators, the transport/truck operators, the shipdesigners and shipyards, the equipment manufacturers, the shipping inspectorates and labour departments, the national government.

This is a complex task, which is necessary in order to diffuse the concept and to obtain impulses for the detailed design process.

We intend to create a trans-European network, supported by a Newsletter, in which feedback, ideas, developments, progress, research is monitored regularly. We invite interested parties, to make themselves known so they can be involved and become part of the shortsea shipping network for change.

OPPORTUNITIES

We are convinced that shortsea shipping of unitloads to and from small ports along the coastline of Europe can become a competitive system. Its impact may have the same magnitude as that of the introduction of the maritime container, several decades ago.

In order to capitalize on these opportunities, the players have to single out an area of competence, in which they define the requirements and innovations to make it work. There are enough problems to attack, but the challenge is not only problem-solving. It rather is the search for opportunities. And there is hardly anything more exciting to do in the industrial world.

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Delft:
Prof.dr.ir. N. Wijnolst
ir. H.B. van der Hoeven
ir. C.J. Kleijwegt

Gothenburg:
ir. A. Sjöbris

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INNOVATION IN SHORTSEA SHIPPING

The acceptance of the container in the maritime industry is an unparalleled example of high speed innovation adoption by hundreds of different players in many segments of transport.

The perceived attributes of the innovation corresponded and coincided with the tremendous increase in cost around the word of liner shipping and stevedoring. There was no alternative for deepsea liner shipping, as is not the case in shortsea shipping. The alternatives of shortsea shipping are foremostly road and railtransport. As the cost increases in these other modes have been very modest over the last decades, there has not been a strong incentive to change all this.

"Selling" the self-loading and unloading ship concepts of unitloads, which is the central theme of the book, does not have the benefit of spiralling costs, which influence major shippers and receivers. Although this may change in the coming decade, Environmental and social costs will more and more be charged to each mode.

If small ports want to become a part of a coastal/shortsea unitload shipping system, this will not happen by itself. The authors believe that a system can be developed with similar impact as the introduction of the container thirty years ago. The technology can be developed, that is not the issue.

Shortsea shipping can and should compete more effectively against road and rail transport. This can be achieved by looking at the total transport chain and not only the hardware of ships and terminals but also the software of VTS, EDI etcetera.

This book is not about the technology of a selfloading and unloading ship system, but about the constraints and conditions under which shortsea shipping can compete against other modes, on the level of transit time, frequency of departure, quality of service and of course, in price.

Therefore the book is a must for all those involved in the shortsea shipping sector.



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