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Improved Port/Ship Interface
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DG VII Transport
4th Framework Program

IPSI

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Project

Co-ordinator: Hamworthy KSE AB

Partners :

Port and Transport Consultants
SAGA
MARINTEK
Wilson EuroCarriers
Fraunhofer Gesellschaft
SINTEF

NIM/TU Delft

**PROJECT FUNDED BY THE EUROPEAN
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RTD PROGRAMME OF THE
4TH FRAMEWORK PROGRAMME**

PARTNERSHIP DETAILS

Partner	*Role*	*Description of Role*	*Type of Organisation*
HKSE	Co-ordinator	• Technical management • Administrative co-ordination • Leader and participant in the development of cargo handling equipment • Prime exploiter of IPSI results • Visualising the IPSI system	IND
SAGA	Contractor	• Responsible for strategic study • Benchmarking against current alternatives • Input on operational requirements and design of operational scenarios	IND
PTC	Contractor	• Responsible for work package on port organisation • Responsible for work package on demonstrating the port operation • Valuable input on operational and commercial aspects • Benchmarking against current alternatives	IND
MARINTEK	Contractor	• Responsible for vessel development • Responsible for specifying a system for managing logistic chains (used as important input to the Infolog project)	ROR
FhG	Contractor	• Link to important industrial logistics expertise • Participant in simulation exercises • Responsible for developing control strategy for the IPSI terminal and for the AGV's	ROR
SINTEF	Contractor	• Link to important industrial logistics expertise • Responsible for specifying the IPSI information and management system	ROR
JWEC	Contractor	• Interface to relevant ship design and ship operation expertise. • Evaluating cost estimates	IND
DELFT	Subcontractor	• Leader and main performer in the development of the two simulation models for evaluating the IPSI performance.	EDU

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1. EXECUTIVE SUMMARY

1.1 Objectives

In order to succeed in transferring transport of goods in Europe from land to sea (Short Sea Shipping or Inland Navigation), the complete logistic chain using waterborne transport as a major component, has to be competitive, ref. Figure 1-1. The competitive advantage **must** include both economic and "just in time" elements.

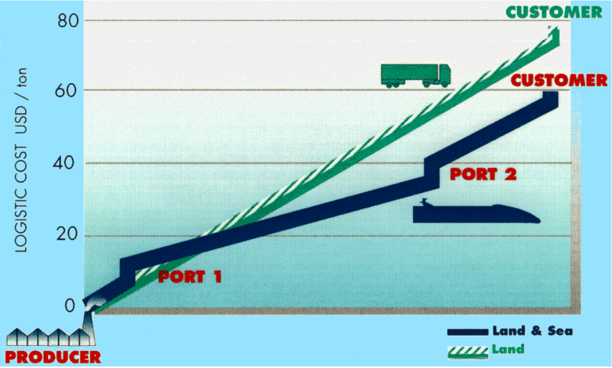

Figure 1-1. The Challenge

Since cargo must be transferred between ship/barge and land transport systems at least twice, the efficiency of the port/ship interface in the intermodal context of a door-to-door logistic chain is of vital importance.

The challenge of the ports is that they must become more active interfaces in the transport chain. They must become efficient and cost effective logistic hubs where all available modes of transport can be effectively interconnected. This applies to sea, rail, road, and to inland navigation as well. The interconnection of modes of transport must be based on competition and flexibility; i.e. interchanges between the various modes of transport must be possible wherever necessary and applicable.

With regard to facilities, adequate infrastructure such as quays and areas must be available to serve Short Sea Shipping and inland navigation concepts at lower cost than today and *without unnecessary new investments in order to decrease overall port costs*. The same applies to superstructure, especially equipment, for the pre-stowing, handling and interchange of cargo.

The IPSI project contributes to making waterborne transport an integrated part of the logistic chain by:

- Developing new concepts for flexible and efficient interfaces between land- and waterborne means of transport
- Developing methods and equipment for effective transfer of cargo and information about cargo with focus on high efficiency and low investments.

- Demonstrating the port/ship interface concept to verify the effectiveness of multimodal cargo exchange in a "door-to-door" context.

1.2 The IPSI Terminal

1.2.1 Requirements

1.2.1.1 Taxonomy of Short Sea Shipping

During the requirement specification phase, it was concluded that three possible scenarios for European waterborne transport had to be taken into account when defining the capabilities of the IPSI terminal concept:

1. High capacity Short Sea Shipping lines are envisioned to be linking major intermodal terminals with services of high frequency and capacity. This type of service is the most demanding, seen form the view of terminal performance. One example of such a service could be a line from Gothenburg to Rotterdam or Zeebrugge. Another example could be a service from Piraeus to Venice.

2. Feeder services, meaning waterborne transport serving smaller ports and feedering the direct, high capacity services described above. (The concept should not to be mixed with the term short sea feedering to overseas services, which may and will be covered also by direct services defined above).

3. Inland waterways, encompassing all services on rivers and canals. For the purpose of IPSI specifications, these services were handled as one group, despite the fact that there are large variations in capabilities, infrastructure, etc.

Other basic requirements in the IPSI project were:

- The investments in permanent infrastructure on land should be kept to a minimum, and
- The IPSI concept should be adapted to terminals (ports) in all three scenarios mentioned above.

1.2.1.2 Cargo Containment Units

In order to function as a real intermodal hub, the IPSI terminal must be able to handle the most widely used cargo containment units in intra-European transport. These are:

- The ISO-container: Millions of ISO-boxes worldwide, the dominating unit for ocean going traffic and supplemented by the Cellular Pallet-Wide Container (CPC), an ISO-box with internal width sufficient for two Euro-pallets abreast.
- Road vehicles: The trailer and the chassis are the most common natural containment units for the intra-European traffic.

- The Swap-Body: It is here to stay in road transport.
- Heavy-duty Cassettes: Frequently used by Scandinavian industries (one example is the Swedish company Stora and its development of the Stora Box – ref the Stora Enso Base Port project).

1.2.1.3 Capacity and Cost

The requirements for unloading cargo from a ship in the most demanding case (case 1 above) is indicated in Table 1-1 (similar figures exist for loading and for unloading and loading in the other scenarios).

Table 1-1. Requirements for high capacity handling

Requirement:	**Target:**	**Measurements:**
Unloading capacity	400 TEU / hour	Actual unloading capacity
Cost of operation	25 ECU per TEU	Actual unloading cost
Impact on carrying capacity of vessels	No loss in payload capacity	Deviations from target
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in unloading process

1.2.2 The Solution

All in all, the insight that came from studying these requirements led to the adaptation of a RoRo alternative, despite the fact that RoRo today is considered a more expensive solution than conventional container handling. An illustration of the IPSI terminal is shown in Figure 1-2.

Figure 1-2. Artist's impression of the IPSI terminal

Realising that trailers already have the ability to roll onboard vessels, the equipment developed especially for cargo handling in IPSI is related to handling all kinds of "boxes". The boxes are places on cassettes, and each cassette is transported using an Automatically Guided Vehicle (AGV).

The AGV and cassette concept is illustrated in Figure 1-3.

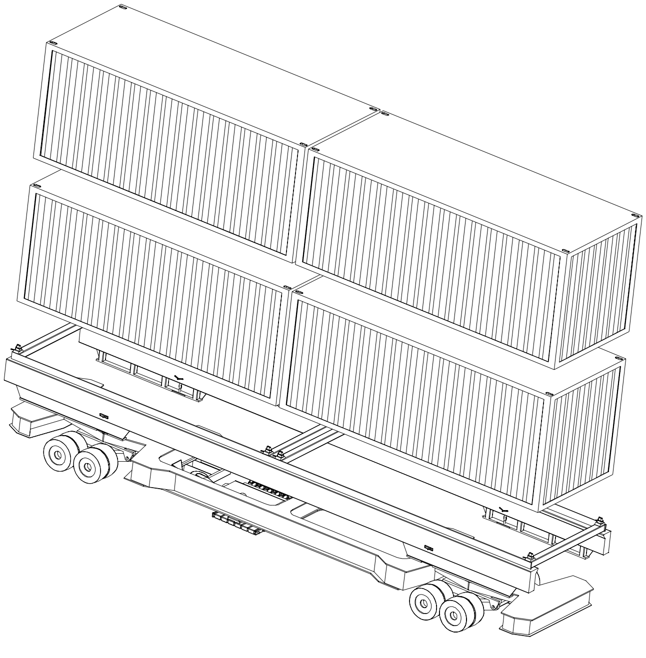

Figure 1-3. The AGV, cassette, and cargo

The layout of the terminal is shown in Figure 1-4.

When a ship arrives, one or more trains of AGV's leave the marshalling area and enter the ship, see Figure 1-5. In the ship, the lowered AGV's position themselves under the cassettes, and, when in place, lifts the cassettes and move back to the marshalling area, see Figure 1-6.

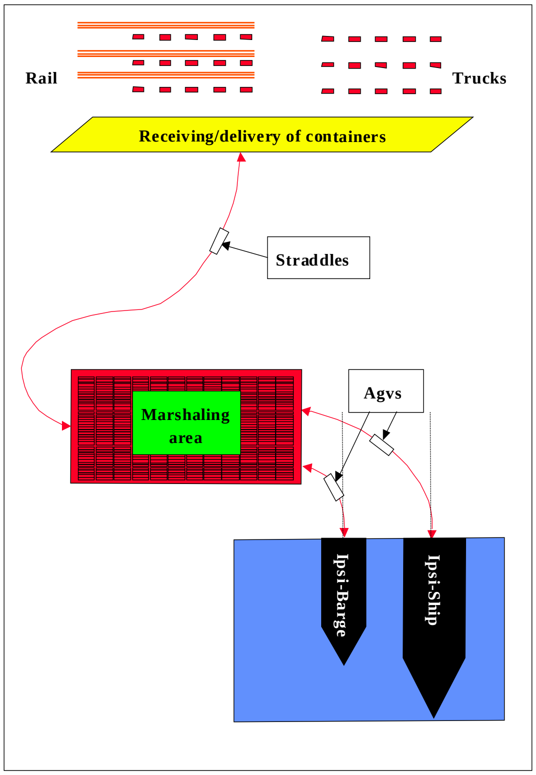

Figure 1-4. The layout of the IPSI terminal

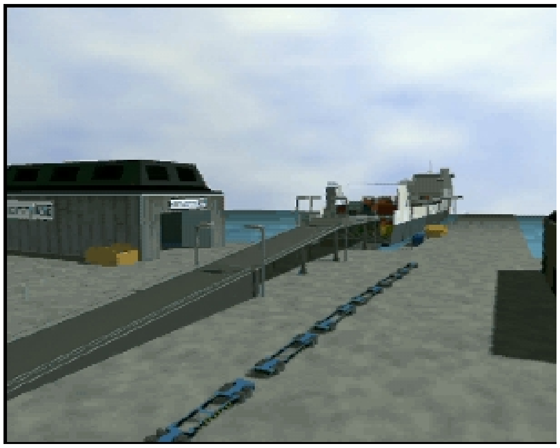

Figure 1-5. AGV-train

Figure 1-6. AGV carrying cassette with containers

Figure 1-7 Straddle carrier

Trucks and trains are served in truck- and rail service centres. Straddle carriers (Figure 1-7) transfer the cargo between the marshalling area and the service centres. During AGV operations, the straddle carriers may only operate the marshalling area from the “free” end. When there is no AGV-operation the straddle carries may operate freely.

When loading a vessel, an AGV-train picks up the cargo of a complete lane and brings it onboard. The deck of the IPSI vessel is equipped with curbs, see Figure 1-8, to make the AGV operation more effective. The curbs are also used for lashing. When a lane is completely filled with cassettes (each holding up to 4 TEUs), the cassettes are lowered onto the deck. When moving out again, the AGV’s trigger the lashing mechanisms automatically, and the cassettes are secured to the curbs, see Figure 1-9.

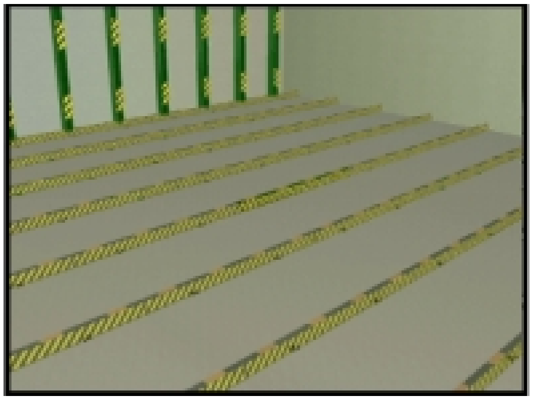

Figure 1-8. Curbs

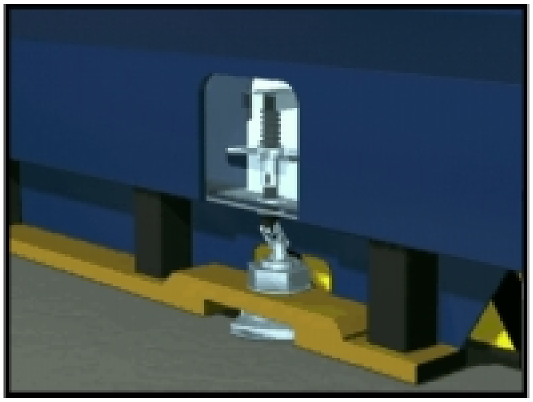

Figure 1-9. Lashing mechanism for cassettes

Trailers are handled using tug-masters and trailer horses. The trailer horses are used for lashing, also using the curbs, see Figure 1-10 and Figure 1-11.

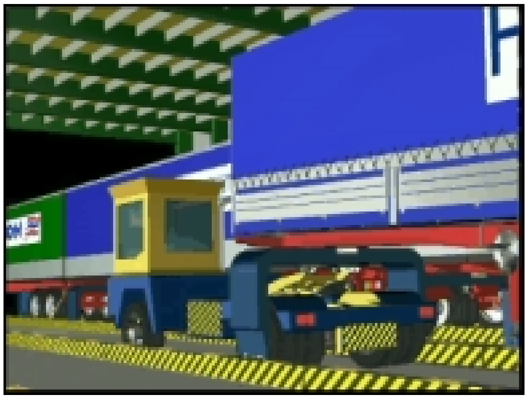

Figure 1-10. Tug-master and trailer

Figure 1-11. Automatic lashing of trailer horse

In the other end of the trailer, lashing is performed manually using equipment stored, ready to use, in the curbs, see Figure 1-12

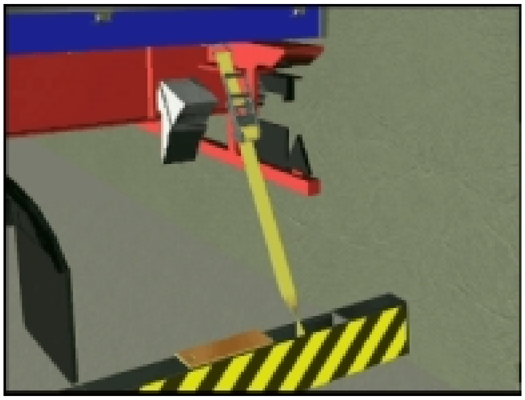

Figure 1-12. Manual lashing of trailers

1.2.3 Performance

The IPSI performance has been demonstrated using simulation, using a special IPSI vessel with 2 decks, see below. The focus of the simulation was to verify whether the system was able to cope with the capacity requirement of 400 TEU per hour. In other words, that the IPSI system was capable of unloading and loading a vessel with the capacity of 200 trailers (400TEU) in 2 hours or less.

From the simulation we can draw the following conclusions:

- In order to satisfy the requirement, 2 IPSI trains of 10 AGV's each must be used. In the worst case, these two AGV-trains are working on the same deck.

- For this evaluation, we assume that all 400 TEU's are loaded onto cassettes (the IPSI solution) with 4 TEU's per cassette.

- Hence, the two AGV-trains will require 20 moves each (10 cassettes transferred by each AGV-train in each move) to unload and load the 400 TEU IPSI vessel.

- According to the simulation, the time it takes for AGV-train to travel onboard the vessel from the marshalling area, discharge or pick up cargo, disembark the vessel and move back to the marshalling area, is 493 seconds, or 8 minutes and 13 seconds.

- The complete loading and unloading of the vessel then takes 4930 seconds, or approximately 1 hour and 22 minutes.

- This capacity is well inside the original requirement of 400 TEU per hour. Strictly calculated, the handling capacity (if all cargo is loaded onto cassettes) of 2 IPSI AGV-trains is above 580 TEU's per hour.

- All calculations etc. regarding the IPSI terminal in comparison with other alternatives are using this configuration.

- For practical purposes, the IPSI concept may be extended to using 4 AGV-trains, two working on each deck. This configuration would lead to a turn-around time for this type of vessel to be approaching 40 minutes. In this case it may be said that cargo handling is no longer the limiting factor in turning the ship around. Other tasks, bunkering, etc., may suddenly become the limiting factor.

- Even if the vessel had to accommodate a number of trailers, the capacity of the AGV-trains leaves ample time for handling of trailers within the previously specified 2 hours.

1.3 The Vessels

The unique attribute of the IPSI family of vessels is the cargo area. It is designed such that all lanes are completely straight, ensuring that the AGV's do not have to turn inside the vessel. The project has developed 4 types of vessels:

- Short sea vessel, 150m overall length, with a capacity of 400 TEU on 2 decks.
- Short sea vessel, 115m overall length, with a capacity of 230 TEU on 2 decks
- Barge of 85m overall length, with a capacity of 35 TEU on 1 deck
- Barge of 110m overall length, with a capacity of 85 TEU on 1 deck
- Barge of 150m overall length, with a capacity of 245 TEU on 2 decks.

In addition, the project has co-operated closely with the Stora Enso Base Port project now building 3 similar vessels with an overall length of 180 meters.

The AGV-train concept is demonstrated to work efficiently when a high capacity is required, see above. However, by examining the IPSI vessel, see Figure 1-13, one will observe that the complete cargo area is easily accessible also using conventional technologies.

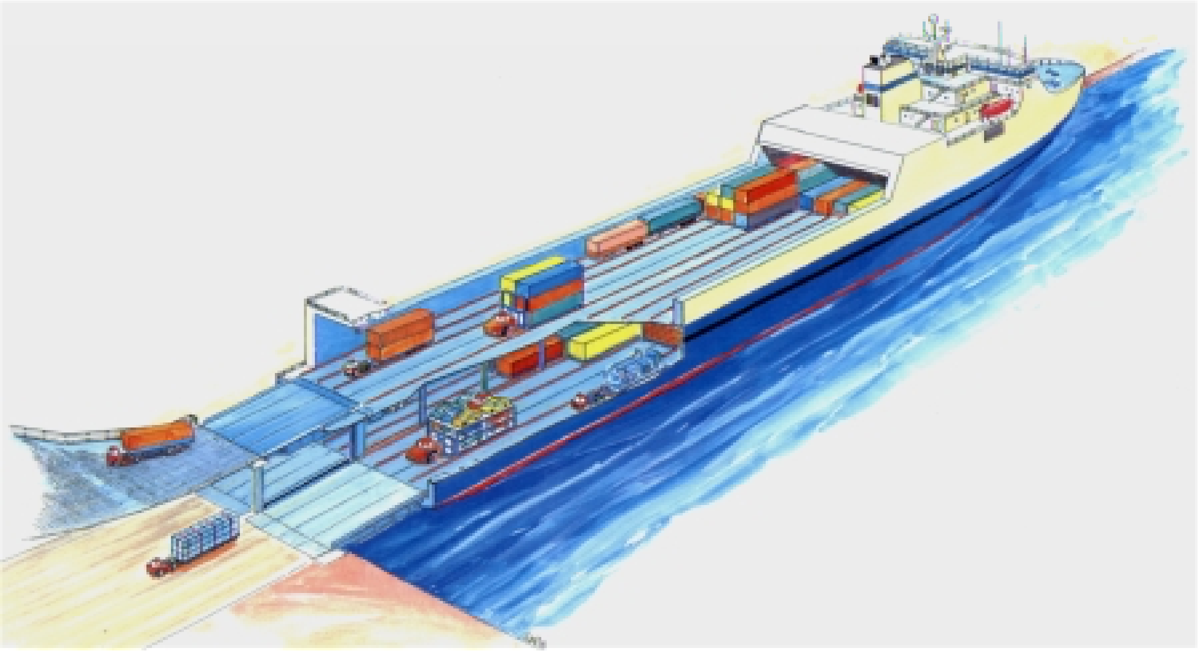

Figure 1-13. The IPSI vessel

Consequently, versions of the IPSI vessel may be configured to call on port with very simple infrastructure.

In the IPSI project, little focus has been placed on vessel speed. This must be decided in specific cases. However, it should be stressed that the general experience form the IPSI project is that frequency, reliability and regularity of service is more important than vessel speed.

The terminal facilities of the IPSI concept could be used for conventional ferries and other RoRo vessels as well. The IPSI vessels are able to operate in conventional trades world-wide, because the only difference to conventional RoRo vessels is the steering and control system for the AGVs within the decks.

The conclusions are:

- The IPSI vessel concept is independent on cargo handling technology. Hence, in addition to the high capacity connections, IPSI vessels may call upon any port able to support a RoRo operation.

- Consequently, IPSI type vessels may easily establish feedering services and the high capacity service.

- Consequently, IPSI vessels may also be applicable for trades different from the originally targeted European Short Sea Shipping. Hence, there may be a market for second hand IPSI ships.

1.4 Lashing of Cargo Inside Containers

Normally lashing of cargo inside a closed cargo containment unit is a manual operation using straps connected to fittings in the containment unit.

The result is that the lashing process may become tedious and there may be situations where lashing is not performed due to the effort required, of because the people responsible for the lashing experiences that the lashing is of no value because of the difficult working situation.

The result is that, in many cases, cargo is not secured properly inside the containment units.

The consequence for cargo owners is that, particularly in harsh conditions, the rate of cargo damage is unacceptably high. An example of this type of extreme situation is loading of containers form supply vessels onto the oil platforms in the North Sea.

The lashing mechanism for IPSI is developed in co-operation with the Norwegian company Air Sack Cargo Safe, and is essentially a rubber sack connected a cassette that is mounted to the roof of the closed cargo containment unit. Figure 1-14 illustrates the situation where the lashing mechanism is not activated, and the rubber sack is "glued" to the roof so that loading an unloading can take place without problems, as if the lashing device was not there.

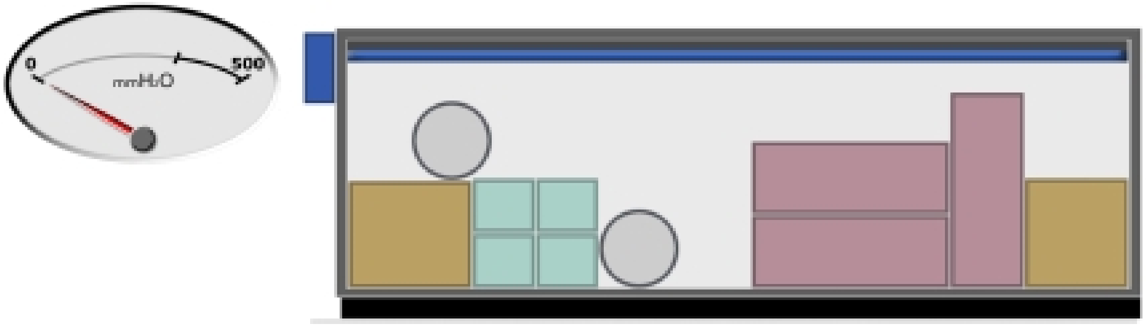

Figure 1-14. Container with the lashing system passive

Figure 1-15 illustrates the situation after the lashing is completed. The air sack is now filled with air with a pressure giving sufficient support to the cargo, keeping it safe under the conditions specifies in the requirements mentioned above.

The lashing system is operated in such a way that after the containment unit is closed and securely locked, the operator can push a button, and a special pump, driven by high pressure air, blows air into the sack at a rate of 6000 litres per minute.

When the transport is completed and the cargo shall be unloaded, the button is pushed again, and the pump is reversed and blows the air out of the sack. The pump is also used to crates a vacuum inside the sack during loading and unloading operations, such that the loss of space for loading and unloading is minimal.

There is a safety mechanism connected to the door of the containment unit, such that the door cannot be opened before the pressure in the air sack is below a certain level.

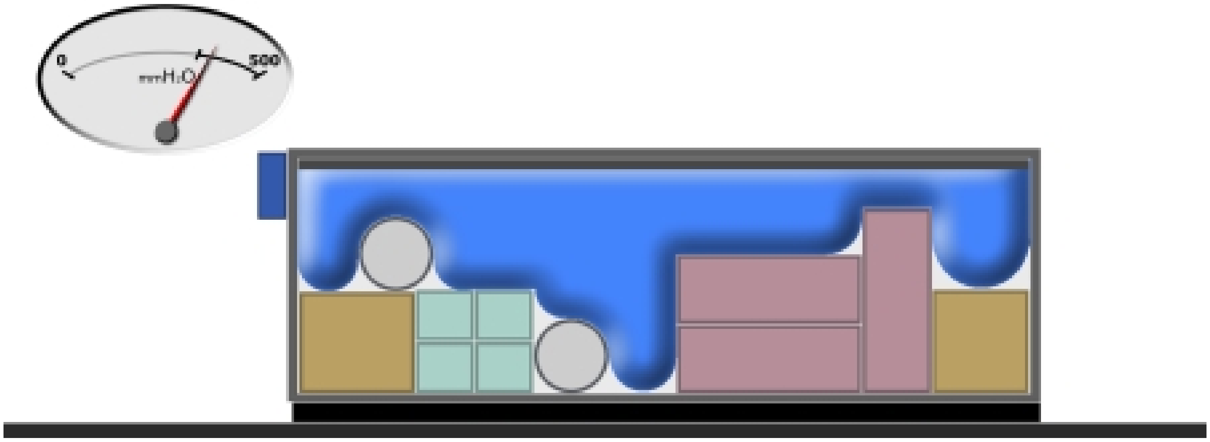

Figure 1-15. Container with the lashing system active

1.5 Cost

Table 1-2 contains first of all a calculation of the cost of transferring cargo form an IPSI vessel to another means of transport in an IPSI terminal with a total capacity of 876.000 TEU's per year. This is equivalent to the capacity of 2.400 TEU's per day, similar to the "central case" in the IPSI terminal simulations.

With this capacity, we are able to achieve the desired 25 Euro per transfer, as specified in our requirements.

In order to illustrate the commercial potential of the IPSI concept, we have compared the IPSI cost with the cost presented by Drewry Shipping Consultants ltd. in a study of World Container Terminals, London April 1998. Even though the IPSI terminal require only 30% of the staff required to operate a container terminal of equal capacity, the indirect cost and overhead are considered to be the same in the two cases. Seen from IPSI, this is a conservative estimate, where there possibly is a potential for further improvement. The same is not necessarily the case for container terminals.

Table 1-2. Cost comparison (Euro) between IPSI-Terminals and Large Container terminals

	IPSI - RoRo Terminal [2]	**Container Terminal [1]**
No of TEU's with theoretical	876 000	

utilisation		
No of TEU's with 75 % utilisation	657 000	
No of TEU's used for cost comparison	657 000	600 000
Equipment costs/year*	1 580 000	5 200 000
Personnel costs/per year**	7 485 000	10 200 000
Indirect costs and overhead * [3]**	7 275 000	7 275 000
Total Terminal cost	16 340 000	22 675 000
Personnel	163	531
Equipment costs/year/TEU	2,4	8,7
Labour costs/year/TEU	11,4	17,0
Indirect costs and overhead/TEU	11,1	12,1
Total cost per TEU	24,9	37,8

*Equipment costs without maintenance and repair, buildings, rail tracks, operating costs and interests

**Personnel costs includes all employees

***Indirect cost and overhead includes maintenance and repair, buildings, rail tracks, operating costs, overhead and interests

Sources:

[1] Drewry Shipping Consultants ltd., World Container Terminals, London April 1998.

[2] IPSI Report WP 6100, D6001, No. 7: Cost Calculation

[3] We have assumed that Indirect and overhead cost will be the same for both terminals

1.6 Conclusion

The IPSI terminal concept has been shown to have capabilities that may make it an efficient hub in intermodal chains, particularly when served with IPSI vessels.

Furthermore, the cost of vessel and operation combined with the performance of the cargo handling equipment compared to conventional container feedering clearly makes the IPSI concept a commercially viable alternative for this type of operation. If the IPSI concept was attempted for container feedering, we could achieve the following benefits also for container shipping:

- The expensive equipment in ports like Gioa Tauro and Rotterdam could be dedicated to handle the cargo from large, expensive intercontinental container ships. A cheaper and more efficient technology could transfer cargo onto a RoRo vessel for feedering, either directly or via a storage area.

- By using IPSI technology for container feedering, we had created an “open” solution. By open we mean a solution that could combine the feedering of intercontinental containers with intra-European transport. Such integration would open up great possibilities for new waterborne transport services in Europe, attracting cargo form the road.

The handicap of the IPSI is essentially the use of cassettes for handling containers and other unitised cargo during loading and unloading. If generally used, management of standard cassettes will be required. This, however, is similar to managing containers, and should not discourage the real life testing and evaluation of the IPSI concept.

2. OBJECTIVES OF THE IPSI PROJECT

2.1 Project Objectives

In order to succeed in transferring transport of goods in Europe from land to sea (Short Sea Shipping/Inland Navigation), the complete logistic chain using waterborne transport as a major component, must be competitive, ref. Figure 2-1. The competitive advantage **must** include both economic and "just in time" components.

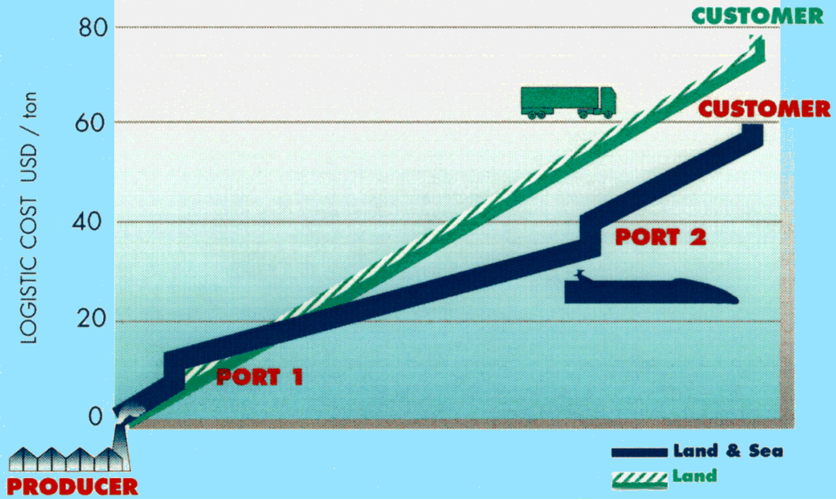

Figure 2-1. Logistics Cost.

Since cargo must be moved between ship/barge and land transport systems twice, the efficiency of the port/ship interface in the multimodal context of a door-to-door logistic chain is of vital importance.

It is obvious that all links in the logistic chain will have to be improved in a balanced way. This means that in an overall concept, the logistic network of the hinterland infrastructure must be adopted to the port capacities and capabilities.

The challenge of the ports is that they must become more important interfaces in the transport chain as efficient and cost effective logistic hubs where all available modes of transport can be effectively interconnected. This applies to sea, rail, road, and to inland navigation as well. The interconnection of modes of transport must be based on competition and flexibility; i.e. interchanges between the various modes of transport must be possible wherever necessary and applicable.

In order to encourage Short Sea Shipping, ports must offer better and cheaper services to shippers and forwarders than other modes of transport by optimising their logistics facilities and procedures. An acceptance of competitive Short Sea Shipping on the clients' side, however, will only be given if a market-oriented frequency of services is provided, reliability in time is given and a logistic system as a whole stands behind.

Within an efficient Short Sea Shipping concept, based on various containment units, ports should be described as ideal hubs with an optimisation concept for facilities, organisation procedures and communication.

With regard to facilities, adequate infrastructure such as quays and areas must be available to serve Short Sea Shipping and inland navigation concepts at lower cost than today <u>and without unnecessary new investments in order to decrease overall port costs</u>. The same applies to superstructure, especially equipment, for the prestow, handling and interchanges of cargoes.

An optimised port organisation especially in the operational and logistic sense must have an impact on shorter ships handling times in ports and thereby improve the turnaround time of vessels. These improvements in organisation also include harmonisation and simplification of procedures and documentation in order to improve the attractiveness by service quality at reduced cost.

New vessel concept for Short Sea Shipping and Inland Navigation must be developed for increased efficiency in port/ship and ship/ship interfaces. Cargo handling technology will be important.

In order to meet the requirements of a hub with an improved logistic function between the various modes of transport most up-to-date communication and information systems must be available in order to facilitate transportation as a whole. Such system must allow transparency of various means of transport in the overall inter modal system and must allow optimal and flexible interchanges between them.

The IPSI projects contributes to developing this kind of logistics concept, and the goals for the project are:

- Develop a concept for flexible port/ship interfaces in the context of added value, inter modal "door to door" (where applicable) logistics in Europe, based in increased use of waterborne transport, including utilisation of inland waterways.

- Develop methods and equipment for effective transfer of cargo and information about cargo in the above mentioned land/water interfaces, with focus on high efficiency and low investments.

- Demonstrate the "new port/ship interface concept" to verify the effectiveness of intermodal cargo exchange in a "door-to-door" context.

2.2 Critical Success Factors

When the project was initiated, the following factors were considered important if the IPSI development was to become a success:

- Availability of trade flow information.

  Information about statistics for shiftable cargo from land based to waterborne modes is required as a basis for further development of waterborne transport, if it is to be an integrated element of the Trans-European transportation network. Relevant information should, at the suggestion of the Commission, be supported from other projects. The IPSI project would benefit from, but not be dependent upon, such input from other EU projects.

- Interaction with consortiums dealing with management systems.

  Availability of effective management systems is a very important issue in the promotion of waterborne transport in the European intermodal network. Effective intermodal planning tools as well as efficient logistics are required. Close co-operation with other consortia dealing with the information logistics issue is required.

- Availability of an information technology architecture

  In order to effectively implement the cargo handling control system, the availability of a well documented information technology architecture is important. The consortium co-ordinator will see to it that such architecture is being made available. However, it would be beneficial for the project if the Commission could make known to the Consortium information about relevant projects that may contribute to defining such architecture.

2.3 Results

The consortium was convinced that the IPSI project would contribute to facilitate a shift in cargo transport to waterborne modes as a crucial element in the future, integrated trans-European transportation network.

In the Technical Annex the IPSI contract, the following main results were be emphasised:

- *Suggested network of ideal hubs.*
  IPSI would identify of ports where transfer of cargo between waterborne- and land-based modes may take place most efficiently, using today's most relevant European ports as a basis, classified in order of importance. Suggestions regarding future network of ideal hubs for maximum contribution to the expected shift to waterborne modes would be made. Specifications of port infrastructure requirements in order to optimally serve short sea shipping and inland navigation would be produced.

- *Specification of port/ship interface.*
  A considerable part of the total logistics costs in short sea shipping comprises cost connected to port operations. Among the main challenges for increased efficiency in short sea shipping is, thus, to increase the effectiveness of the port/ship interface. A considerable part of the IPSI project deals with developing the specification of new

concepts for increased efficiency of the port/ship interface without unnecessary new port investments.

- *Specification of and prototype development cargo containment units.*
  Effective cargo containment units are of vital importance for high efficiency in multimodal logistic chains. If short sea shipping shall become fully integrated in the trans-European transport network, cargo containment units that fully fulfils the intermodal, door-to-door requirements must be developed. IPSI would specify and develop such cargo containment units.

- *System for efficient handling of cargo units.*
  Effective cargo handling is the backbone for the efficiency of logistics operations. Time in port is a critical issue for the effectiveness of short sea shipping. IPSI would develop actual designs for cargo handling equipment, making sure that the solution shall be applicable to existing tonnage as well as being the basis for the development of new, competitive ship concepts.

  Systems for planning and controlling the cargo loading and unloading operations would be developed.

- *Specification for logistic analysis tool.*
  When persuading transporters and cargo owners to utilise logistic chains that involve short sea shipping, it is necessary to be able to evaluate the economics of the alternative scenarios. A tool that is capable of performing such analysis would be specified.

- *Specification for cargo management system.*
  Efficient management, communication, and information systems that may be utilised throughout the logistic chain are crucial to the success of short sea shipping. The requirements for such a system would be produced in the IPSI project, in close co-operation with other consortia.

  The management system would be concerned with the cargo itself, information about the cargo, and empty cargo containment units.

- *Design of short sea shipping vessels.*
  New short sea ship concepts that fit into the logistic chain philosophy would be specified. The specifications would be evaluated against the cargo handling technology and cargo containment unit concept that would be developed. Conventional as well as FWTS would be covered.

- *Design of vessels for inland waterways.*
  Concepts for increased efficiency of inland waterways would be specified to meet the requirements of the logistic chain. Combined sea/river concepts and the interface problems between ship/barge and barge/port would be emphasised.

- *Demonstration*
  Key concepts that are specified and developed throughout IPSI would be demonstrated at a preliminary level (scenario descriptions, simulations, geometric models, early prototypes, etc.) to secure that all parties, technical financial, etc., may be convinced that the objectives of the IPSI project were properly met.

3. MEANS TO ACHIEVE THE OBJECTIVES

3.1 Strategic analysis and Requirements Specification

Although several projects related to Short Sea Shipping and multimodal transport were either completed or underway at the time of the start-up of the IPSI project, it was important for the IPSI Consortium to establish a common solid understanding of the real needs and challenges. Hence, it was decided to undertake a significant strategic study both regarding:

- Cargo streams and transport modes

  This activity should establish the ground rules and the specifications for all development activities. Information about statistics for shiftable cargo from land-based to waterborne modes is required as a basis for further developing waterborne transport as an integrated element in the Trans-European transport network. Availability of shiftable cargo is a prerequisite for increased transportation by waterborne modes.

  A considerable effort is required to validate the industry and transport users for the benefits they may have from the efficient waterborne logistics concepts. In this context evaluation of the decision process needs to be analysed.

- Environmental requirements and analysis

  No major actors in the transport market seemed to credit environmental friendly solutions exceeding minimum environmental standards as defined by legislation. However, in spite of slow progress on international legislation and/or implementation of incentive schemes to stimulate environmental friendly solutions, it could hardly be denied that environmental considerations would be important evaluation criteria for future transport systems.

  Therefore, it was recommended for the IPSI project that environmental impact evaluations be prepared for all new solutions described. The evaluations should be based on aggregated transport chains, with present transport solutions as the basis for comparison.

On the basis of these investigations, the requirement specifications for the IPSDI concept could be derived.

3.2 The Development

In order to produce all the results specified in the Technical Annex, the IPSI project was divided into the following main activities:

- Specifications of systems for overall logistics analysis and control. This activity was of vital importance for being able to provide the right form of operational environment for the IPSI system in the logistics chain. The specifications were divided into two parts:

1) Planning systems for logistics operations, taking into account the alternative transport chains available for cargo to move form origin top destination.
2) Information and management system for intermodal transport.

The IPSI specifications were later used as a starting point for the Infolog project.

- Organisational aspects of the ideal hub in an intermodal network based on waterborne transport, also looking for a network of ports that could form the basis for a new type of Short Sea Shipping.

- The actual system and equipment for moving cargo between vessels and land-based transport means, realising that it is difficult to develop a cargo handling concept for a vessel without also looking very carefully at the vessel design.

  Originally, and as specified in the objectives above, the IPSI project should attempt to develop a new type of universal cargo containment unit. Even during the strategic study it became clear that this was a fruitless activity. The effort that would have been required to introduce a new cargo containment unit in the transport market would have required resources way beyond those available in the IPSI Consortium.

  Instead, the IPSI project focussed on becoming an “open” system being able to handle all the major cargo containment units already in use.

- When the concept and equipment was well developed, it would be a challenge to visualise the capabilities of the IPSI system both in terms of technical and commercial performance. Special resources were dedicated to this important activity.

Figure 3-1 illustrates a network of activities required to complete the project. The figure also illustrate how these activities were composed into a set of work packages, see Table 3-1.

As can be seen from Table 3-1, approximately 50% of the resources in the IPSI project have been dedicated to the core activities of developing the cargo handling- and vessel concept. If the visualisation is included, 65% of the resources have been spent on the IPSI core activities.

As described above, the supporting activities have been necessary for providing the right context for the technical development.

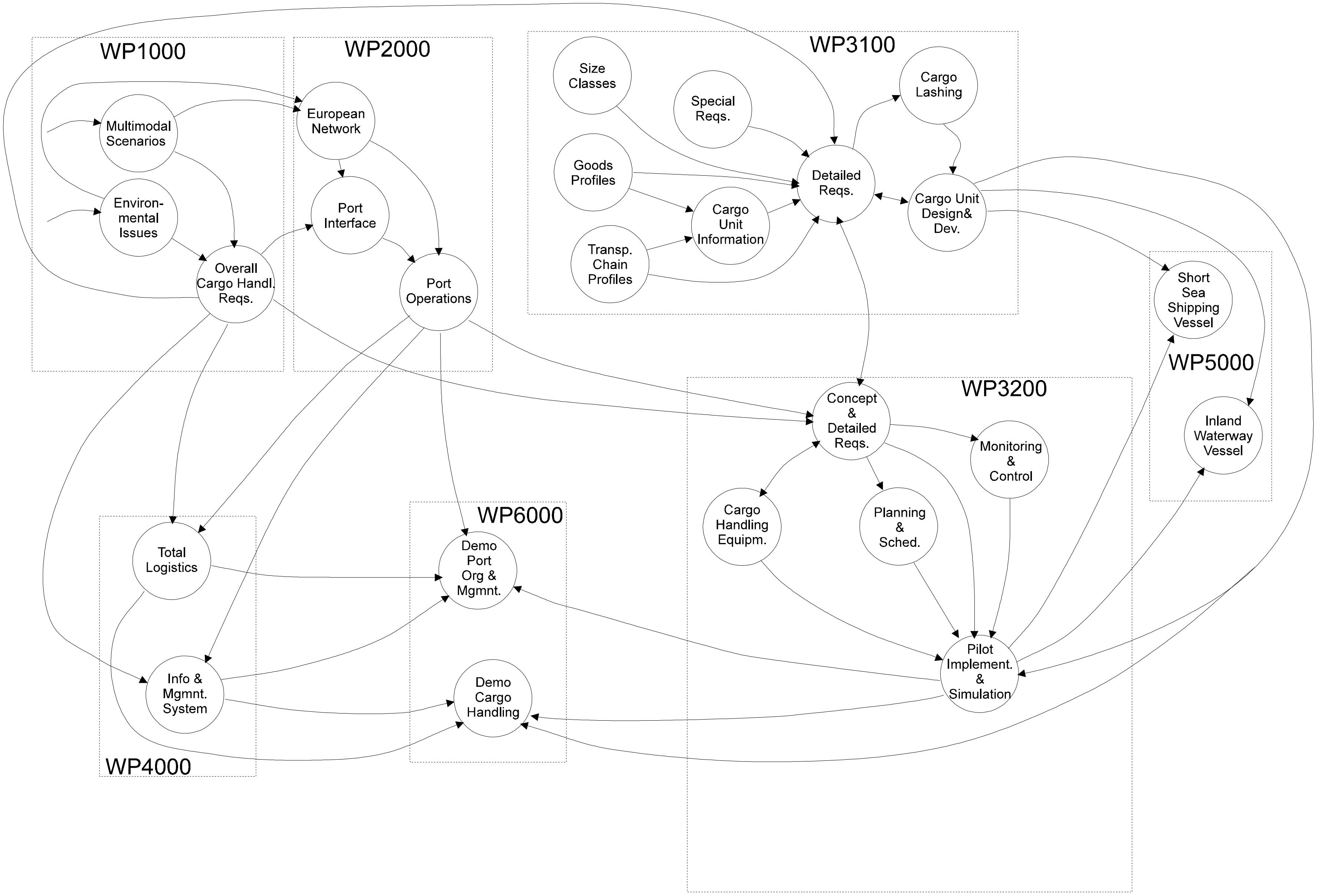
WP1000
Multimodal Scenarios
Environ-mental Issues
Overall Cargo Handl. Reqs.
WP2000
European Network
Port Interface
Port Operations
WP3100
Size Classes
Special Reqs.
Goods Profiles
Cargo Unit Information
Transp. Chain Profiles
Detailed Reqs.
Cargo Lashing
Cargo Unit Design& Dev.
WP5000
Short Sea Shipping Vessel
Inland Waterway Vessel
WP3200
Concept & Detailed Reqs.
Monitoring & Control
Cargo Handling Equipm.
Planning & Sched.
Pilot Implement. & Simulation
WP6000
Demo Port Org & Mgmnt.
Demo Cargo Handling
WP4000
Total Logistics
Info & Mgmnt. System

Figure 3-1. The IPSI project network

Table 3-1. Work packages

Number	***Name and content***	***type***	***Workpackage leader***	***% of total available resources***
WP1000	Strategic analysis • Multimodal Scenarios • Environment Issues • Cargo Handling Requirements	Specifications	SAGA	10%
WP2000	The Ideal Hub Organisation • European Network of ports • Port Interface • Port Operations	Support	PTC	8%
WP3000	Technical System • Unit Cargo Specifications • Cargo Handling solution	Core	Hamworthy KSE	42%
WP4000	Management System • Total logistics planning facility • Information and Management System for logistics chains	Support	SINTEF/ MARINTEK	6%
WP5000	Vessel Concepts • Vessels for Short Sea Shipping • Vessels for inland waterways	Core	MARINTEK	6%
WP6000	Pilot Installations • Demonstration of port organisation and management • Demonstration of cargo handling in the IPSI project	Core	Hamworthy KSE/ PTC	15%
	Project co-ordination • Technical and administrative management, quality assurance	Management	Hamworthy KSE	12%

4. SCIENTIFIC AND TECHNICAL DESCRIPTION OF THE IPSI PROJECT

4.1 The Strategic Analysis

4.1.1 Scenario Investigation

4.1.1.1 Introduction

The scope of this work was to identify the Short Sea Shipping market, and to develop the overall requirements for future services, as seen from current and future transport participants.

The goal was to present the IPSI Vision of Short Sea Shipping and to allow the following work packages to cope with the difficulties mentioned and the requirements that were identified.

For this, it was decided to rely on existing studies and provide herein an analysis of the studies we found, most of which were provided by the European Commission.

Because the IPSI development should be based also on practical facts and experience, wanted direct contact with potential partners in this business was established. To facilitate such contacts effectively, questionnaires were created. These questionnaires were tailored to the different participants that would be interview, and included information about how they work, what their perception of Short Sea Shipping is, and what it would take to develop waterborne transportation within their logistic chains.

Most of the questions were « open » (not answered by « yes » or by « no »), and lead us to a better perception of the Short Sea Shipping business, although it made the analysis more difficult.

It is worth mentioning that those participants who collaborated in the investigation were very interested in the work related to Short Sea Shipping and were themselves eager to propose ideas.

4.1.1.2 Scope of Analysis

The European Commission provided the existing studies on Short Sea Shipping. The studies cover Europe, and especially the major European axes, Baltic Sea, North Sea, Atlantic / Channel and the Mediterranean Sea. The list of references is presented in chapter 6.

After examining these studies four (4) different types of questionnaires concerning the main market participants in Short Sea Shipping were developed:

1. port operators and port authorities
2. cargo owners and forwarders

3. Short Sea Shipping Companies
4. Deep Sea Shipping Companies.

The close cooperation with the industry and transport users should guarantee the practicability of the project.

These studies, interviews, and evaluations lead to the definition of the reference scenario, that was detailed and used as a baseline for developing new concepts for intermodal chains utilising waterborne transport.

4.1.1.3 Sample information

Substantial effort has been spent in creating an overview on the maritime cargo flows between countries. However it has to be noted that the available trade flow and cargo flow statistics are based upon different approaches and scenarios for the various regions. They show significant inconsistencies and the available databases are incomplete. It was not within the scope of this study neither to calculate the cargo flows gathering information from the very beginning nor to create a new fully consistent database. Therefore this study is mainly built upon available strategic studies. Several additional sources like national statistics have been used to complete the view.

In all cases the data are presented in the same context like in the corresponding sources and without significant modifications.

The investigations focus mainly on a general analysis of SSS in Europe for all types of cargoes. But due to the orientation of the project special attention was focused on unitised cargo. For the general analysis the investigation area has been divided into 4 maritime regions, see Figure 4-1:

- Baltic Sea
- North Seas
- Atlantic Ocean and Channel
- Mediterranean Sea (incl. Black Sea)

These regions have been considered with their internal and external flows as far as available.

For the dedicated analysis of container flows the investigation results are described for 8 maritime areas, Figure 4-2:

- Nordic area: Norway, Sweden, Finland
- East Baltic: Poland, Estonia, Lithuania, Latvia, Russia
- Denmark/Germany
- Channel area: Belgium, Netherlands, France
- Great Britain

- Ireland
- Atlantic area: French Atlantic ports, Spanish Atlantic ports (except Algeciras), Portugal
- North Mediterranean: Spanish and French Mediterranean ports, Italy, Greece

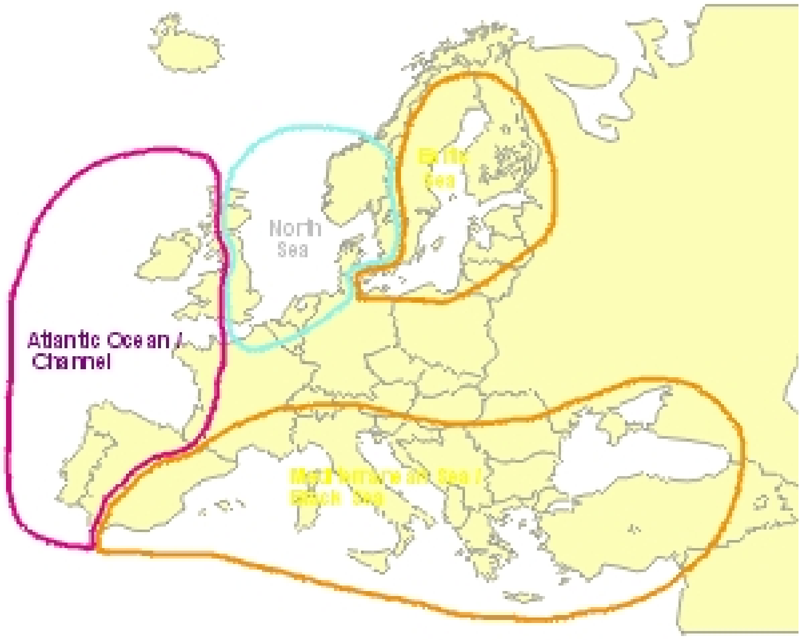

Figure 4-1. European maritime regions

Figure 4-2. Regions for container transport investigation

As an example of the findings, the following table indicates the main intra-Union trade flows between the member states of the European Union in 1992. The member states, entered the Union in 1996 are not included.

The largest single trade flow is from Germany to Netherlands with 47,1 Mio tons p.a., followed by the flow from Netherlands to Belgium and from Belgium to France. Each of these three flows account for more than 34 Mio tons p.a., i.e. 5% of the total Intra-Union trade volume. All other flows account for less than 3,5 Mio tons p.a., i.e. 0,5% of the total Intra-Union trade volumes.

Table 4-1. Intra-Union Trade flows in Million Tons in 1992 (Source: UNO 1993)

to	Belg. / Lux.	DK	France	Germ.	Greece	Ireland	Italy	NL	Port.	Spain	UK	**Total**
from												
Belgium / Luxembourg		0,79	34,37	23,56	0,38	0,39	5,22	29,00	0,65	2,00	5,60	**101,95**
Denmark	0,44		0,80	7,51	0,11	0,06	1,27	1,18	0,18	0,21	2,70	**14,45**
France	19,86	0,68		30,87	1,02	0,79	20,50	8,35	3,07	10,95	9,90	**105,99**
Germany	21,13	4,83	23,02		1,02	0,72	17,30	47,10	0,92	4,04	10,00	**130,08**
Greece	0,20	0,16	1,20	1,15		0,04	4,66	0,51	0,01	0,65	1,00	**9,57**
Ireland	0,26	0,06	0,69	1,02	0,02		0,27	0,66	0,03	0,15	5,30	**8,45**
Italy	2,04	0,50	10,74	12,56	1,76	0,14		1,59	1,53	3,46	3,40	**37,72**
Netherlands	40,65	1,50	13,44	72,07	0,96	0,98	8,57		1,16	2,53	12,00	**153,86**
Portugal	0,47	0,10	1,18	1,29	0,06	0,02	0,52	0,51		2,94	1,80	**8,90**
Spain	1,63	0,57	7,83	4,65	0,44	0,24	3,47	2,60	4,80		4,30	**30,51**
UK	6,38	3,00	14,64	19,77	0,69	8,30	7,46	13,90	1,48	6,79		**82,41**
Total	**93,05**	**12,19**	**107,92**	**174,44**	**6,46**	**11,68**	**69,24**	**105,39**	**13,83**	**33,70**	**56,00**	**683,89**

4.1.1.4 Summary of findings related to IPSI developments

The scenario study gave important input to the understanding of the IPSI requirements. A summary of the findings is:

1. Assessment of administration and political aspects
- Free working times/new shift systems (24 hours)
- New marketing strategies because short sea shipping is unknown in the European inland
- Different regulations of transport of goods at sea and for land transport (customs, dangerous goods etc.)
- Cost

2. Technical innovations
- Decreasing of time in ports including fast hinterland connections
- Reduction of cargo transhipments
- Dedicated short sea shipping terminals
- Special packaging for sea transport
- Different sizes of pallets and containment units
- Cost

3. Logistical improvements
- Fast round trips with high frequency depending on changing cargo structures
- Decreasing of time in ports including fast hinterland connections
- Door-to-door service
- Special packaging for sea transport
- Cost

- Decreasing time in ports including fast hinterland connections.
- Different regulations for transport of goods at sea and for land transport (Customs, dangerous goods...).

4.1.2 A European Network of Ports

In order to succeed in transferring the transport of goods in Europe from road to sea, the complete logistical chain using waterborne transport as a major component must be competitive. To fulfil this requirement, an ideal organisation must be established. In this respect ideal means the port must provide multimodal interconnectivity, high frequency, schedule effectiveness and reliability. The logistical network of the hinterland infrastructure must be aligned with the port capacities and capabilities.

The maritime cargo flows form an important basis for the design of the hub port network. Four criteria have been investigated to analyse the cargo volumes in Short Sea Shipping (SSS):

- Existing maritime cargo flows,
- Basic forecast for the development of cargo flows, based upon the expected economic development,
- Modified forecast, based upon the development in transport and transport policy,
- Estimates of SSS potential, i.e. cargo flows capable to gain market from land based transport.

The analysis of present maritime cargo flows shows the following main results (ref. Table 4-2): Among the four European maritime regions the North Sea has the largest part of SSS trade in Europe with 43% of the European SSS trade. This is true for both intra-North Sea (245 million tons) and for trade from and to other European regions (251 million tons). Both trade flows have more or less the same volume. In the Atlantic region most of the maritime cargo flows are flows from and to other regions while in the Mediterranean the intra-area trade is dominating.

Table 4-2. The intra-European maritime trade in the four European maritime regions (in million tons) in 1992/93

	Intra-area		From and to other areas		Total	
Baltic Sea	137	22%	97	18%	234	20%
North Sea	245	39%	251	47%	496	43%
Atlantic	84	13%	121	23%	205	18%
Mediterranean	159	25%	63	12%	222	19%
Total	625		532		1157	

For the future, a general growth of maritime cargo flows in SSS may be expected. The volumes on different routes may vary, depending on individual growth rates for different countries and regions. For the following countries major changes are expected in economy with a growth of trade volumes above average:

- Russia (3,1% in export and 5,3% in import),
- The Baltic States (5% - 7% in export and 7,9% - 9,7% in import),
- Poland (6,6% in export and 4,1% in import)

For the former communist countries in the Black Sea the current political situation and the economic problems does not allow an exact forecast for the development of maritime cargo flows.

The growth rates vary between different types of cargo. In general a larger growth is expected for unitised cargo than for bulk and oil, see Table 4-3.

Table 4-3. Average annual growth rates for the cargo types

	general cargo	containers/ RO-RO	dry bulk	liquid bulk	oil
Baltic Sea	4,2%	N/A	3,8%	4,5%	1,6%
North Sea	2,7%	2,5%	1,2%	1,7%	
Atlantic	N/A				
Mediterranean	1,0% - 3,3%				

Source: COWI 1995, CONSULTRANS 1995, NEA 1995

An additional growth of cargo volumes in SSS has to be taken into consideration as a third factor, if the legal or financial framework conditions change or if the traffic obstacles cause a change of traffic patterns. This may be expected for some congested areas in Central Europe. If those restrictions apply to land transport, the maritime cargo volumes may increase. These restrictions would influence first of all the maritime trade in the North and Baltic Sea. For the Baltic Sea region e.g. an increase of RO-RO and LO-LO traffic up to 40%, i.e. up to 57,6 million tons compared to the basis forecast may be expected (COWI 1995).

The SSS potential is the fourth criteria that may influence the hub port network design. Those cargo flows that are capable of making maritime trade exist for certain relations involving all EU-countries. Thus no port areas in Europe should be excluded from improvements and from measures to increase the attractiveness. All hub ports have to be able to serve growing SSS cargo flows in the future. The largest SSS potentials exist on the routes from Benelux and France to the Mediterranean (10,2 million tons in total). The opportunity for necessary extensions of port facilities has been taken into consideration.

Beside the existing maritime cargo flows the major industrial zones in Europe are considered as a key factor for a European hub port network. Since statistics for a detailed quantitative analysis of cargo origins and final destinations are not available the following criteria have been selected for the evaluation of the industrial zones:

- Main industries in the zone,
- Accessibility for waterborne transport.

Primarily those zones, that have more than one main industry, are considered as relevant for a general evaluation of cargo origins.

The accessibility to waterborne transport was divided into three levels:

- Direct sea port access,
- Inland waterways available,
- No direct access to waterborne transport.

The last requires land based hinterland transport to the nearest sea or inland waterways port. This increases the overall cargo handling costs compared to those zones, that have direct seaport or inland waterways access. In this case land based transport may be chosen not only for the transport to the closest port, but it compete with waterborne transport on the total route. However, all three levels of industrial zones have been taken into consideration for the design of the hub network.

In Scandinavia and Finland, as well as in Southern Europe the main industrial zones are often located at the coastal line or very close to it. These zones are offering good conditions for using sea borne transport without long distance hinterland transport.

However, in Central Europe (including France and Northern Italy) and in the UK major industrial zones are situated not only at the coastal line but also in the far hinterland with up to 600 km to the nearest seaport. For these regions the hinterland transport network with its performance and bottlenecks is another key factor, that was considered for the design of the hub network. E.g. in the universal North Sea ports the part of hinterland transport vary between 40% and 85%, with about 60% for the largest hub ports.

Rail, road and inland waterways are the competing hinterland transport modes that influence the evaluation of hub ports. The partition of hinterland modes shows a clear correlation with the performance of the different networks. While in Central Europe most of the agglomerations have access to inland waterways (esp. in the Rhine area), this is less the case around the Alps, in central UK and in Eastern Europe. Thus in the last areas the inland waterways play only an unimportant role for the hinterland traffic, e.g. only between 1% and 7% in the UK compared to 30% to 70% in the Benelux. The average percentage of inland waterway hinterland transport for the North Sea ports is 23%.

Road transport is the dominating mode in hinterland transport in most cases with more than 50%. Thus sufficient performance of the hinterland road network is necessary to strengthen the competitive position of Short Sea Shipping (cf. Multimodal Scenario

Report of WP 1100). However, severe bottlenecks in the road network linking the industrial zones with the seaports exist in the UK, around the Dutch ports and around some Spanish ports (e.g. Barcelona, Gijon/Aviles and Valencia) as well as in Eastern Europe. The contribution of railway hinterland transport is less important (e.g. only 13% for the North Sea ports). Major bottlenecks in the railway connections to the seaports exist in the Dutch port area and in the UK (both with less than 11% of rail transport) and at the French and Spanish Mediterranean coasts. In areas with better railway infrastructure the partition is significantly higher (e.g. German North Sea ports with 20% to 50%).

At the moment there are more than 1 000 European ports at the European coast. They present a close but unorganised network. In general, every port can be included in the ideal hub organisation if it provides the necessary performance.

To choose the necessary ports for the network two categories with two subpoints will be established (Table 4-4).

Table 4-4. Port Categories

1. Major Gateway Ports
1.1 Multifunctional Ports
1.2 Container Transhipment Ports

2. Hub Ports for Short Sea Shipping
2.1 Ideal Hub Ports
2.2 Complementary Hub Ports

The major gateway ports cover the **multifunctional ports** and the **container transhipment ports**. These ports are indispensable and absolutely essential for a complete network. Major gateway ports comprise the largest European inland ports as well.

The hub ports for short sea shipping cover the **ideal hub ports** and the **complementary hub ports**. The ideal hub ports provide interconnections with all modes of transport. This applies to sea, rail, road and inland navigation. The volume of total cargo traffic (throughput) is important but even more important is the multimodal interconnectivity. The category complementary hub ports has to be prepared to fill in the gaps within the network of the major gateway ports and the ideal ports. Complementary hub ports have to provide mainly excellent road and railway connections and have to meet further criteria (Table 4-5).

Table 4-5. Criteria

1. mainly excellent railway connections
2. inland waterway connections
3. mainly excellent road connections
4. cargo volume
5. cargo streams/industrial zones nearby
6. reliability
7. free of congestion
8. space for future conceptions
9. public port (no plant-operated ports)
10. short sea shipping lines (regular/unregular)

The **multifunctional ports** were divided into container ports, bulk ports and inland ports. The location of the main hubs in the network depends on the volume of cargo only. To be included in the network a container port needs a throughput of more than 1 mil TEU. The restriction for bulk ports is a throughput of more than 35 Million tons. 75 % thereof must be dry and liquid bulk (oil ports will be excluded). Main container ports and bulk ports are also partially important container/bulk ports (Table 4-6).

Table 4-6. Multifunctional Ports

1. Rotterdam
2. Hamburg
3. Antwerp
4. Felixstowe
5. Bremerhaven
6. Le Havre
7. La Spezia
8. Marseille
9. London
10. Genoa
11. Tees and Hartlepool
12. Trieste
13. Dunkirk
14. Duisburg
15. Paris

The **container transhipment ports** (feeder ports) connect the deep-sea container lines with the short sea shipping lines. Feeder containers could be a backbone for new short sea shipping conceptions.

Table 4-7. Container Transhipment Ports (1995)

Ranking	Port	TEU
1	Algeciras-La Linea	1,150,000
2	Marsaxlokk	514,767*
3	Gothenburg	380,000
4		350,000**
5		120,175 (1994)

* large decrease estimated 1996, not a EU member state
** estimated, 1997 600,000 TEU

Ideal hub ports must provide multimodal interconnectivity. They should have connections to all modes of transport that applies to inland waterways, mainly excellent railways and mainly excellent roads. In our terms inland waterway connections are rivers, canals or large bays, gulfs and lagoons that must enable efficient navigation and there must be provided sufficient water for a defined period. Mainly excellent roads are "autobahnen", highways or congestion free roads. Excellent railways have to be mainly double-tracked and electrified or/and free of congestion. The railways and roads have to be constructed for heavy weights.

Moreover, the ideal hub ports must be situated close to large cargo streams, areas with high density of population or/and big industrial zones (Table 4-8).

Table 4-8. Criteria for Ideal Hub Ports

1. inland waterways (river/canal, efficient navigation)
2. mainly excellent railways (double-tracked, electrified)
3. mainly excellent roads (autobahn/highway)
4. sufficient cargo volume (throughput)
5. cargo streams/industrial zones/density of population
6. interfaces free of congestion

The largest and most important inland waterways in northern Europe are the Neva, Nerva Saimaa Area, Lake Vattern/Vanern Area, Oder, Elbe, Weser, Rhine, Seine and Thames. The rivers Rhone, Po, Danube, Dnepr and Volga are the important waterways located in southern Europe and Central Asia.

The assessment of the railway and road connections and systems was influenced by the present situation at the ports and by future development plans of the European Union. The trans-European transport network outline plan, sections of railways and roads, was considered by the investigation. The section railway includes a rail traffic management system to replace incompatible national signalling and management equipment. The section roads include a road traffic management system to reduce congestions.

The Black Sea area will be included in the investigation depending on future market developments after the opening of the eastern bloc. In addition, a complete short sea shipping network within Europe should include the Black Sea to achieve sufficient connections/logistical chains in the east/west corridors. The Black Sea is connected with the Mediterranean Sea and a large inland waterway system (Table 4-9).

Table 4-9. European Ideal Hub Ports

1. Stockholm	13. Greenock
2. Lappeenranta	14. Limerick
3. Vyborg	15. Zeebrugge
4. St. Petersburg	16. Nantes/St. Nazaire
5. Riga	17. Bordeaux
6. Klaipeda	18. Venice
7. Szeczecin	19. Piraeus
8. Lubeck	20. Istanbul
9. Emden	21. Constantza
10. Hull	22. Odessa
11. Bristol	23. Kherson
12. Londonderry	24. Taganrog

The **complementary hub ports** have to fill in gaps within the network. The network which is composed of multifunctional ports, container transshipment ports and ideal hub ports must be added by ports which have to provide mainly excellent road and railway connections, close positions to cargo streams/industrial zones and which have to meet further criteria (Table 4-10).

Table 4-10. European Complementary Hub Ports

1. Tallinn	22. Ancona
2. Gdansk	23. Taranto
3. Rostock	24. Oslo
4. Aberdeen	25. Ploce
5. Southampton	26. Durres
6. Liverpool	27. Thessaloniki
7. Fishguard	28. Izmir
8. Dublin	29. Kristiansand
9. Brest	30. Helsingborg
10. La Rochelle	31. Bergen
11. Bastia (Corsica)	32. Copenhagen
12. Bilbao	33. Fredericia

13. Lisbon	34. Esbjerg
14. Sete	35. Helsinki
15. Cadiz	36. Raahe
16. Cartagena	37. Pori
17. Valencia	38. Trelleborg
18. Barcelona	39. Gravle
19. Naples	40. Samsun
20. Fiumicino	41. Novorossisk
21. Palma	42. Varna

The geographical European network of ports consists of **85 ports** at the time. The ports were chosen from more than 1 000 ports at the European coast. The network is a flexible system. Ports can be excluded and other ports can be included into the network. This depends on the interconnectivity and services provided.

The network is composed of 15 multifunctional ports, 4 container transhipment ports, 24 ideal hub ports and 42 complementary hub ports. 24 ports are located at the Baltic Sea, 23 at the North Sea, 8 at the Atlantic Coast, 22 at the Mediterranean Sea and 8 at the Black Sea.

The short sea shipping network should be divided into 6 different **market areas** with 10 different **transport corridors**.

The map (Figure 4-3) shows the European network of ports.

The ideal- and complementary hub ports are partially not well known in the transport market and will be described in detail to attract them for customers. On the other hand if establishing a port network for short sea shipping and developing new transport conceptions in progress of the study the present situation must be investigated.

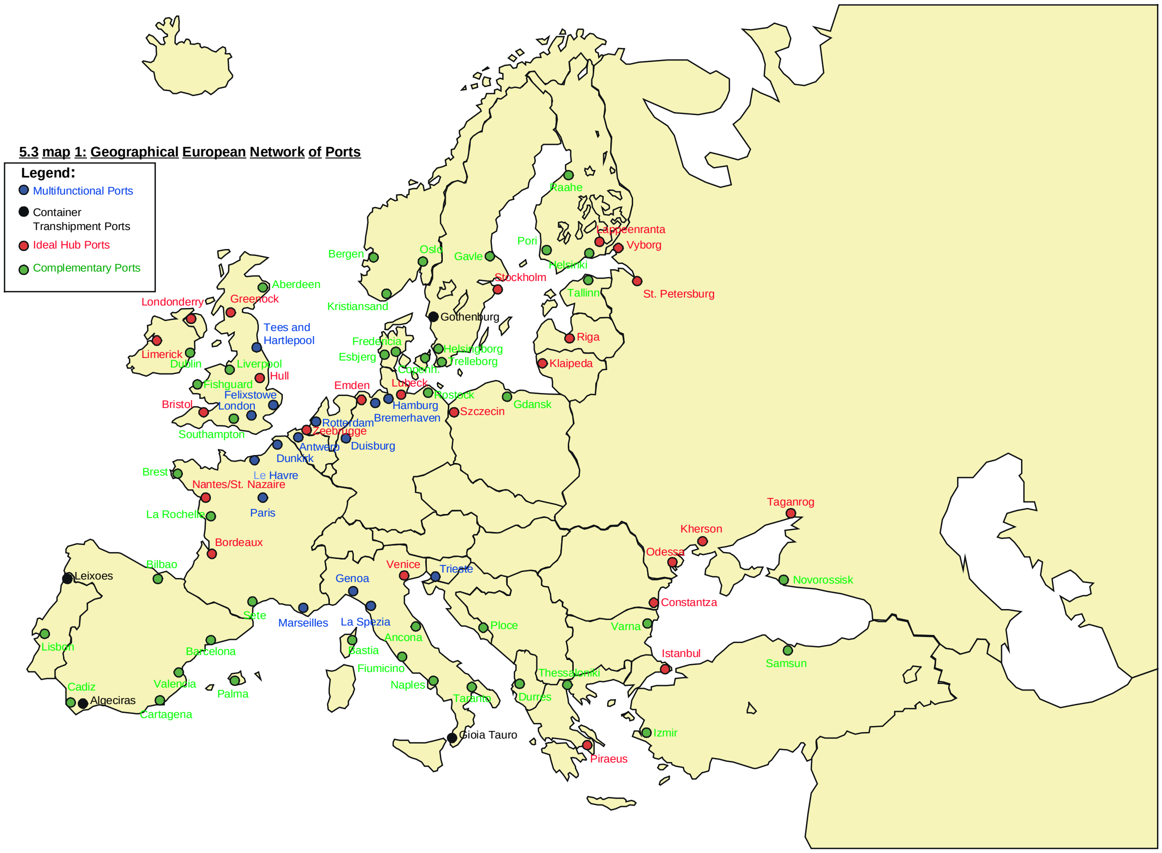

Figure 4-3. European network of ports in a Short Sea Shipping Network

4.1.3 IPSI System Requirements

4.1.3.1 <u>The Short Sea Shipping Hierarchy</u>

Figure 4-4 illustrates the market areas and the transport corridors related to Short Sea Shipping in Europe. Using this illustration as a background, we are dividing a future Short Sea Shipping concept into 3 types of services: Direct, feeder, and inland waterways. The motive for this division is to make sure that the specified requirements are unambiguous and clear, and that we are able to target the different needs of waterborne transport.

- Direct services.
  These are the main services linking the most important ports in the network together. One example could be a line from Gothenburg to Rotterdam or Zeebrügge. Another could be a service from Piraeus to Venice.

  These services are linked *to* the »Inter City» services of the European rail system, and will be characterised by high volumes and high frequencies. The frequencies must be high enough to challenge flexibility associated with truck transport. Using trucks, the transport user feels that the cargo is under transport continuously on the way to the point of destination. Using waterborne transport, there is a distinct feeling that the cargo spends most of the time waiting in ports. This is a psychological barrier that must be overcome if Short Sea Shipping shall be successful. Further, high frequency would provide short transit times, thereby also competing with trucking in terms of lead times.

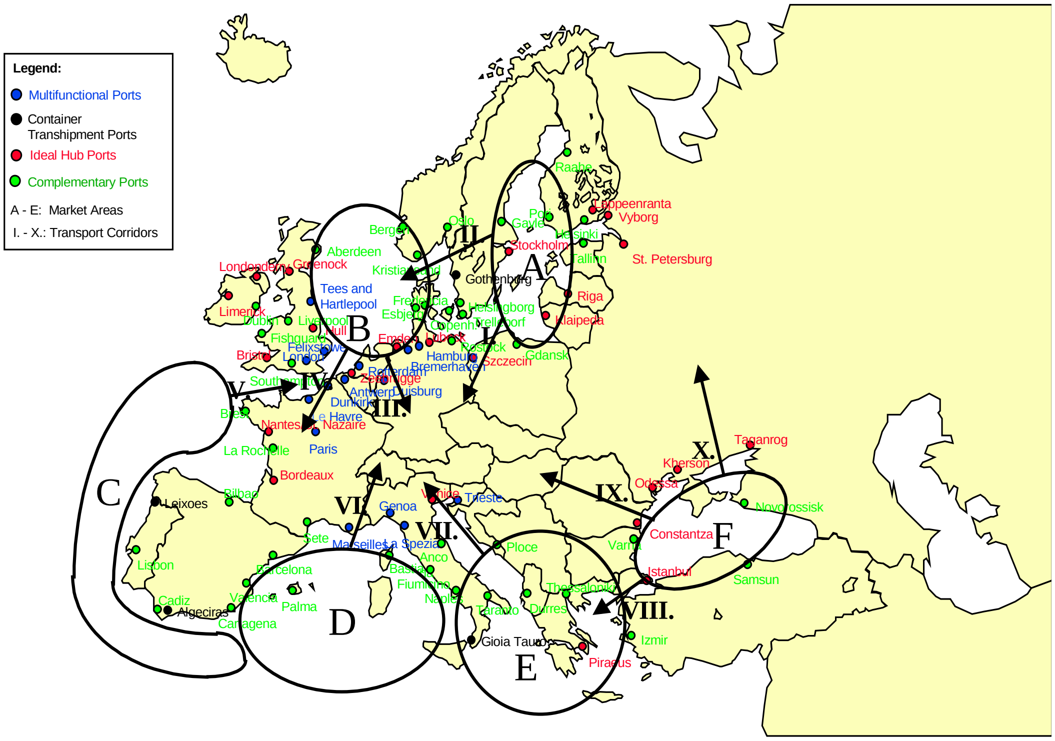

Figure 4-4. Important Short Sea Shipping zones and transport corridors in Europe

- Feeder services
  With feeder services in this context, we will mean sea-born transport serving smaller ports and feedering the direct services defined above. (The concept should not to be mixed with the term short sea feedering to overseas services, which may and will be covered also by direct services). These feeders serve the purpose of bringing cargo between the minor ports in an area, including that of making cargo available at the end ports of the direct service lines.

  The feeder services must be able to call on all ports in the network.

- Inland waterways
  With inland waterway services we mean all transport services using rivers and canals in Europe. For the purpose of IPSI specifications, we will be handling these services

as one group, despite the fact that there are large variations in capabilities, infrastructure, etc.

4.1.3.2 Overseas feedering.

An important part of the present unitised cargo flows handled by short sea shipping is feedering services for overseas (deep-sea) container traffic. Some statistics illustrates the issue. Of the global sea-born container traffic in 1993 (Wijnolst, Wergeland 1996), 18 % (TEUs) were short sea (intra-)European shipping. In comparison, the outgoing traffic from Europe to America and the Far East were 11,1 % and in-going traffic from the same regions were 11,8 %. Although much feedering to overseas lines goes by train and truck, a fair proportion is taken care of by short sea shipping. Figure 4-5 shows the interconnections between the short sea network and the main intercontinental flows.

For the purpose of IPSI specifications, we will handle the interface between overseas and short sea traffic as a transfer operation, although there may be a case for more direct cross docking on shared terminals.

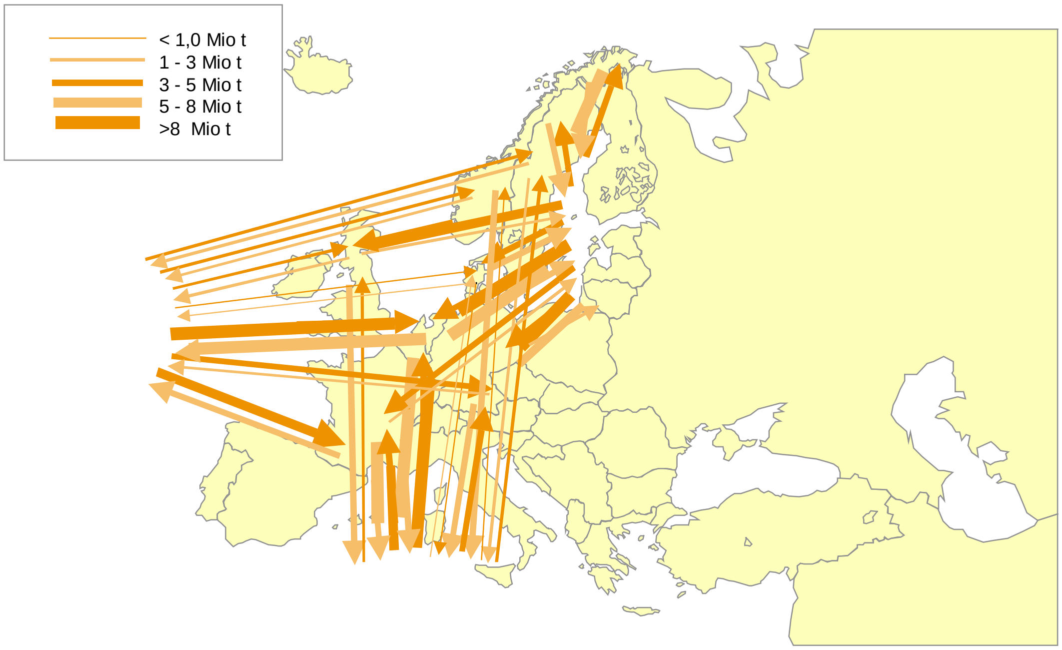

Figure 4-5. Intercontinental flows and Geographical European network of Ports

4.1.3.3 Cargo Containment Units.

In order to be efficient, the Short Sea Shipping concept must be based on handling a minimum set of standard cargo containment units. Ideally, only one type of unit should be used. However, the development of containment units on land and at sea has been going on for a long time, and there is a significant population of cargo containment units in circulation. Hence, it is unthinkable that anyone may be able to introduce a widely accepted service for Short Sea Shipping if the condition was made that all current cargo containment units must be discarded.

In IPSI, we have come to the conclusion that the types of cargo containment units described in this section shall be supported effectively. Furthermore, the IPSI project will actively investigate ways and means for cargo that normally does not utilise such units, to change to unitised, waterborne transport.

- The ISO-container

  This is a family with a constantly growing number of members. In common they have the requirements for top-lift handling, stackability and the outer width dimensions.

  The most common dimension for length is 20 feet and 40 feet. The height is between 8 feet to 10.5 feet. The breadth is 8 feet.

  The breath is in conflict with pallet standards in inter-European traffic as the internal dimension is less than a multiple of the Euro-pallet breadth of 1.2 m. This has fostered the introduction of a number of containment units allowing two Euro-pallets abreast. These units can be taken on both rail wagons and trucks.

  Today there are more than 7 millions ISO-boxes world wide, which makes it the dominating unit for the ocean going traffic. The total number of units (TEUs) carried yearly are more than 100 millions of which seagoing traffic has a share of little less than 30 %. The carrying capacity of the cellular ocean going container ship fleet is steadily growing. The number of «post-panmax» vessels with a capacity of 5,000 TEU and more is increasing.

  This growth imposes demands for heavy investments in those ports that have the ambition of maintaining their role as «central ports».

  The number of central ports has a tendency to decrease in number while remaining central ports grow in size. A pronouncing factor is also that the big container ships want to minimise the number of calls per voyage. This means an increasing feeder traffic with ships of size 200 TEU to 800 TEU with possibility to call smaller ports, including river ports, closer to the customer.

  As a consequence of the development described, the fleet of geared container feeder ships is also growing.

- The Cellular Pallet-Wide Container (CPC)
  This type of unit can briefly be described as an ISO-box with internal width sufficient for two Euro-pallets abreast. The corner castings are located as for the ISO-box, but in between those, the external width is increased to 2.5 m, which is the same as for truck max. width. The CPC-box is liftable and stackable as for the ISO-box and can be handled in the cell arrangement of most box-ships.

  The CPC-box was invented and introduced some 10 years ago by Bell Line for the trade UK/Ireland-Rotterdam and are also applied in pendulum train to some inland European destinations like Milan.

  The CPC-box has gained an increasing market share and coverage across Europe. Several users are considering this to be a containment unit with high prospects for intermodal transports within Europe.

  With its capability to be handled in box ships it can also go overseas - something that has already happened (ACL).

  Those patents Bell Line filed for the CPC-box have recently been sold to one of the major equipment leasing companies - CRONOS - who aims at series production thus pressing the prices down to ISO-box level.

  About 20,000 CPC-units exist today in Europe (namely 40’ and 45’). EU recently approved the 45’ unit for road transport.

- Road Vehicles
  The trailer and the chassis are the most common natural containment units for the Inter European RoRo traffic. The only «standard measurement» for this family of units is a max. breadth of 2.5 m (with some exceptions up to 2.6 m). The total length and weight/axle load varies. A standard is under development. The trucking units can participate in sea voyages as attended units, i.e. including truck and driver, or unattended.

  On short voyages (e.g. like Rödeby-Puttgarten) almost 100% of the equipages are attended and the loading/unloading is an extremely fast and cheap operation. The cost associated with carrying the driver together with the cargo is however increasing with the distance of the sea leg providing the sailing time is longer than the required resting hours for the drivers. As a consequence, longer voyages (e.g. like Gothenburg-Gent) it will generally be too expensive to carry truck and driver. Costs will then occur at the handling of the trailer by port personnel.

  With increasing voyage distances, there is also a breaking point where carrying the trailer wheels would be uneconomical, (e.g. like Gothenburg-Piraeus), as compared to only taking the containment unit only like e.g. the container.

The potential to improved competitiveness for combined land-sea-land voyages compared with direct road or direct rail is derived from concentration of cargo to motivate high frequency sea voyages.

As an example, in the traffic Gothenburg-Gent there is already at a frequency of two sailings per day obtained a lead-time for the cargo equal to what is achieved by direct trucking.

The combined land-sea voyage often provides an environmental friendly solution with outstanding low energy consumption per ton cargo compared to direct trucking. Also in comparison with direct train transports the energy consumption may be quite favourable.

- The Swap-Body
  The swap-body is an effective containment unit made for trucks with adjustable air suspension. The principle for its handling is that the driver without external assistance can load and unload the unit.

  The swap-body exists in a few «standard-lengths» (e.g. 7,15 m and 7,82 m) and has an internal width permitting two Euro-pallets abreast. Although European recommendations goes for the 7,15 and 7,82 units, in practice there exist a broad variety of lengths.

  The swap-body is not stackable and is not directly sea going but has to be stowed on a terminal wagon or together with the truck. In terms of cost, the swap-body is an expensive unit - about 3 to 3.5 times the corresponding ISO-unit. A major reason for this is the limited series.

  An interesting member of this group is the container rack that is a flat rack (with or without collapsible walls). This has the same dimensions and requirements for handling as the bottom of the ISO container.

- Heavy Duty Cassettes
  This group covers a broad variety of dedicated and some semi-standardised units designed mostly for high-density industrial cargo.

  The semi-standardised units applied in particular in Scandinavia and the Baltic are the cassettes. They can be described as heavy-lift flat-racks, or «rolltrailers without wheels». A normal carrying capacity for a cassette is 50 to 60 tonnes.

  Special units called «translifters» handle the cassettes. The translifter is a low wagon with a hydraulically liftable top, pulled by a tug-master. The wheels for the RoRo units will then be on the translifters. For easy handling and manoeuvring of the cassette units, the translifters are often equipped with sensors.

The cassettes have been popular as containment units for cargoes with high density like paper and steel. It is also used in combinations with other containment units like containers and flat-racks which are then put on top of and secured on the cassette. The role of the cassette will then be to serve as «a roll-trailer without wheels» which in some cases may give cost advantages compared with standard rolltrailer systems, and may additionally provide for an increased stowage factor and simplified lashing in the vessels.

A common dimension is 2.5 m width and 12.5 m length. The cassette cannot be transported by truck and - for the moment - nor by rail. For the latter an intensive development is going on in Sweden. It is at the time being well suited for, but limited to, sea going transports - terminal to terminal.

Development of cassettes with higher capacities is a continuous effort.

4.1.3.4 Cargo Handling

With reference to the previously described taxonomy of Short Sea Shipping, the specification of requirements will be divided into three classes:

1. Direct line connections, supporting the main legs.
2. Feeder lines - feedering the direct lines.
3. Inland waterways.

For each of the three scenarios, the following requirements will be specified:

- Unloading operations:

  Unloading capacity (speed)
  Cost of operations
  Technical requirements to the transport units
  Terminal movements and positioning of cargo after the actual
  Technical requirements given by the cargo in terms of shocks, vibrations
  and other transport environmental requirements (temperature, humidity)
  Requirements to containment units if any deviations from standards occur

- Terminal movements:

  Cargo positioning system
  Scheduling and positioning of cargo for fast loading operations
  Cross-docking functionality in cargo transfer between transport units

- Loading operations:

Loading capacity (speed)
Cost of operations
Technical requirements to the transport units
Positioning of cargo units within transport unit
Lashing and stowing systems for cargo within transport units (vessels)
Technical requirements given by the cargo in terms of shocks, vibrations and other transport environmental requirements (temperature, humidity)
Requirements to containment units if any deviations from standards occur

Most probably the loading and unloading functionality will be based on horizontal movements of cargo. The system should provide for the necessary flexibility of cargo units to be handled either individually or if more effective in modules of several units.

- General Requirements

  The following requirements will be general across the requirement classes.

  In general, the cargo handling should not be in conflict with the technical requirements given by the cargo in terms of shocks, vibrations and other transport environmental requirements (temperature, humidity). The system shall meet the strongest requirements in terms of avoidance of physical damage to cargo caused by shock, vibrations and physical movements. For documentation purposes, the characteristics of the critical movements for each cargo unit should be monitored and made auditable. The actual time without energy supply to units carrying cooled, frozen or heated cargo should be made small enough to avoid any impact of cargo. As a norm, this time should be less than 0,5 hour or smaller when specified special cargo requirements.

  The system’s requirement to containment units should be consistent with the ISO equipment’s’ standards in terms of location and construction strengths for fixing points for cranes, handling equipment’s and lashing points. If additional requirements to the construction of containment units should result from the design of the handling system, these should be as few as possible and should not cause any direct conflict with existing standards.

  As to safety requirements for handling of dangerous cargo, the system shall handle units with dangerous cargo according to the rules and regulations set for cargo classified by IMO’s IMGD. Generally, the cargo handling system shall be designed for standard (non-hazardous) cargo. It must however be able to handle the portion of dangerous cargo, which generally are allowed for transportation on standard RoRo and container vessels without any additional modifications or precautions.

  For the required safety level for people involved in the operations, the operations shall be made according to the highest level of European (EU) national safety rules and regulations, and within the objectives of zero system induced injuries on life or health.

Table 4-11 shows general cargo handling requirements.

Table 4-11. General requirements

Requirement:	**Target:**	**Measurements:**
No damages due to physical stress or environment	Zero impact on cargo	Deviations from target. Physical measurement of movements, accelerations and shocks compared with cargo requirements.
No breaking in cooling/heating capabilities	0,5 hours break or less.	Deviations from target
Consistency with ISO standards (annex 2) for handling points	Zero deviations from standard	Deviations from target.
Induced conflict with ISO standard requirements (annex 2) by additional installations	Zero conflicts with standards	Deviations from target.
Accordance with IMO regulations for handling of dangerous cargo	Zero deviations from regulations	Deviations from target
Safety	Zero injuries	Deviations from target.
European and national safety regulations	Zero deviations from regulations	Deviations from target.

- Direct, high capacity connections

  In the hubs where direct lines are connected, the main challenge is to make sure that the frequency of direct lines can be supported. This leads to high demands to speed in the cargo handling processes to reduce port times for vessels to a minimum.

  The derived specifications can be split in requirements related to operational efficiency and technical requirements for the processes involved:

  - Unloading operations
  - Terminal movements
  - Loading operations

  Unloading operations

  In terms of operational efficiency, the unloading capacity should be increased compared with present levels of streamlined operations. This means that the targets for the unloading capacity should be in the level of 400 TEU per hour or more, and for the cost of operations the level should be at 25 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual unloading should be direct without breaks in the work process and physical movements.

The detailed technical requirements to the transport units will be set in detail as part of the construction process for the system. As general guidelines, the vessels should not carry with them, as part of their construction, major parts of the cargo handling system if this has any significant impact on their cargo carrying capacity. Further, the land transport units to be covered for feedering purposes, should be standard units.

Table 4-12. Cargo handling requirements for high capacity solutions

Requirement:	**Target:**	**Measurements:**
Unloading capacity	400 TEU / hour	Actual unloading capacity
Cost of operation	25 ECU per TEU	Actual unloading cost
Impact on carrying capacity of vessels	No loss in payload capacity	Deviations from target
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in unloading process

Terminal movements

In terms of cargo handling requirements, the management and operations of the terminal movements for the cargo units must be cost effective and support effective loading and unloading operations. This shall be facilitated by cargo positioning systems allowing the positioning of units to be handled by an automated system. The system shall keep tracks of positions, and allocate positions from the point of view of minimising terminal movements time in the loading and unloading processes. Complete traceability of cargo to cargo units should be kept. The tracking should both identify detailed geographical location and position in stacks (when appropriate).

Further, the demands for scheduling and positioning of cargo for fast loading and unloading operations require that the system should plan the schedule of units to be loaded to minimise loading times. It should further provide for an effective unloading schedule between ports of destination and within the same ports

Increased efficiency may, when feasible, be achieved through cross-docking functionality in cargo transfer between transport units. To get a fast throughput in the terminal, cross docking between the transport units should be facilitated by the system.

Table 4-13. Terminal handling requirements in high capacity ports

Requirement:	Targets:	Measurements:

Cargo positioning	Fully automation of tracking, positioning and allocations	Level of coverage by automated systems
Scheduling of operations	Fully automation scheduling	Level of coverage by automated systems
Cross-docking	Full facilitation of cross-docking	Deviations from target

Loading operations

In terms of operational efficiency, the loading capacity should be increased compared with present levels of streamlined operations. This means that the targets for the loading capacity should be in the level of 400 TEU per hour or more, and for the cost of operations the level should be at 25 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual loading should be direct without breaks in the work process and physical movements.

The detailed technical requirements to the transport units will be set in detail as part of the construction process for the system. As general guidelines, the vessels should not carry with them, as part of their construction, major parts of the cargo handling system if this has any significant impact on their cargo carrying capacity. Further, the land transport units to be covered for feedering purposes, should be standard units.

An additional requirement to the system is related to the positioning of cargo units within transport unit (the vessel). The system should plan the schedule of units to be loaded as to minimise loading times, and to provide for an effective unloading schedule between ports of destination and within the same ports due to further distribution patterns and priority considerations between cargo and cargo owners.

For the lashing and stowing of cargo within the vessels, the system shall provide for automated lashing and stowing operations.

Another important dimension for the cargo handling system’s effectiveness is the lashing within/on to the containment units. This consideration applies in particular for heavy-duty cassettes, and in some cases for less unified cargo on rolltrailer equipment. The cargo shall be secured before loading operations take place. Requirements to simple and fast solution based on units or special cargo on cassettes and rolltrailers shall be a part of the cargo handling systems. Further, fast and efficient lashing and stowing within container and flat-rack units shall be included as part of the system.

Table 4-14. Loading requirements in high capacity solutions

Requirement:	Target:	Measurements:
Loading capacity	400 TEU / hour	Actual loading

		capacity
Cost of operation	25 ECU per TEU	Actual loading cost
Impact on carrying capacity of vessels	No loss in payload capacity	Deviations from target
Positioning of cargo within vessels	Automated planning capabilities	Coverage of automated capabilities
Automated lashing and stowing	Automated lashing and stowing systems in vessels	Deviations from target. Time and cost of lashing operations
Lashing of cargo on heavy-duty cassettes and roll-trailers, and within containers.	Depends on cargo (differentiated targets to be set)	Time and cost of lashing

- Feeders

  The main challenge for the feeder cargo handling is a combination of short lead times and cost effectiveness. In relative terms, the priorities will be stronger towards cost efficiency as compared to the direct lines.

  The derived specifications can be split in requirements related to operational efficiency and technical requirements for the processes involved in the same way as for the direct lines as unloading operations, terminal movements and loading operations.

  Unloading operations

  In terms of operational efficiency, the cost level will have priority above the capacity when comparing with present levels of streamlined operations. This means that the targets for the unloading capacity should be in the level of 50 TEU per hour or more, and for the cost of operations the level should be at 20 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual unloading should be direct without breaks in the work process and physical movements.

  The detailed technical requirements to the transport units will be set in detail as part of the construction process for the system. As general guidelines, the vessels should not carry with them, as part of their construction, major parts of the cargo handling system if this has any significant impact on their cargo carrying capacity. Further, the land transport units to be covered for feedering purposes, should be standard units.

Table 4-15. Unloading requirements for feedering ports

Requirement:	Target:	Measurements:
Unloading capacity	50 TEU / hour	Actual unloading capacity
Cost of operation	20 ECU per TEU	Actual unloading cost

Impact on carrying capacity of vessels	No loss in payload capacity	Deviations from target
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in unloading process

Loading operations

In terms of operational efficiency, the cost level will have priority above the capacity when comparing with present levels of streamlined operations. This means that the targets for the loading capacity should be in the level of 50 TEU per hour or more, and for the cost of operations the level should be at 20 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual loading should be direct without breaks in the work process and physical movements.

The detailed technical requirements to the transport units will be set in detail as part of the construction process for the system. As general guidelines, the vessels should not carry with them, as part of their construction, major parts of the cargo handling system if this has any significant impact on their cargo carrying capacity. Further, the land transport units to be covered for feedering purposes, should be standard units.

An additional requirement to the system is related to the positioning of cargo units within transport unit (the vessel). The system should plan the schedule of units to be loaded as to minimise loading times, and to provide for an effective unloading schedule between ports of destination and within the same ports due to further distribution patterns and priority considerations between cargo and cargo owners.

For the lashing and stowing of cargo within the vessels, the system shall provide for automated lashing and stowing operations.

Another important dimension for the cargo handling system's effectiveness is the lashing within/on to the containment units. This consideration applies in particular for heavy-duty cassettes, and in some cases for less unified cargo on rolltrailer equipment. The cargo shall be secured before loading operations take place. Requirements to simple and fast solution based on units or special cargo on cassettes and rolltrailers shall be a part of the cargo handling systems. Further, fast and efficient lashing and stowing within container and flat-rack units shall be included as part of the system.

Table 4-16. Requirements for loading in feedering ports

Requirement:	Target:	Measurements:
Loading capacity	50 TEU / hour	Actual unloading capacity

Cost of operation	20 ECU per TEU	Actual unloading cost
Impact on carrying capacity of vessels	No loss in payload capacity	Deviations from target
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in unloading process

- Inland Waterways
  The main challenge for cargo handling in inland waterways is a combination of short lead times and cost effectiveness, with a strong emphasis on cost efficiency. Further, the investment needs in the cargo handling system should be kept as low as possible both for terminal operators and the barge owners.

  Unloading operations
  In terms of operational efficiency, the cost level will have priority above the capacity when comparing with present levels of streamlined operations. This means that the targets for the unloading capacity should be in the level of 50 TEU per hour or more, and for the cost of operations the level should be at 20 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual unloading should be direct without breaks in the work process and physical movements.

  For the technical requirements to the transport units, in principle all standard units (including barge RoRo-services) should be handled.

Table 4-17. Unloading requirements for inland waterway ports

Requirement:	Target:	Measurements:
Unloading capacity	50 TEU / hour	Actual unloading capacity
Cost of operation	20 ECU per TEU	Actual unloading cost
Transport units	Ability to serve standard units (barges, trucks)	Coverage of standard units
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in unloading process

Loading operations
In terms of operational efficiency, the cost level will have priority above the capacity when comparing with present levels of streamlined operations. This means that the targets for the loading capacity should be in the level of 50 TEU per hour or more,

and for the cost of operations the level should be at 20 ECU per TEU or less. Operationally, the terminal movements and positioning of cargo after the actual loading should be direct without breaks in the work process and physical movements.

For the technical requirements to the transport units, in principle all standard units (including barge RoRo-services) should be handled.

Table 4-18. Loading requirements for inland waterway ports

Requirement:	Target:	Measurements:
Unloading capacity	50 TEU / hour	Actual loading capacity
Cost of operation	20 ECU per TEU	Actual loading cost
Transport units	Ability to serve standard units (barges, trucks)	Coverage of standard units
Direct movements in operational process	Zero breaks between unloading and positioning in terminal	Number of breaks in work process and movements in loading process

4.2 IPSI Cargo Handling

4.2.1 Outline of a Cargo Handling Concept

The requirements for intermodal transportation is that the transport is well planned and that the changes between transport modes are streamlined so that the most suitable transport mode can be used for each section of the total distance. The purpose of the IPSI project is to improve the port to ship interface regarding physical handling and planning to make short sea shipping the best choice for as large part as possible of the total transport distance. The focus of the concept will be the port to ship handling. The port to ship handling of the cargo units will also draw up some of the requirements for the vessel design.

The transport chain for transportation starts at the cargo owner and ends at the consignee. The following table describes the different links that can be identified within the intermodal chain with focus on short sea shipping.

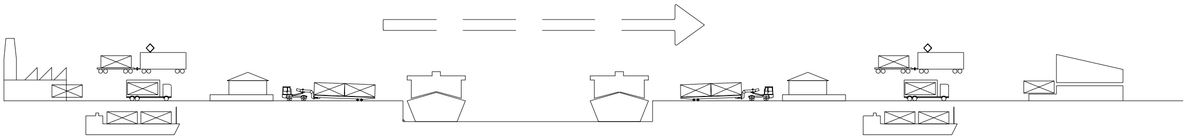

Figure 4-6. The intermodal transport chain

The complete cargo handling system will be built up by individual sub systems that can be used independently from each other. What degree of automation/investments a trade can motivate will determine which sub systems within the complete IPSI system to adopt. The conditions like terminal situation, cargo profile, speed demand and frequency will be critical decision factors.

The sub systems in Table 4-19 will form the IPSI Cargo Handling System.

Table 4-19. Bricks in the IPSI cargo handling system

1.	**Mode to mode transfer** IPSI truck cargo releaser IPSI railway wagon cargo releaser
2.	**Terminal handling** IPSI planning system IPSI AGV train system including IPSI control system
3.	**Shore to ship transfer** IPSI train system including IPSI control system IPSI ramp system
4.	**Automatic lashing** IPSI lashing system
5.	**Vessel design** IPSI vessel concept

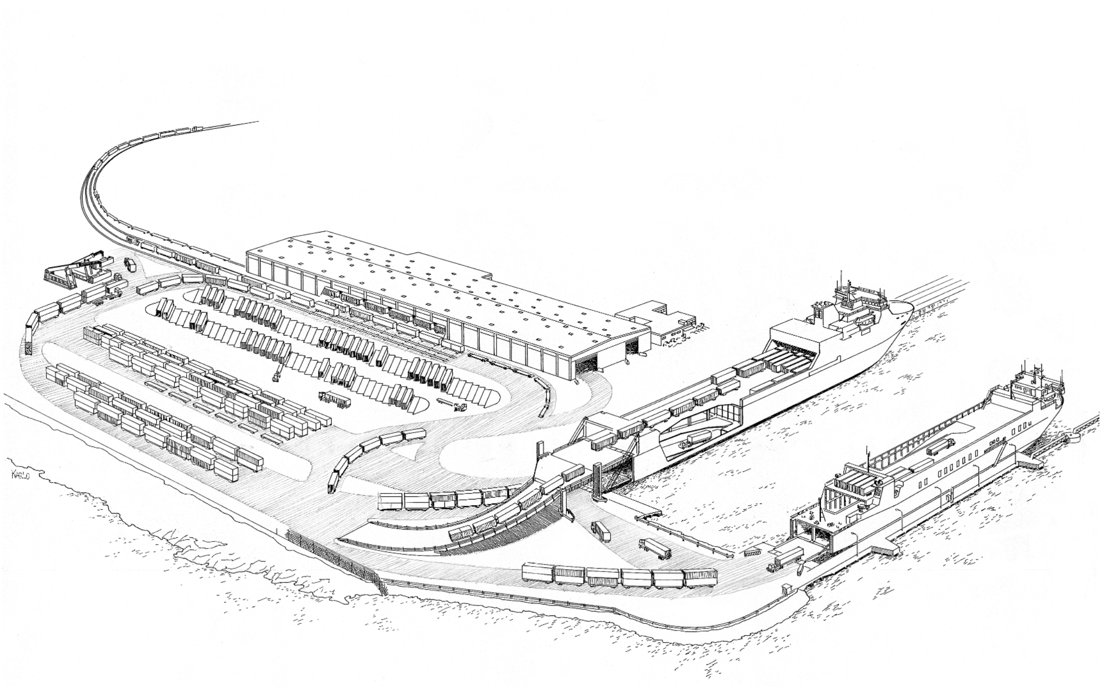

Figure 4-7. Artist impression of the IPSI Cargo Handling System implemented in a typical intermodal Short Sea Shipping terminal.

4.2.2 Port to ship handling

4.2.2.1 General

To find the best way to load and unload a ship has engaged people for as long as there have been floating crafts on the earth. It is hard to find anything else in the transport chain that, for so many years, has engaged so many people in the hunt for perfection and economy. One must respect the history. The latest revolutionary change in this area, besides the containerisation, was the development of the RoRo concept for commercial use in the 1950s. Even if the RoRo technique started a completely new era regarding cargo handling it is hard to define what was so new about it, except for the way it combined well-known techniques.

In this work package it became clear for us very soon that the key to improvement was to find new ways to combine existing knowledge. Therefore, we started out with a mapping of existing systems and state-of-the-art for cargo handling techniques.

Basically there are two different ways to handle cargo between terminal and ship:

- Vertical handling
- Horizontal handling

These two basic techniques can be further split into sub groups and there are many examples of existing, sophisticated systems today.

In the literature there are numerous examples of bright ideas and some of the ideas have been tested. Many of those have failed for one reason or another. One observation is that highly sophisticated systems need a steady cargo flow and well-defined cargo units. High investment barriers and lack in flexibility are often the drawbacks of these systems, and sometimes the reason for less successful implementations.

Typical characteristics for horizontal handling are high speed and flexibility. For vertical handling, the typical characteristics are efficient ship and space utilisation.
With the conditions that were set before this work package, speed and flexibility was given high priority. Bearing in mind that we are trying to create alternatives to long distance road trailer traffic, it is quite obvious that speed and flexibility are what have to be improved. After reaching that level of understanding, it was decided that for dual and multi port traffic we needed a RoRo concept. It is our belief that this RoRo concept will be attractive also to some parts of the inland waterway traffic. Where the demand for cargo handling speed is less and the space utilisation is more important due to the limited vessel dimensions, traditional lolo technique will be recommended for inland waterway traffic.

The requirements for intermodal transportation is that the transport is so well planned and the changes between transport modes are so streamlined that the most suitable transport mode can be used for each section of the total distance. This means that traditional techniques will be used for some parts within the chain also in the future, and that they will benefit from the removed bottlenecks within e.g. the terminal logistics for the intermodal change between inland waterway traffic and short sea shipping.

4.2.2.2 Brief description of existing cargo handling systems

Regarding RoRo technology basically no specialised equipment at all is required. The extensive ferry traffic is a good example where all types of vehicles are handled. By adopting specific handling systems and purpose built vehicles the cargo handling production can be increased.

When forming the IPSI cargo-handling concept a number of existing cargo-handling systems were identified and used as a starting point for the development.

LUF system

LUF, Large Unit Frame, was developed somewhat prematurely almost twenty years ago. It consists of large skeleton-pallets (frames) that are handled fairly well by a very heavy mining tractor and a special trailer. Capacity in the most advanced model is eight TEU and 160 tonnes. By preparing the containers into larger units the actual shore to ship handling was improved. It was developed beyond the prototype stage, but has been more or less abandoned after the trailer literally sank through the terminal tarmac.

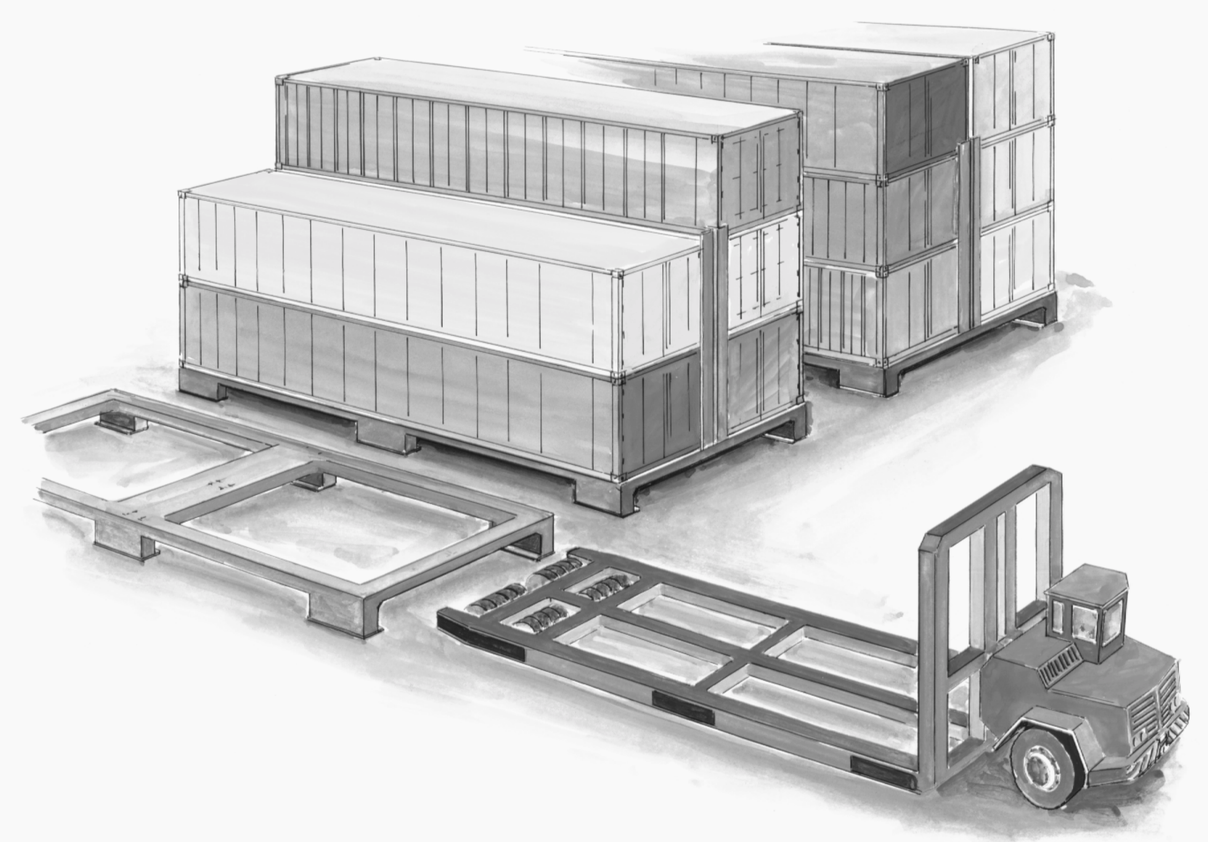

Figure 4-8. Large Unit Frame System

Translifter/cassette system

Electrolux introduced the translifter/cassette system more than ten years ago. The brand name of the Electrolux system is RoLux. A number of other companies are now selling similar solutions that are fully compatible with the original system.

The components within the system are the cassette, the trailer and the terminal tractor.
The cargo is loaded and secured on the wheel-less cassette. A trailer is then placed under the cassette. A hydraulic lifting arrangement lifts the trailer and cassette approximately 300 mm. The trailer with the cassette is then transported onboard the ship by a terminal tractor. The cassette is put down in the ship.

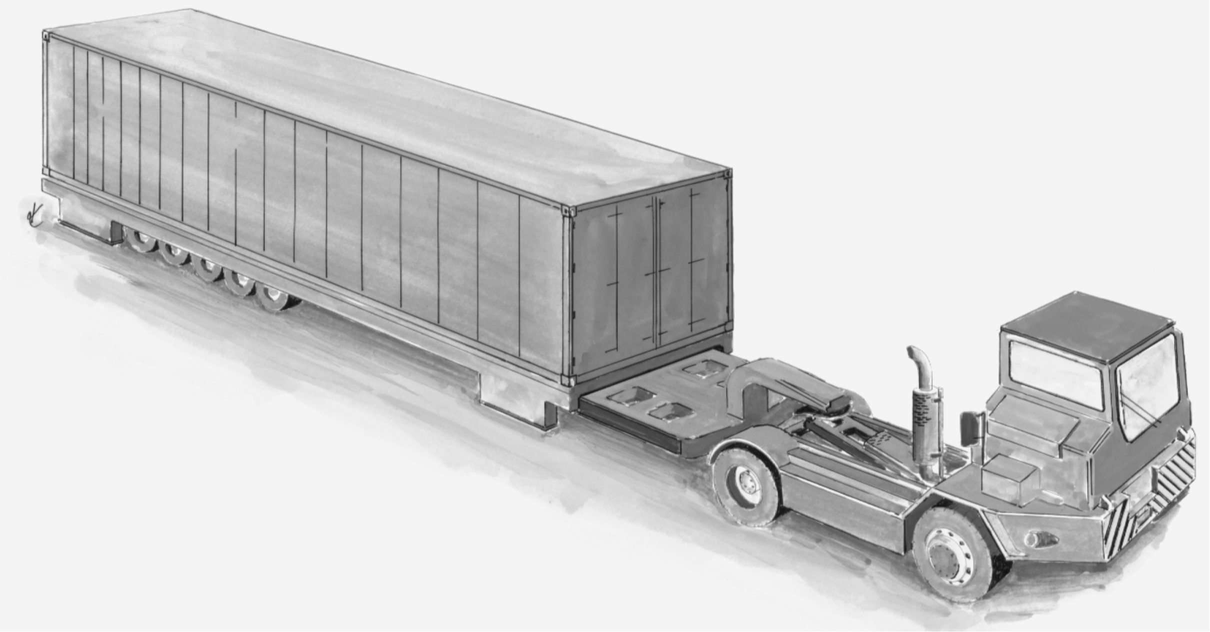

Figure 4-9. Translifter/cassette system

<u>CASH</u>

CASH, Cassette Aboard Ship, is the only non-RoRo system that was found able to meet the capacity requirements of IPSI. The CASH system is a lolo system based on a purpose built ship and large cassettes with a gross weight of 70 tons. The ship is designed to take 280 large cassettes. The system is fully automatic with two computer controlled onboard gantry cranes loading and discharging the units over the stern. Trucks with hydraulic liftable trailers handle the terminal movements. The CASH system is developed by Ahlmark Lines in Karlstad, Sweden and has not yet been realised.

<u>AGV</u>

AGV, Automatically Guided Vehicle, is today a driver-less vehicle used in container terminals for transporting containers from the stowage area to the quay cranes.

4.2.2.3 Characteristics of the IPSI Port to Ship Handling System

Among existing techniques the AGV, Automatically Guided Vehicle, is a rather new concept that has a good developing potential. By combining the vehicle with the train concept presented e.g. by professor Wijnolst, a flexible high capacity cargo handling system can be formed. The system we have chosen to develop has the following main characteristics.

- Automatically Guided Vehicle assembled into sets of several carriages
- Length of vehicle approx. 12.6 m and extendible to take 45’ ISO and CPC containers and high cubic swap bodies
- One unit abreast and one layer, optional two layers high
- Navigation by magnetic cable, laser, optical system or DGPS

- Train sets to serve both main and weather decks. Double stack on main deck, single stack on weather deck.
- Cargo units to be put down onboard, carriages normally to stay ashore. Though for certain conditions it might be advantageous to have the handling equipment sailing with the vessel.
- Mode to mode transfer system where a railway train discharges a number of units automatically and simultaneously and where the rubber carriage train loads all units automatically and simultaneously.
- Onboard lashing to be automated

One important feature with the proposed concept is that there will be no restriction to use conventional handling techniques parallel with the AGV train system.

4.2.2.4 The Direct Affects of the Cargo Handling Concept on the Vessel Design

To obtain full benefit from the cargo handling system the vessel must have a full width stern ramp, straight lanes, and simultaneous access to main and weather deck. To increase the handling speed regarding positioning and lashing within the ship it will be recommended that removable curbs are fitted between the lanes.

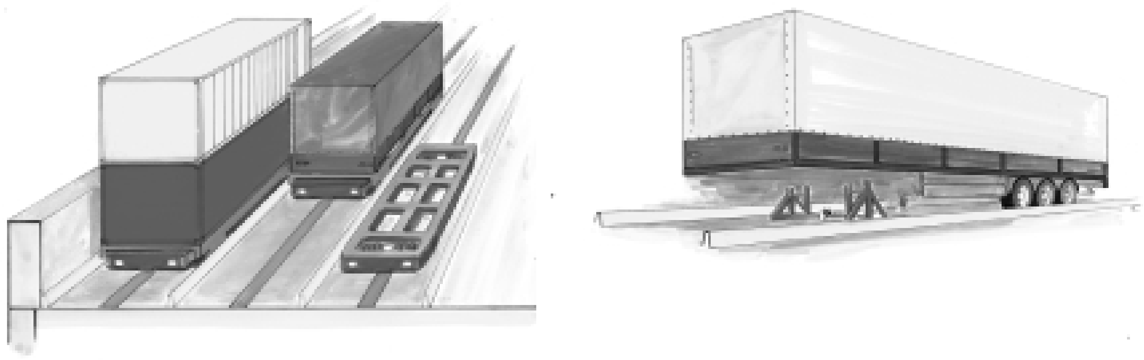

Figure 4-10 Curbs between lanes for increased handling speed

4.2.2.5 Evaluation of different concepts

To get an idea of the competitiveness of the chosen concept, the evaluation table (Table 4-20) was set up.

By this table the best choice, if just counting the pluses and minuses, would be the trans-lifter concept. The choice to develop the rubber wheel carriage train system was made due to the fact that the basic criteria high loading speed and low personal intensity are fundamental for this project. A lot of the IPSI sub systems in the cargo handling chain like mode to mode transfer, lashing, organisation, administration can be implemented regardless of what type of shore to ship handling system that is used.

Table 4-20. Evaluation table

Function	**IPSI train system**	**Rail bound train**	**LUF**	**Trans Lifter**	**CASH**
Unit to be handled					
ISO Containers	**B**				
Swap body			-		-
Road trailer	**E**				-
Dedicated cargo handling equip.			-		-
Level of technical complexity	**N**	+	+	+	-
Cost effectiveness					
Reliability	**C**			+	
Flexibility		-		+	-
Degree of personal intensity				-	
Possibility of gradual implementation	**H**	-		+	-
Pay load/ tare weight	**M**				-
Interface					
Interface to rail		-	-	-	-
Interface to road	**A**	-			-
Interface to inland water way		-			
Automatic lashing			-		+
Terminal handling	**R**	-	-		-
Initial terminal investments		-			-
Max. Loading capacity TEU/h or tons/hr	**K**	+		-	
Scalability					-
Maintenance		+		+	-
Ship utilisation					+

4.2.3 IPSI

4.2.3.1 Automated Guided Vehicle (AGV)

Automated Guided Vehicles are today used in ports only to transport cargo between shore cranes and storage cranes. By building the vehicle very low and installing lifting cylinders, the vehicle can pick up cargo at the terminal by itself. The IPSI AGV is designed to fit under the standard cargo cassettes on today’s market, see Figure 4-11. These cassettes are standardised and designed to hold double stacked containers, both 20´ and 40´. The AGV will enter under the cassette and lift it 350 mm.

Furthermore the IPSI AGV system has a built-in function that allows the AGVs to run in a train formation without being mechanically connected. This means that a set of AGVs running in train formation can pick up a complete ship length of cassettes at one time and transport it onboard. Onboard the ship, the AGVs will lower the cassettes onto the deck and when leaving, the AGVs will activate an automatic lashing device. The AGVs are terminal bound, while the cassettes always follow the cargo.

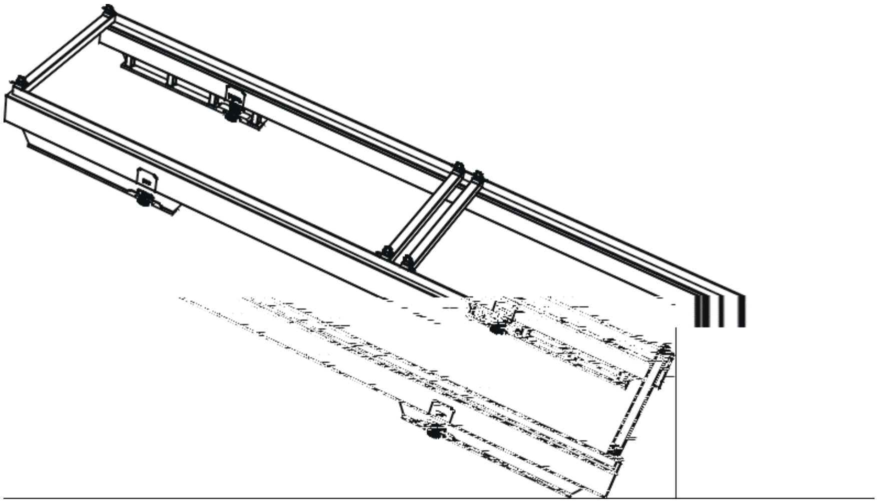

Figure 4-11. The IPSI cassette

Technical specification of the AGV

Figure 4-12 illustrates (in an “exploded view” how the AGV is positioned underneath a cassette holding 4 TEU of cargo. Table 4-21 shows the technical characteristics of the AGVs.

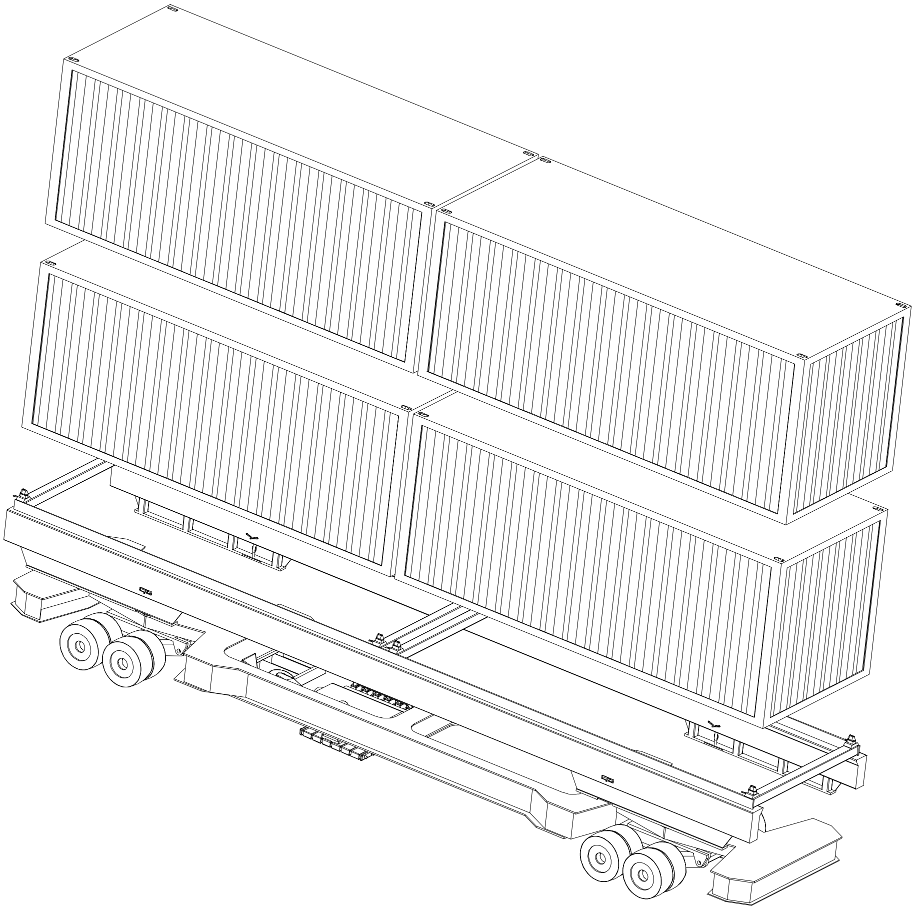

Figure 4-12. Exploded view of AGV under a cassette holding 4 TEU

Table 4-21. Technical characteristics of the AGV system

AGV Chassis	
Length	12.2 m
Width	2.34 m
Height	650 mm
Lifting distance	350 mm
Weight	12 tonnes
Loading capacity	82.5 tonnes
Lifting cylinders	2 x Ø200 stroke 250 (single acting)
Turning radius	18 m
Steering cylinders	2 x Ø80/40 stroke 450 (double acting)
Climbing capacity	4º (1/14)
Wheels	645x250 - 410 solid rubber wheels
Propulsion	Hägglunds radial piston Hydraulic motors, two pcs 12-00850 and two pcs 32-02200 max pressure 350 bar
Main engine	Propulsion Diesel Engine Volvo Penta THD102KB 9.6 L 210 kW 2200 rpm
Hydraulic pump	Sauer-Sundstrand series 90 Axial Piston Variable Displacement pump 250 cm^3
Brakes	Svendborg Brakes BSFG 415 Braking force 120 kN at 280 bar.
AGV Cassette	
Length	12.2 m
Width	2600 mm
Height	850 mm
Weight	3.5 tonnes
Loading Capacity	78 tonnes
AGV Control system	

Design of the AGV chassis

The AGV chassis consists of a rigid steel frame with an eight-wheeled double boogie in each end. The complete manoeuvring of the AGV is done hydraulically. A 210 kW horizontal diesel engine is fitted in the central part of the frame together with a hydraulic axial piston pump with variable displacement. Four hydraulic wheel motors are fitted symmetrically on the AGV, one on each side of each boogie. Each boogie is equipped with two hydraulic disc brakes to ensure a safe and short emergency stopping distance. Turning of each complete boogie does the steering of the AGV. Two double acting hydraulic cylinders fitted between the steel frame and the turntable of each boogie turns the boogies relative to the frame. The turning of the forward and the rear boogie are independently controlled to maximise the manoeuvrability of the vehicle.

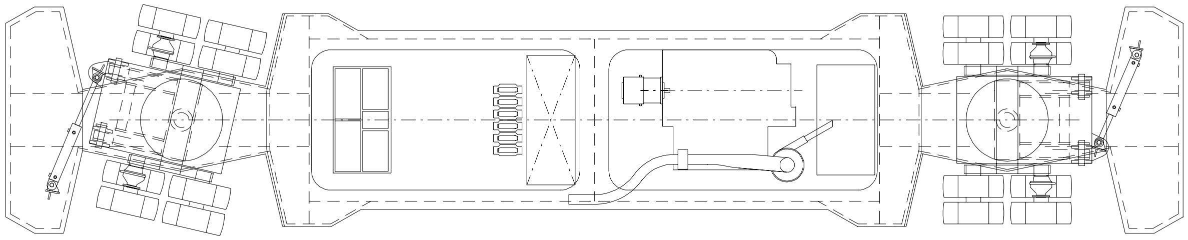

Figure 4-13. Arrangement of AGV chassis

Two plunge type hydraulic cylinders, one in each wheel boogie, lifts the chassis 350 millimetres. The flow to the lifting cylinders are connected via a flow divider to ensure that the chassis is lifted in parallel, independent of uneven distributed load.

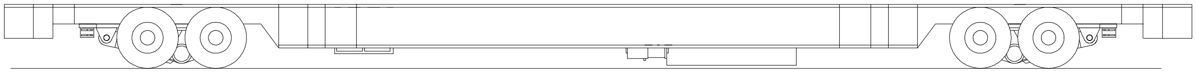

Figure 4-14. AGV chassis in lowered position

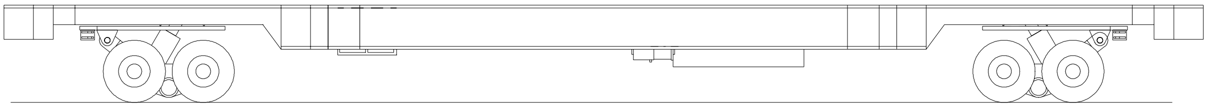

Figure 4-15. AGV chassis in lifted position

<u>Boogie design</u>

The main components of the boogie are the turning table, the main link and the two wheel yokes. The turning table is connected to the chassis via a conical bearing. The main link is a rigid steel frame working as the hinge between the turning table and the wheel yokes. The lifting cylinder is connected to the main link with a ball joint allowing free angular movement relative to the link when the chassis rises. The main design criteria for the boogie is to allow 350 millimetres lifting height using a lifting cylinder with the shortest possible stroke. This has to be done because of the limited space available when the vehicle is in its lowered position. The limiting design criteria for the steering cylinder turned out to be to be the limitation of the maximum allowable stroke before buckling of the piston. The stroke of the piston is designed to allow a turning angle of the boogie of 15°.

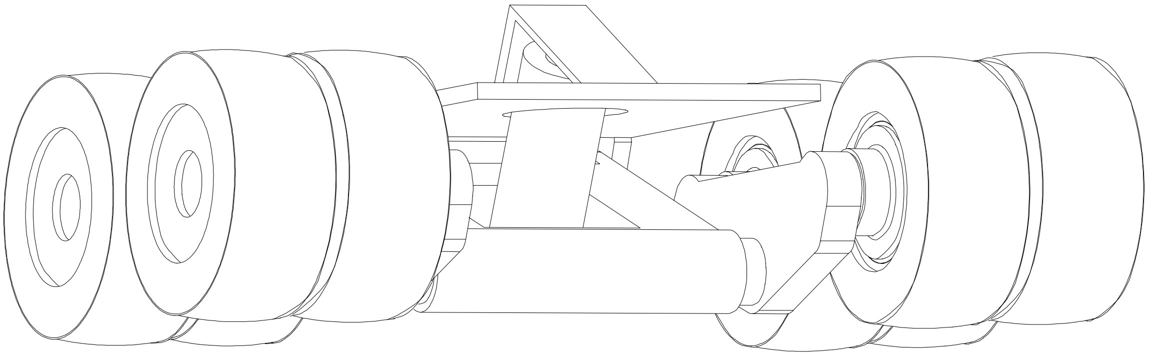

Figure 4-16. Boogie arrangement with lifting cylinder

Stability

A theoretical limitation to the maximum allowable speed when turning is the centrifugal force acting on a double stacked cassette. The figure below shows that the resulting force of the centrifugal force and gravity force of the load is well inside the wheelbase. The example shown uses a speed of 10 km/h and a turning radius of 18 meters. (The gravity force and the resulting vector has been cut to make the figure readable)

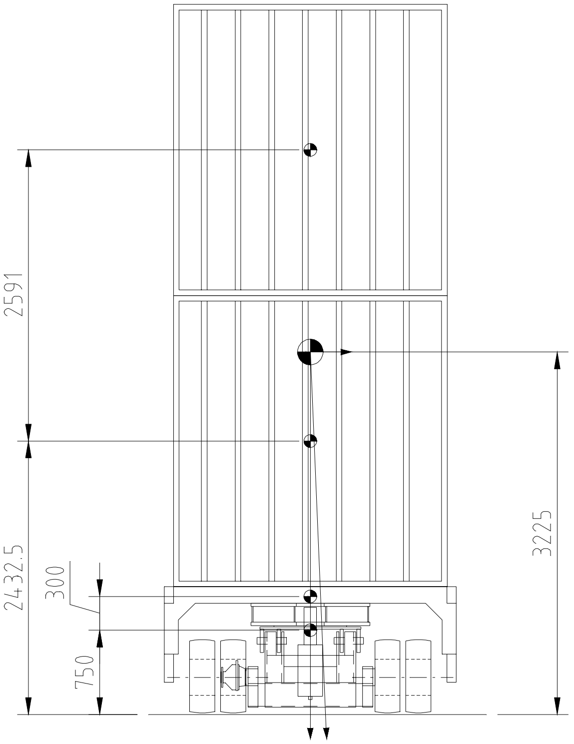

Figure 4-17. Centrifugal and gravity force and their resulting vector

When turning there is also a possibility that the vehicle starts slipping at a certain speed. This happens when the centrifugal force exceeds the frictional force. Since both forces include the moving mass, the mass actually becomes irrelevant. The maximum speed then depends only on turning radius, earth gravity and the frictional coefficient. With a turning radius of 18 m and a friction coefficient of 1, (applies for dry road), the maximum speed possible is 14 m/s which is far greater than design speed.

4.2.3.2 Cassette design

The cassette has the same general dimensions as the translifter type cassette used today in e.g. the Rolux system, see Figure 4-11. The cassette in the IPSI system will be designed to handle unitised cargo why there will be no need for a loading surface on the cassette. The cassette will be built as a steel frame with container corner castings to fit pattern for 20’ and 40’ containers.

4.2.3.3 Hydraulic system

Capacities and characteristics

Table 4-22 shows the capacities and characteristics of the hydraulic system of the IPSI AGV.

Table 4-22. Capacities and characteristics of the hydraulic system

	Loaded, climbing	**Loaded, on flat ground**	**Empty, on flat ground**
Tractive effort, F (daN)			
F = G * (sin(alfa) + Rr * cos(alfa) + a/g)	8388	1870	240
4 x 20´ container 4 x 19,5 tonnes	78000	78000	0
AGV Chassis	12000	12000	12000
Cassette	3500	3500	0
G (vehicle weight kg)	93500	93500	12000
Rr (rolling resistance)	0.02	0.02	0,02
a (acceleration m/s2)	0	0	0
alfa (road grade)	4	0	0
Total motor torque, Mvtot (daNm)			
Mvtot = F * R	2726	608	78
R (wheel radius, static m)	0.325	0.325	0,325
Pressure differential required, deltaP (bar)			
deltaP = Mvtot/z/mv/etahm	295	183	30
z (number of motors)	4	2	2
mv (specific torque for wheel motor daNm/bar)	2.43	1.75	1,36
etahm (hydromecanical efficiency)	0.95	0.95	0,95

Wheel motor speed, v (rpm)			
n = v * 1000/(2*R*pi*60) rpm	57	163	245
v (vehicle speed) km/h	7	20	30
Oil flow required, Q (lit/min)			
Q = z * n *Vi * 1/etavol	370	378	438
Vi (displacement of the wheel motor lit/rev)	1.5375	1.1	0,85
etavol (volumetric efficiency for the wheel motor)	0.95	0.95	0,95
Axial pistons variable Displacement Pump			
Max displacement (cm^3)	250	250	250
Rated input speed (rpm)	2200	2200	2200
Weight (kg)	154	154	154
Max oil flow (lit/min)	550	550	550
Used engine power (kW)	192	121	23

Hydraulic circuit design
The main components of the hydraulic system consists of:

- One hydraulic axial piston pump with variable displacement
- One booster pump with fixed displacement
- Two larger hydraulic wheel motors that can run also on half displacement
- Two smaller hydraulic wheel motors with fixed displacement
- Two hydraulic steering cylinders
- Two hydraulic lifting cylinders
- Four hydraulic braking cylinders

The principal hydraulic diagram is shown in
Figure 4-18.

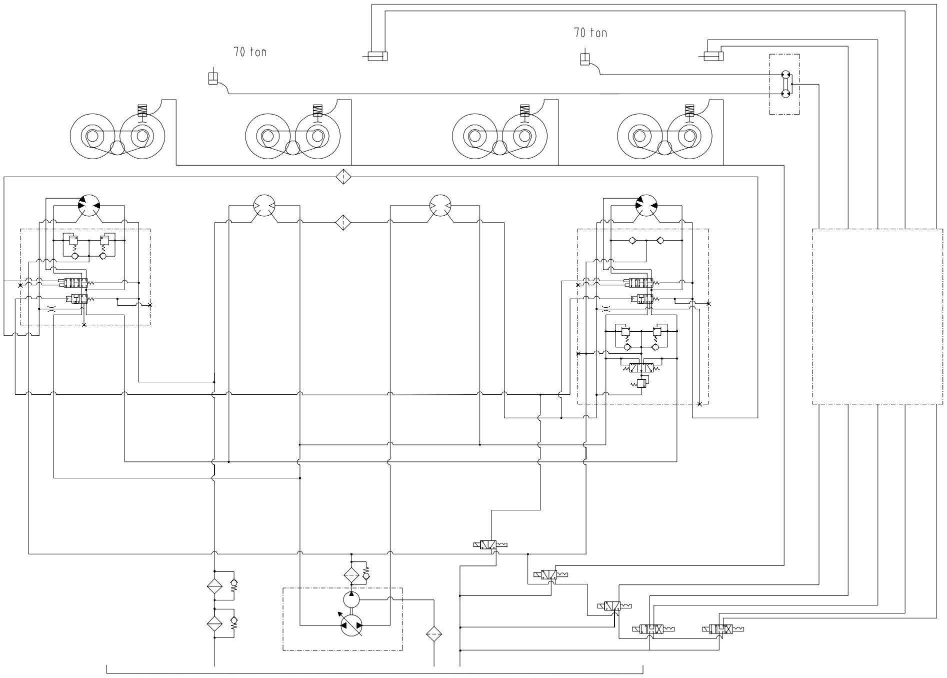

Figure 4-18. Principal hydraulic diagram

<u>Propulsion configuration philosophy</u>

The hydraulic system is designed to give three different speed ranges with the same pump capacity. This is obtained by running the motors in three different configurations:

- When climbing the ramp with full load, all four motors are running - the two large ones with full displacement.
- When running on flat ground with full load, all four motors are used and the two large motors run on half displacement.
- When the vehicle is running without load, the two larger motors are by-passed. The propulsion circuit is a closed loop on the variable displacement pump.

The auxiliary cylinders, i.e. lifting and steering cylinders are installed on the booster pump circuit. The booster or charge pump is needed in all closed circuit installations to make up for internal leakage.

Speed range	Large motor	Small motor	Tractive effort
0-7 km/h climbing, full load	Full displ.	Running	84 kN
0-20 km/h flat ground, full load	Half displ.	Running	19 kN
0-30 km/h flat ground, empty	By-passed	Running	2,4 kN

4.2.3.4 Electrical Control system

The AGV itself is one part of the cargo handling equipment. All cargo handling equipment is controlled and co-ordinated by the TOS (Terminal Operating System) described in Report D 3014.

The on-board vehicle controller controls vehicle guidance, steering, speed, acceleration, stopping, routing decisions, safety monitoring, collisions, traffic avoidance, and communication with the central computer. The on-board controller has complete navigation capability and can control the vehicle between two points without detailed instructions from the terminal operating system. An assignment is given to an AGV with instructions that identifies the AGV destination. The on-board software can navigate the vehicle from one destination to the next at a given speed. The on-board computer stores the guide-path segments in blocks of information containing the parameters of distances, vehicle direction and vehicle speed. At the final destination the AGV gets a new assignment or stops and waits for the next instruction.

The on-board controller functions are:

- Communication with the Terminal Operating System
- Steering of the vehicle
- Position detection
- Loading and unloading functions
- Drive control
- Safety functions
- Warning functions
- Diagnostic functions

The vehicle controller receives instructions from the Terminal Operating System to go from present position to position X, Y, on this position to load a cassette or unload a cassette. The vehicle controller controls the movement of the vehicle and all other functions of loading and unloading. It sends status information to the terminal controller. The automatic route planning requires precise knowledge of the vehicle’s environment including the trajectories of the vehicles in the scenery.

The vehicle controller operates in three levels, as illustrated in **Error! Reference source not found.**:

- Navigation controller
- Vehicle co-ordinating controller
- Basic controller(s)

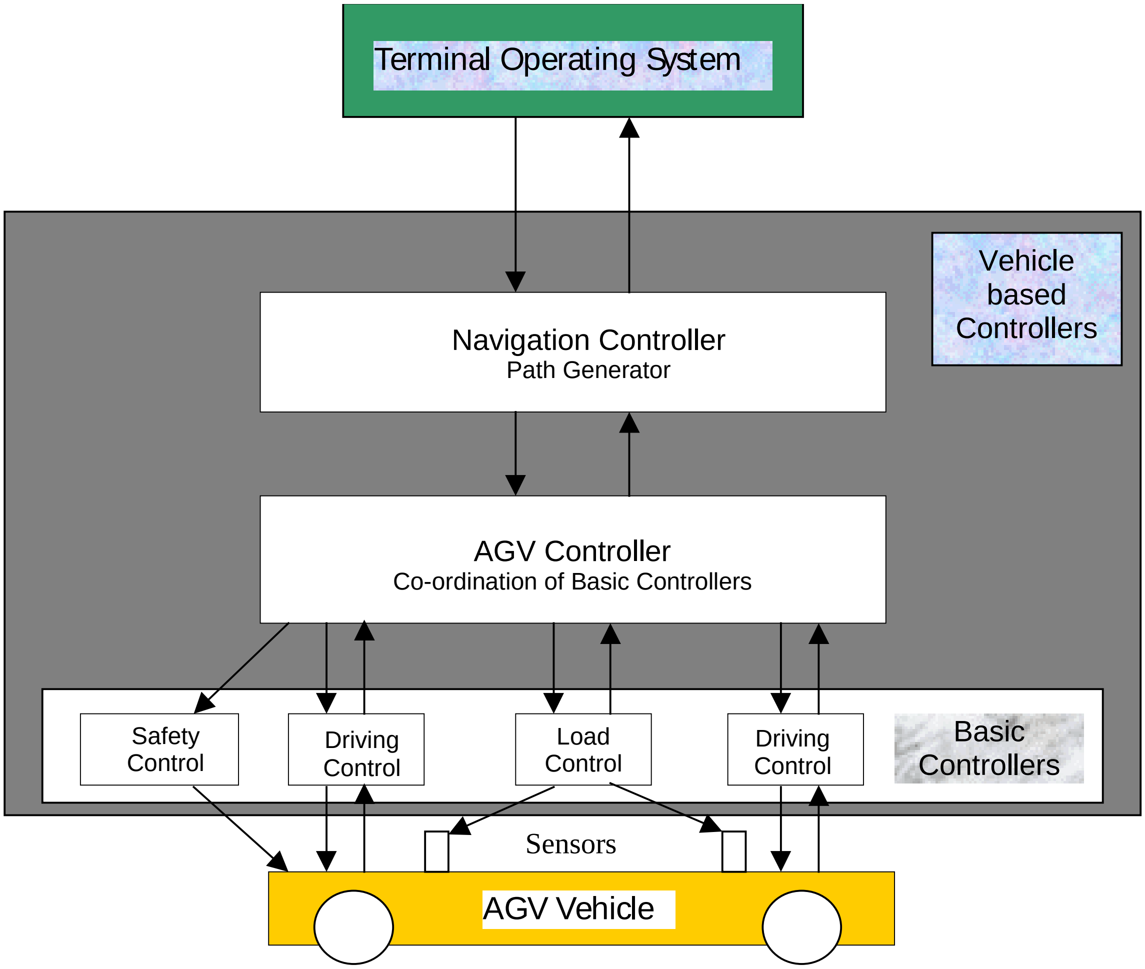

Figure 4-19. Structure of Vehicle control system

Navigation Controller

For the automatic guidance, the position and heading of the vehicle are most important. These parameters have to be determined in the absolute co-ordinate system.

A navigation system has to provide all information necessary for the automatic guidance of the autonomous vehicle. For this task, the system can utilise diverse information sources. These sources differ strongly in type, amount, precision and reliability of information made available. The processing of information must be accomplished in real time. This restriction, in conjunction with the limited computing resources available on a vehicle, has to be considered in the development of suitable algorithms.

From an actual position the navigation controller computes actual velocity and the actual path for the next steering step.

Outdoor navigation in an automatic guided vehicle requires combination of positional information from multiple sensors. For high precision navigation it is important to use data from as many sensors as possible.

The guide-path monitor located on the vehicle shuts the vehicle down if it deviates from the guide-path. The wandering tolerance depends on the AGV used. This feature prevents the vehicle from travelling when there is no guide-path signal.

Co-ordination Controller

The co-ordination controller controls and co-ordinates all functions and all signals of the vehicle. It communicates with the TOS over digital radio and with the navigation controller over a bus.

This controller receives instructions from the navigation controller. These instructions are:

- Next velocity
- Next direction of the vehicle
- Lift the cassette (only when stopped)
- Lower the cassette (only when stopped)

The co-ordination controller computes inputs to the velocity controllers for all wheels and inputs to the direction controllers for all wheels.

The dynamic behaviour of a vehicle depends on the weight of the vehicle. The velocity of the vehicle in curves must be adapted, taking into account the total weight of the vehicle.

The co-ordination controller receives signals from the security sensors and stops the vehicle in case of emergency.

The co-ordination controller watches over the functionality of all sensors and basic controllers. If anything breaks down, the vehicle will be stopped.

Basic controllers

The basic controllers are:

- Hydraulic pressure controller
- Velocity controller for one wheel
- Direction controller for one wheel
- Load lifting controller
- Safety controller

The pressure of the hydraulic system has to be constant. Hydraulic pressure is not actively controlled. The diesel engine will run with constant speed (constant speed control necessary). The hydraulic pressure will be a function of the external load. A hydraulic pressure control valve will open and by pass the flow if the hydraulic pressure (external load) exceeds a set value.

The basic idea of the hydraulic drive system is to have four hydraulic wheel motors and one hydraulic pump with variable displacement controlling the overall speed. All motors will be fed from the same system. The principal schema of the velocity control system is illustrated in Figure 4-20.

The control variable is the velocity of the wheel. The velocity will be measured using electric speed indicators (tachometers) or using revolution counters on all 8 wheels with summation of pulses and following differentiation. The mean velocity will be calculated as the mean value of all eight wheel velocities.

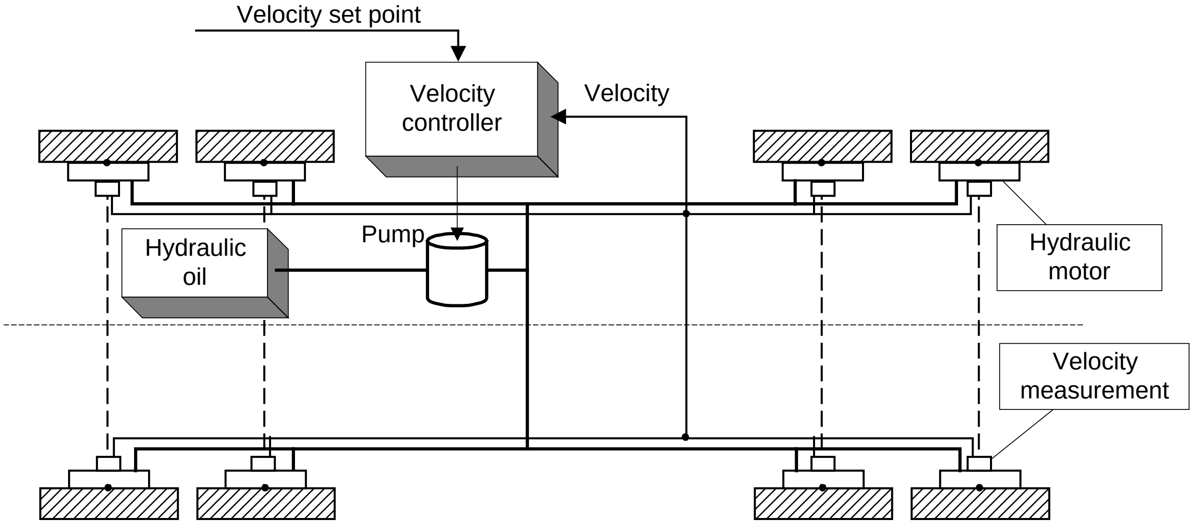

Figure 4-20. Principal schema of velocity control

The wheel angle will be measured and controlled with an electro-hydraulic controller. The wheel angle set-point is set by the co-ordination controller. If switching valves are being used, the output of the angle steering is digital. If control valves are used, the output is analogous.

The load will be lifted with a hydraulic mechanism. The platform of the vehicle has to be exactly balanced, especially if two cargo units, one upon the other, are lifted. All four edges of the platform must be lifted exactly in parallel. There are two lifting cylinders. A flow divider will give the same amount of oil to each cylinder to give an even lifting movement.

The position of the lifted platform will be controlled with the load-lifting controller. The set- point of the controller will be set in the co-ordination controller, this is “UP” or “DOWN”. Load can be lifted only when the vehicle is in a stationary position.

The position will be detected with end switches. A failure in the hydraulic control flow will be signalised, if the right position is not reached after some time.

The brakes are fail to safe disc brakes. This means that the hydraulic pressure is used to disengage the brakes. The brakes also act as emergency brakes. Hence, when the hydraulic pressure drops the brakes will be engaged.

The braking system is separated from other hydraulic systems. It has its own brake fluid tank and separate pipelines.

The set-point of the brake power will be set by co-ordination controller. The pressure of fluid will be measured. Controller output is a set point for the brake pump. The brake pump increases the pressure of the brake fluid until the desired brake power is reached. Through the increasing of pressure the brakes will be engaged.

The hydraulic drives of the vehicle have an effect as a brake. This means that the velocity controller first uses the normal drives for braking. The braking controller will be used only when the AGV is descending the ramp or when the AGS is approaching a stopping point.

The safety controller is an algorithm in the central vehicle controller. Its task is to evaluate signals from all sensors in order to avoid collision with obstacles occurring suddenly in the path of the vehicle.

Optical and acoustic signals will be used if the vehicle starts moving.

<u>Signal list</u>

This signal list is made under following assumptions:

- Each vehicle has 8 wheels, every wheel has its own hydraulic engine
- Steering wheels are coupled to two groups of four wheels, the groups are steered with one steering controller. All wheels of the group have the same steering angle.
- Lifting device has four lifting cylinders, every cylinder has its own controller
- Controllers are provided with standard signals as “activate”, “ready”

Table 4-23. Analog inputs

	Signal	from
1	fuel tank level	diesel engine
2	engine starting battery voltage	diesel engine
3	electronic supply battery voltage	diesel engine
4	speed of diesel engine axis	diesel engine
5	oil pressure in pressure oil tank	oil supply
6	weight of load	load platform
7-11	4 x velocities of wheels	velocity controller
12-16	4 x position counters of wheels	velocity controller
17-18	2 x steering angles of wheels	steering controller
19	inclination angle of the vehicle chassis in length axis	inclinometer chassis
20	inclination angle of the vehicle chassis in transverse axis	inclinometer chassis
21	inclination angle of the load platform in length axis	inclinometer load platform

22	inclination angle of the load platform in transverse axis	inclinometer load platform
23-24	2 x position of load (on 2 lifting valves)	lifting device
25-28	4 position of edges of the vehicle to the cassette	Fine position sensors

Table 4-24. Analog outputs

	Signal	to
1	diesel engine power up/down	diesel engine
2	brake power	brake controller
3-10	4 x velocity of wheel	velocity controller
11-14	4 x steering angle of wheel	steering controller
15-16	2 x position of load (on 2 lifting valves)	load platform

Table 4-25. Binary inputs

	Signal	from
1	Fuel tank nearly empty	diesel engine
2	Motor oil pressure o. k.	diesel engine
3	Gear oil pressure o. k.	diesel engine
4	Brake fluid pressure o. k.	diesel engine
5-6	2 x load lifted end switch	lifting device
7-8	2 x load lowered end switch	lifting device
9	switch for recognition of the cassette	load platform
10	mechanical bumper on, front-side of the vehicle	chassis
11	mechanical bumper on, backside of the vehicle	chassis
12-15	4 x not out switch	chassis
16-19	4 x ready signal of velocity controllers	velocity controller
20	ready signal of load lifting controller	lifting controller
21-22	2 x ready signal of wheel steering controllers	steering controller
23	ready signal of pressure oil controller	oil supply
24	emergency stop from scanner if available	scanner
25-29	4 x lashing device open	lashing device
30-33	4 x lashing device closed	lashing device

Table 4-26. Binary outputs

	Signal	from
1	Diesel engine on (pulse of some seconds)	diesel engine
2-5	4 x active signal to velocity controllers	velocity controller
6	active signal to load lifting controllers	lifting controller
7-8	2 x active signal to wheel steering controllers	steering controller
9	ready signal to pressure oil controller	oil supply

10	Light on/off	Light
11	Beeper on/off	beeper
12-15	4 x positive voltage to lashing device (close)	Lashing device
16-19	4 x negative voltage to lashing device (open)	Lashing device

Controller Cabinet

The controller cabinet, Figure 4-21, may have dimensions of about 1100 x 600 mm due to flat vehicle. The complete electronic configuration of the vehicle controller has to be placed in this cabinet. Use of European format of electronic units makes it possible to place two double European cards one on top of another. The height of one rack is 265 mm. The height of some racks for PLC is 302,6 mm.

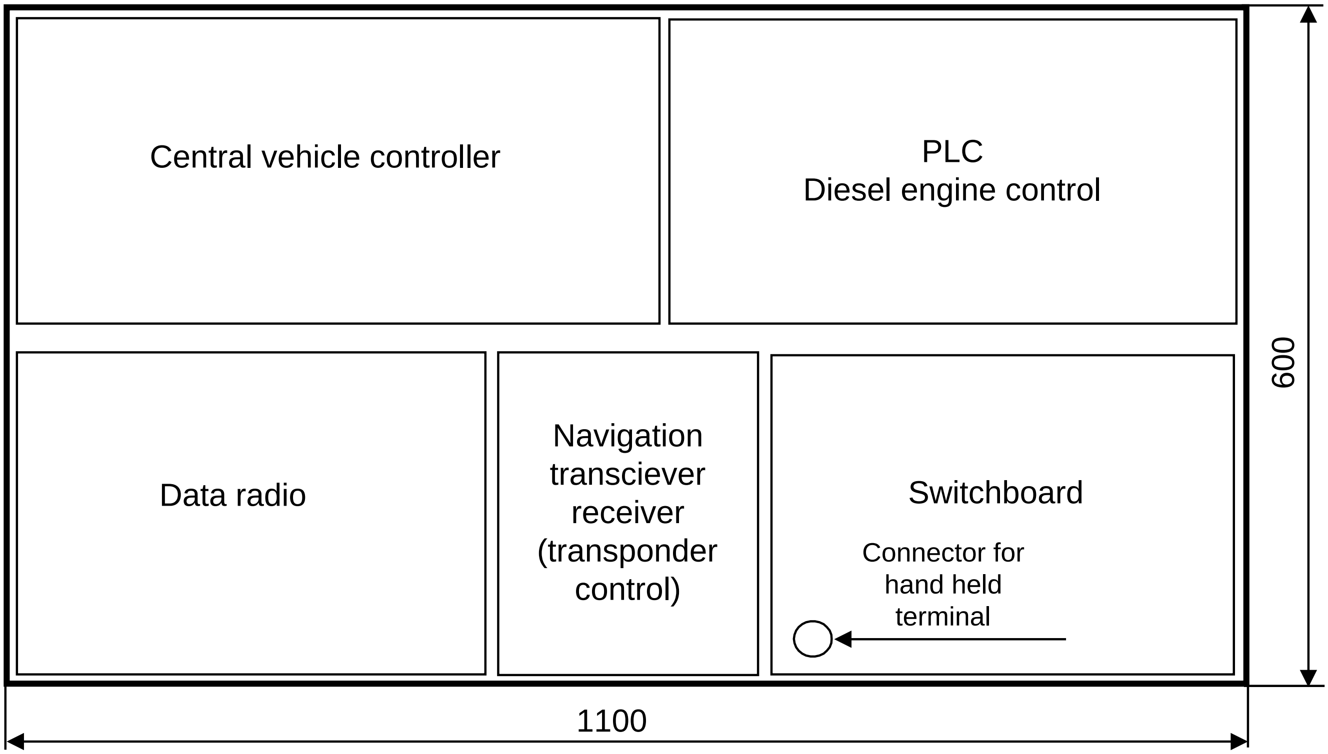

Figure 4-21. Vehicle controller cabinet

More details are presented in Report D 3014 Cargo Handling Monitoring and Control System

4.2.3.5 Lashing System

To meet the requirements for time reduction in port, either automatic or semi-automatic lashing can be applied. When using a semi-automatic lashing system the lashing is manually connected to the vehicle, while the tensioning of the lashing is done automatically. The main objective of the IPSI lashing system is to reduce time and cost of the lashing operation, and still maintain a satisfactory safety level. A less automated system may be preferred if it can support this objective at a fairly good level and at a price that is significantly more reasonable than a fully automated system. It is easier to apply an automatic system to a cassette than to a semi-trailer. This is true because the cassette is a standardised construction. Trailers on the other hand come in many different designs.

It must be stressed that this chapter deals with the lashing of complete cassettes with containers or complete trailers. We assume that lashing of containers to cassettes will be handled in a conventional fashion, using semi-automatic twist-locks.

The basis for the IPSI lashing system is the curbs. In order to ease the movement of cargo inside the IPSI vessel, curbs are fitted to separate the lanes (in an IPSI vessel, the lanes are completely straight). Figure 4-22 and Figure 4-23 show a cassette with containers and a tug-master with trailer inside the curbs.

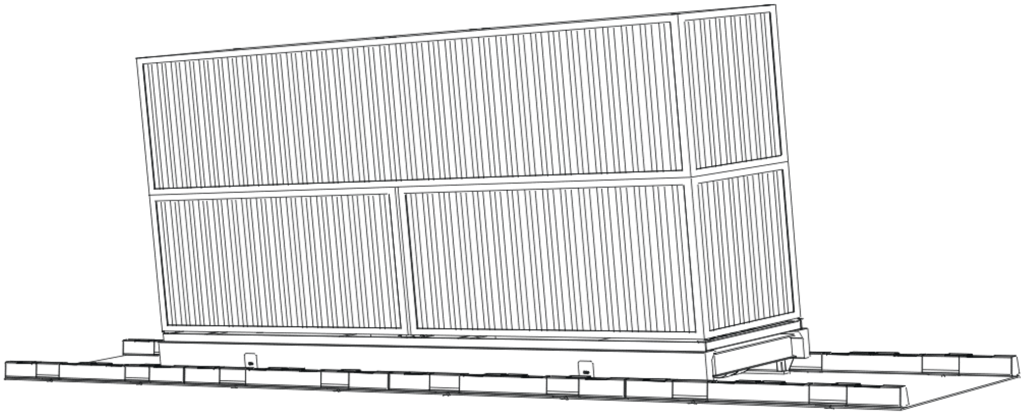

Figure 4-22. Cassette with containers in the curbs

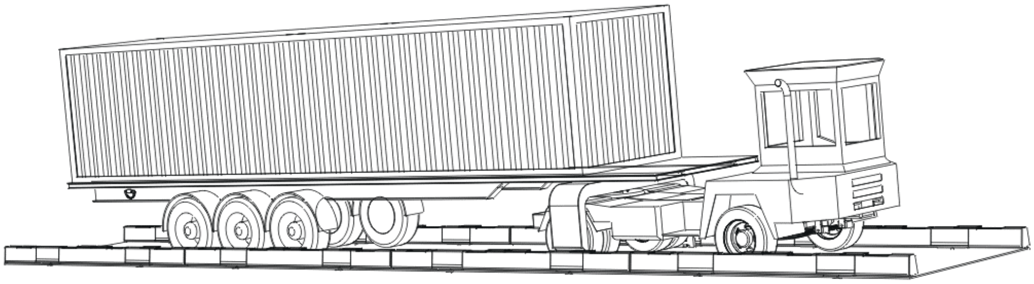

Figure 4-23. Tug-master with trailer in curbs

The curbs are produced in elements of 5 meters. If the curbs were made in steel, the weight per curb would be approximately 700 kilo. They are mounted onto the deck of any RoRo vessel using the standard flush elephant foot fittings, as illustrated in Figure 4-24. Should the curbs not be required, they may easily be dismounted and moved.

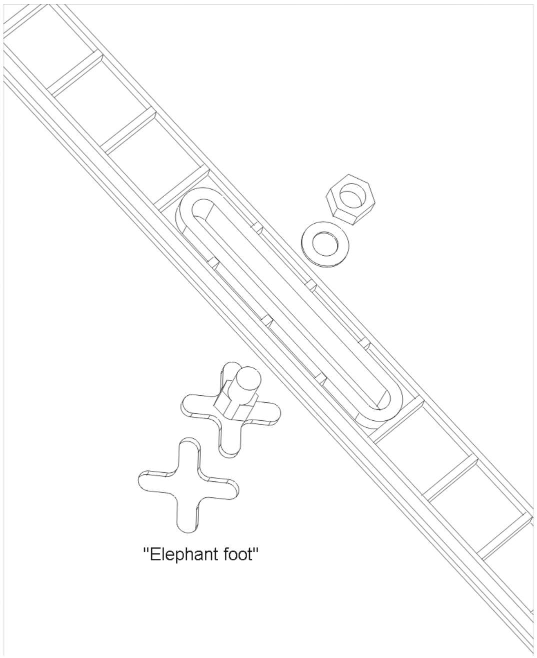

Figure 4-24. Locking of curbs to deck

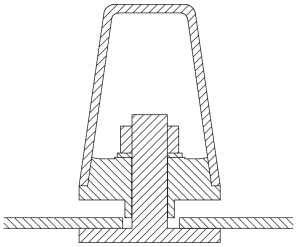

Figure 4-25. Corss section of curbe

A cross section of the curbs is shown in Figure 4-25. The fissure underneath the curb is used for lashing of cassettes and trailer-horses (see below), while the opening inside the curb is used to store lashing equipment for the "free" end of the trailers.

<u>Cassette lashing system</u>
The cassettes are equipped with an automatic lashing system, see Figure 4-26.

The principle of the lashing system is that there is a locking plate fitted under the locking device of the cassette. When sitting on the deck (or in port) the plate is always in the locked position, and locks the cassette to the curb as indicated in Figure 4-27.

When the AGV enters under a cassette, it pushes a lever-wheel that deactivates the lashing system by twisting the locking plate 90 degrees. When the AGV leaves, again pushing the lever-wheel, the locking plate twists out 90 degrees and under the curb. The system is designed and placed in the cassette so, that when the AGV enters or leaves each lever-wheel will only be pushed once. Since the system is designed to rotate in both directions, it is independent of in which direction the AGV enters or leaves. The system will always be disengaged when the AGV enters and engaged when the AGV leaves. The lever-wheel is prevented to self-twist by a spring pushing it down in a v-shaped cut out in the side plate of the cassette, see Figure 4-28. The cassettes will be stored so close in the longitudinal direction that only the most forward and aft cassette will be lashed longitudinally.

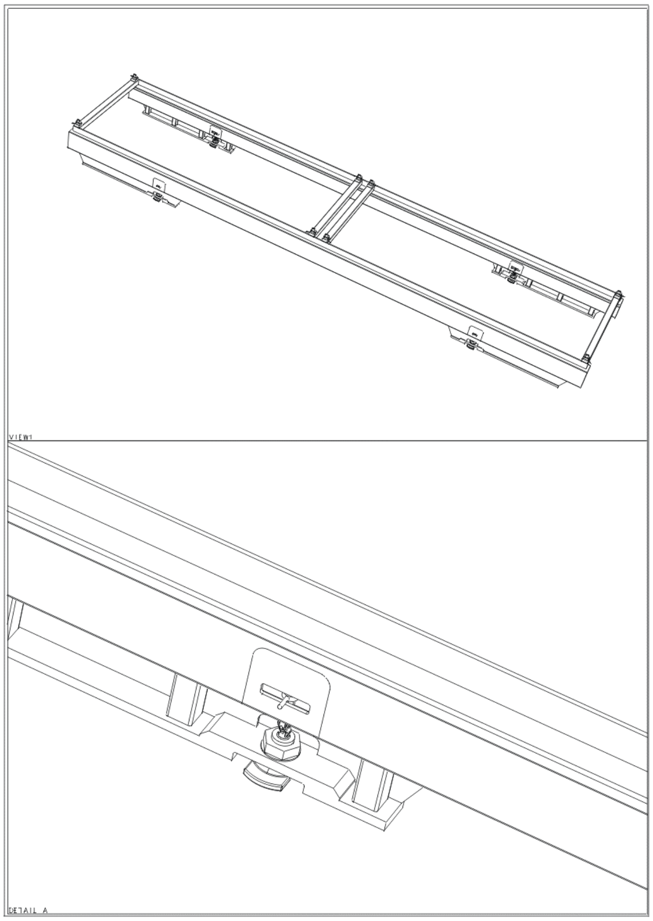

Figure 4-26. The lashing device of the cassettes

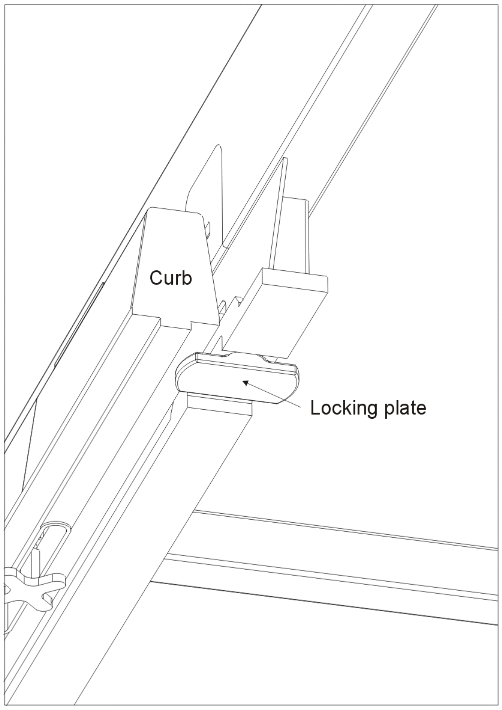

Figure 4-27. Locking of cassette to curb

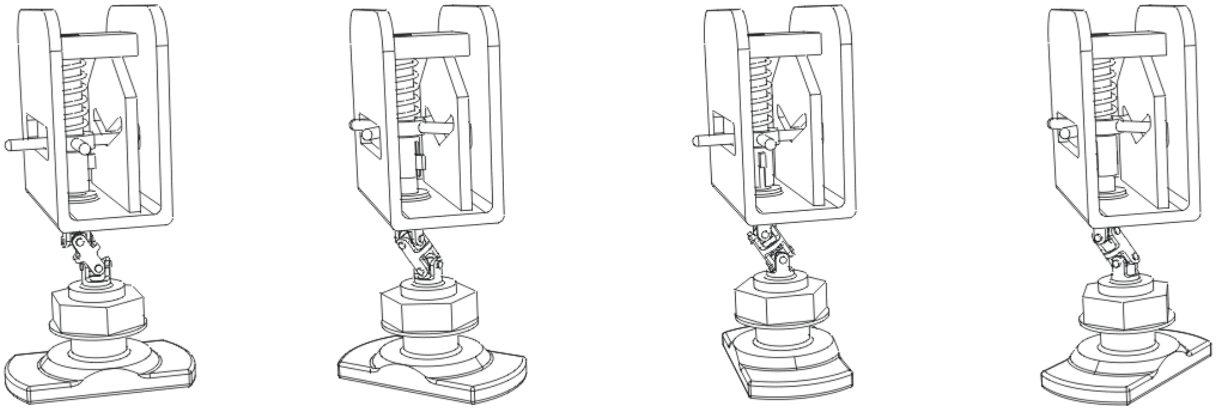

Figure 4-28. The locking- and unlocking sequence

Trailer Lashing System

The lashing system for trailers consists of two different types, semi-automatic for the rear end and automatic for the forward end. The rear end lashing equipment, web on a reel with automatic spring return is stored inside the curbs, Figure 4-29. This reduces the need for the stevedores to carry or move the equipment over large distances. Because of the curbs, there will be limited space between the trailers. This is unfavourable for the stevedores operating the lashing system. The curbs will, however, have a width that makes it possible to walk on them.

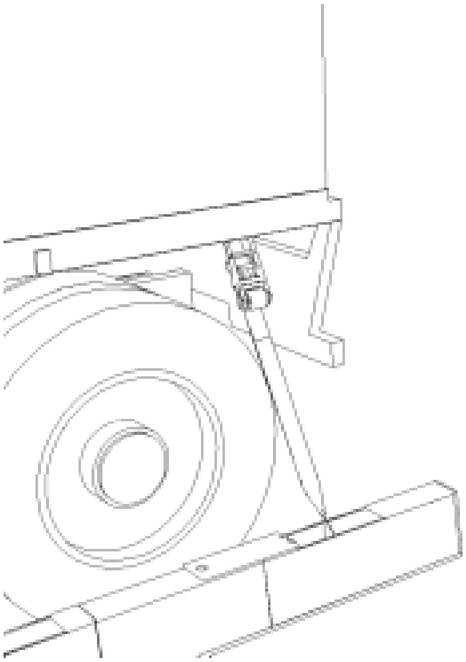

Figure 4-29. Web on reel for trailer lashing

The forward lashing system consists of a trailer “horse” with automatic lashing similar to the cassette lashing system, see Figure 4-30.

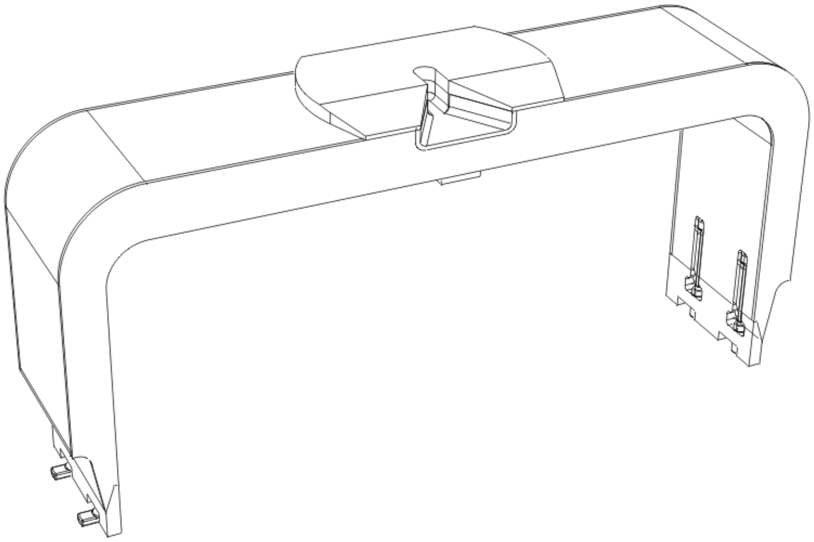

Figure 4-30. Trailer horse

There are plates in the bottom of the horse that slides out under the curbs. When the tug master picks up a horse it pushes a lever that deactivates the locking device and then a lever that through a wire system pulls the lashing plates in unlashed position. After having picked up the trailer and leaving it onboard the lashing plates slides out again under the curbs due to spring force and the locking device slides down behind the plates. Some of the details of the trailer horse lashing system are shown in Figure 4-31.

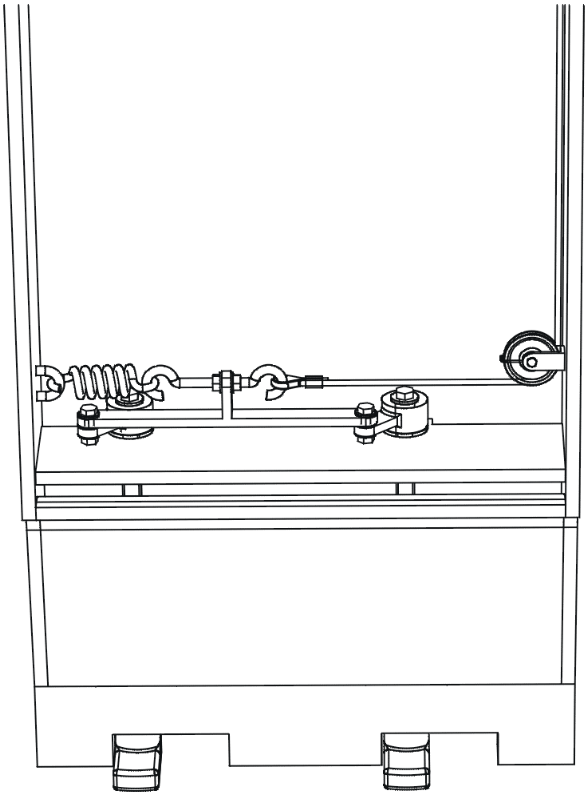

Figure 4-31. Details of the trailer horse lashing system

4.2.3.6 Terminal Ramp

The terminal ramp system has two different principal designs. The first design is a fixed two level land ramp, the second design is a two level link span with a floating pontoon at the outer end. The fixed land ramp can be used for differences between low and high water up to approximately 2 m. For larger variation between high and low water the link span system should be used. The typical characteristics for the IPSI terminal ramp systems:

- Small climbing angle. Climbing angle is limited to 4°
- High loading capacity. 20 fully loaded vehicles simultaneously.
- 12 m wide lanes to speed up conventional handling.

Fixed land ramp

The fixed land ramp consists in principal of four parts, the concrete slope, the inclined steel lane, the flat steel platform and the hinged ramp. The concrete slope is 12 m wide and 59 m long. The inclined steel lane is 12 m wide and 50.8 m long with supports half way. The inclination on both these parts are 4°. The flat steel platform widens from 12 m to 21.4 m towards the hinged ramp in order to allow the AGV's sideways manoeuvring before entering the lanes along the ship's sides. The hinged ramp is 21 m wide and 15 m long extended with foldable finger flaps at the outer end. The 12 m lane width allows two

AGV train sets to run simultaneous in both directions. However, the traffic control system will only allow a maximum of 100 tonnes to meet on the upper steel platform. A support in the centre of the platform would increase the maximum allowable weight to the double. Two hydraulic cylinders control the hinged ramp. The total steel weight of the fixed ramp is 383 tonnes.

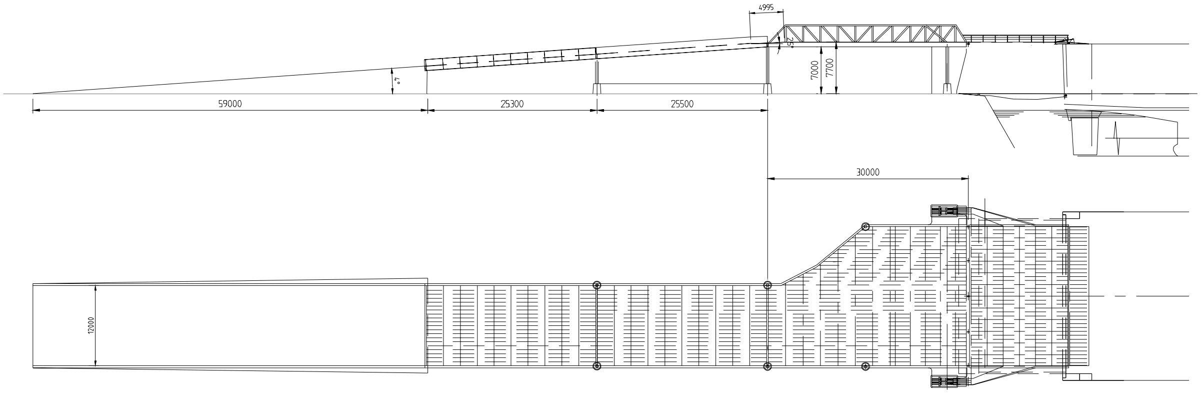

Figure 4-32. Fixed land ramp

<u>Link span system</u>

The link span system is designed for a difference in highest and lowest water level of 4.3 m and a maximum inclination of 4°. To meet these requirements and the difference in draft of the pontoon when loaded and not loaded the span of the link is far greater than the fixed land ramp. The only way this large span can hold the load of an AGV train is to use a steel frame structure. The upper level of the link span is reached with two 6 m wide one-way lanes on each side of the pontoon. The lower level is reached with a 12 m wide two-way lane in-between the two upper lanes.

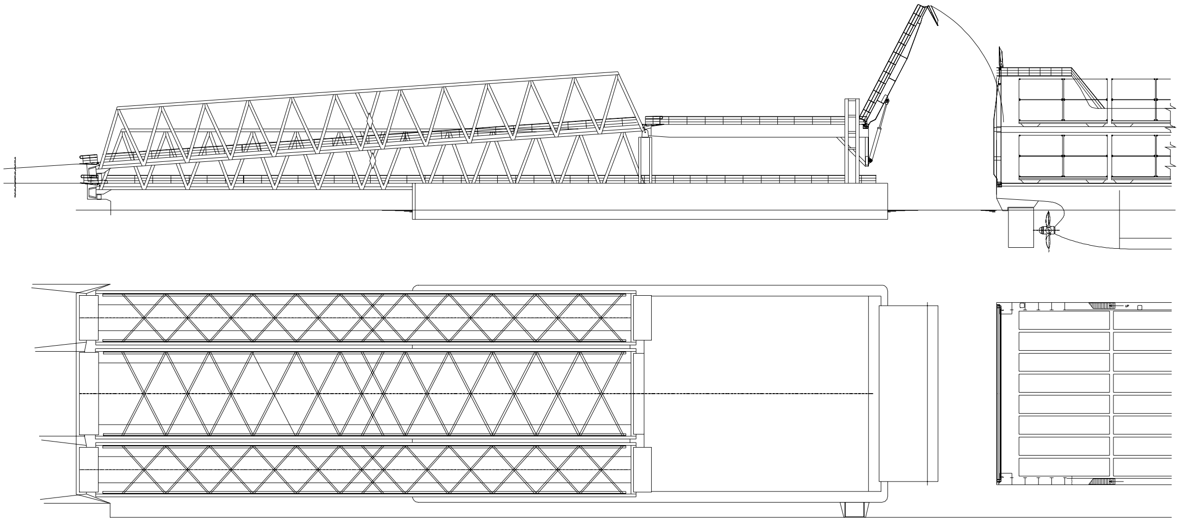

Figure 4-33. Link span arrangement

The link span can hold 21 half loaded AGV’s at a time. If the AGV’s are fully loaded the distance between each AGV must be increased with the length of one AGV. When the link span holds 21 half loaded AGV’s the increase in draft of the pontoon is 0.61 m. The waterline area of the pontoon is 1574 m^2 and the displacement is 7460 m^3. The total steel weight of the link span is approximately 1800 tonnes out of which the pontoon itself represents almost half that weight.

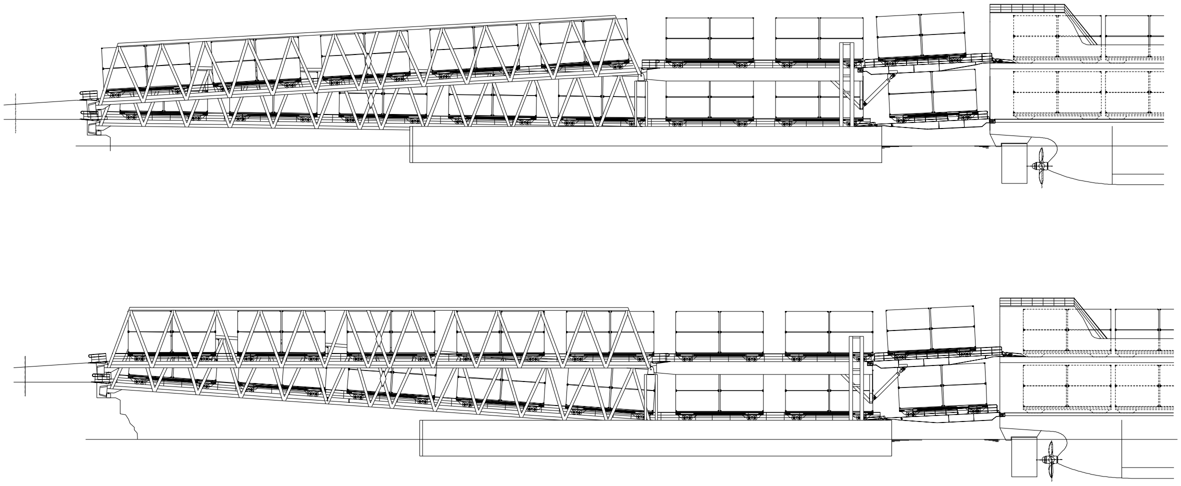

Figure 4-34. Link span in highest and lowest water.

4.2.3.7 Cargo Access Equipment

The IPSI ship design holds cargo in three levels. Tank-top will only hold trailers since the fixed ramp down from main deck has a too large inclination due to limited space. The fixed ramp is covered with two hydraulic deck covers. Main deck and weather deck holds double stacked IPSI cassettes. Main deck is accessed via the stern ramp of the ship. Weather deck is accessed via the ramp on the end of the fixed land ramp system or the ramp on the end of the link span system.

Stern door/ramp

The stern door/ramp is operated by wires and a hydraulic winch. The door/ramp is hinged to ship’s stern at main deck level. Finger flaps are provided at both ends, outer flaps are divided into 8 parts and hydraulically operated. The flaps are folded forward in stowed position. The inner flaps are stowed by ramp movement. In stowed position the ramp will act as a watertight door with hydraulically operated mechanical cleats. The ramp is made watertight by using a sealing system consisting of Kvaerner single lip EPDM gasket compressed by a stainless steel flat bar. The ramp is provided with preventer wires, allowing 10 tonnes of SWL on the ramp, 7 meters aft of stern. The ramp is equipped with lifting eyes for attachment of device for emergency operation.

Ramp covers in main deck

There are two hydraulically operated ramp covers placed in main deck above the fixed ramps between main deck and tank-top. The covers are built in one section with a flap at aft end and hinged to main deck at forward end. In open position the covers will be mechanically secured by hydraulic cleating devices. In closed position the covers are flush with main deck and watertight. The covers are kept in closed position by hydraulically operated cleats. The covers are made watertight by using a sealing system consisting of Kvaerner single lip EPDM gasket compressed by a stainless steel plate. The covers are equipped with lifting eyes for attachment of device for emergency operation. The ramp can also be emergency operated by a portable emergency pump unit.

Internal ramps in fixed ramps between main deck and tank-top

There are one hydraulically operated hoistable ramp in each of the two fixed ramps between main deck and tank-top. The aft end of these ramps is hoisted in line with the fixed ramp from main deck to allow access to tank-top. The forward end of the ramp is hinged to tank-top and the ramp is flush with tank-top in stowed position. The ramps are made in one section and operated by hydraulic pulling cylinders. The ramps can be lowered and raised fully loaded and are mechanically locked in ramp position by hydraulically operated cleating devices. Cleating and guiding devices are arranged in ship’s structure. The ramp is emergency operated by a portable emergency pump unit.

4.3 IPSI Vessels

4.3.1 Short Sea Shipping

The IPSI ship concept is based on a mono-hull with two, alternatively three decks. Straight lanes decks and direct access from shore to all decks are necessary for fast operation. It is regarded as important for the IPSI concept to innovate the port operation, reducing the turnaround time. Curbs are dividing the lanes to guide the AGVs or tug-masters to their positions. In this way it is possible to operate in all lanes simultaneously.

Figure 4-35 shows the IPSI ship concept.

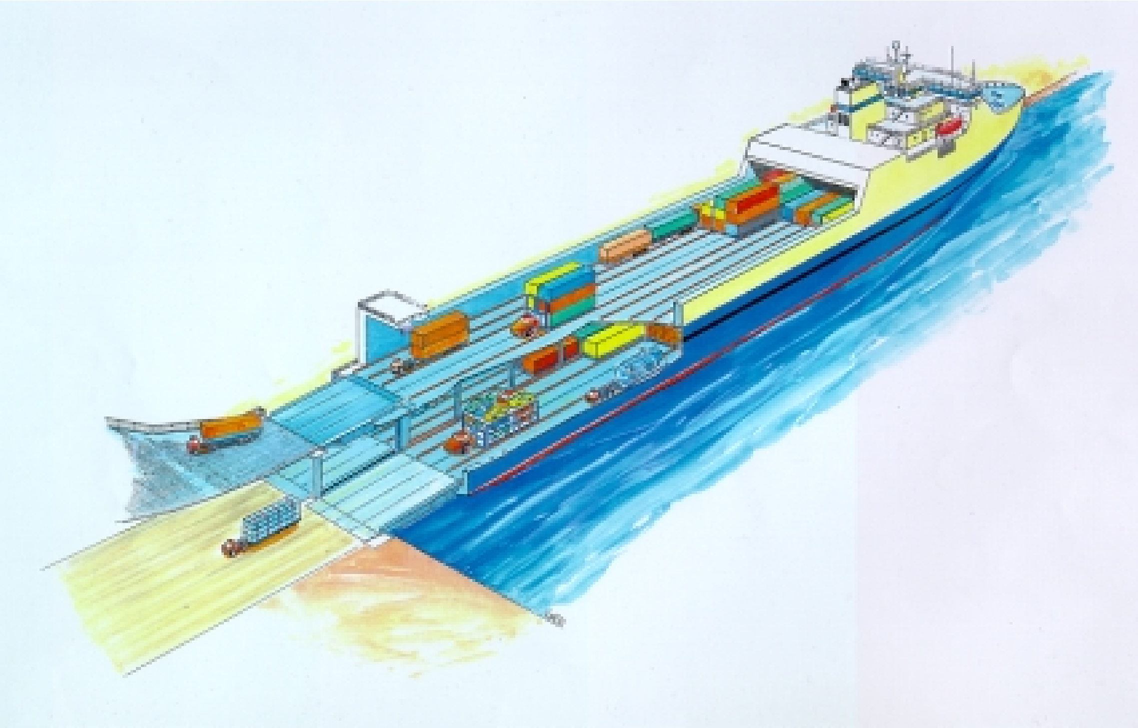

Figure 4-35. The IPSI ship

The IPSI ship must have low investment cost deriving from standardisation of ships equipment, sizes and design, material selection and building series of similar ships. The IPSI project has designed a family of ships. The choice of sizes is suitable for most short sea operations. The standardisation of the IPSI ship design and the possibility of building large number of ships based on the same cargo handling concept provide the opportunity for selecting an IPSI ship for every short sea shipping operation.

The layout of the ship is simple in the way that the decks are straight lanes and using curbs dividing the lanes. No obstacles hinder the use of the straight lanes. This makes it necessary to locate the engine room forward. With this design, the IPSI ship has stern access to main and weather decks. The tank top is operated by an internal ramp from the main deck. Another important benefit is that it balances the ship in loaded and part-loaded conditions.

The IPSI concept has the ability to carry five different cargo units. To optimise the cargo handling operation not all of the cargo units can be carried at the same time. Three alternatives are proposed:

- Containers stacked one or two high on frames driven onboard by AGV. Utilising main and weather decks (only one high on the weather deck).
- Traditional RoRo operation transporting trailers driven onboard by tugmasters. Utilising the tank top, main and weather deck.

- Combined operation with containers located on the main deck and trailers on the weatherdeck. Tugmasters and AGVs shall not mix in the same area on shore. Hence, the two level ramp diverts tugmasters and AGVs into separate areas.

Using AGVs exclusively only the main and the weather deck can be used, due to the inclination of the internal ramp down to the tank top. The tank top may be used if a combination of transport units is chosen, e.g. using both frames and trailers. Then we utilise two alternatively three decks in the IPSI ship. The width of the deck must be in accordance with a number of lanes. Ideally, for the AGV operation the number of lanes should be 6 or 8 to gain symmetric design.

The IPSI concept will have stern ramp for making access to the main deck and a two level shore based ramp to the weather deck. Additionally the ship may have an internal ramp for accessing the weather deck. If an internal ramp shall be used, which is likely in ports having low throughput, the weather deck will be fed by tugmasters. Due to the cost of having an internal ramp the ramp should not be built if the ship may be dedicated to a trade with large transport flows.

The decks are designed with straight lanes, and curbs dividing the lanes. The number of units, frames or trailers, in each lane will vary due to the shape of the hull and location of the engine room. The lanes are longer in the centre on the weather deck than on the main deck where the engine room is reducing the lane length. A fully automated lashing system will reduce the lane width. Transportation of frozen goods will require reefer plugs and monitoring control cables and should be allocated to dedicated lanes.

The basic idea is to develop a family of ships with standardised components. Basic assumptions for the design process are shown in Table 4-27. This report describes the design process of two ships of length 115 meters and 150 meters respectively. The design process for the ship with length 180 meters is not described. That ship is designed by STORA. The first delivery of the STORA ship is said to be in November 1999.

The figures of capacity and speed in the table below show the basic assumptions that were used in the design process.

Table 4-27. Pre-set ship data

	Length (L.O.A.)	**Beam**	**Draft**	**Capacity**	**Speed**
Short sea	180 m	25 m	7,8 m	560 TEU	<20 kn
Short sea	150 m	23 m	6,5 m	402 TEU	20-25 kn
Short sea	115 m	21 m	6,5 m	228 TEU	20-25 kn
Inland navigation	95 m	12 m	2,7 m	-	-

A weight requirement in excess of 8,0 tons per lane-metre is calculated. Each cargo unit is assumed to be 12,6 metre in average or some 0,4 metre more than a 40ft unit. In average 13 lane-metres are needed for each unit.

4.3.1.1 Cargo Spaces

To keep the needed power for AGVs down the angle of the ramp can not be more than four degrees. That limits the number of decks. Short turnaround time in ports is another factor impacting the number of decks. In addition ship size and design have an impact.

Each ship is designed with three decks:

- tank top
- main deck, and
- weather deck

The main deck and the weather deck will be fully accessible by AGVs, while the tank top may be accessed by tugmasters only, because of the steep angle of the internal ramp. With the required angle there will not be any usable space left on the tank top. When a fully automated concept is proposed the tank top cannot be used, hence having only two decks. Utilising only two decks the space utilisation has to be higher, thus stacking containers two high on the frames.

The area utilisation of the ship will be better if a combination of cargo handling methods is used, e.g. trailers on the tank top and frames on the other two decks. Such an operation cause conflicts due to interference between automated and manual cargo handling. That is not desired from an IPSI viewpoint.

There is a possibility for a fourth deck on the ships being designed. It may be applicable if the ship is being used as a trailer ship. The IPSI ship shall carry trailers, frames and containers or a combination of trailers and frames and therefore a fourth deck is not wanted. Another reason for excluding a fourth deck is the loading situation, which would require an internal ramp to the fourth deck. A result is increased turnaround time in port, which is not favouring the short sea operation. For a fully automated system using AGVs the fourth deck will not be accessed due to the climbing angle or the required engine power of the AGV.

The cargo handling operation benefits from a deck layout where there are only straight lanes. Straight lanes mean reduced operation time, because it is possible to drive straight to the position without going through bends and narrow ramps.

The 115-metre ship has 6 lanes abreast and 6 to 8 units in each lane. On the tank top there are 4 lanes of 3 units each.

The 150 metre ship has 7 lanes abreast and 8 to 11 units in each lane. On the tank top there are 5 lanes of 4 units each.

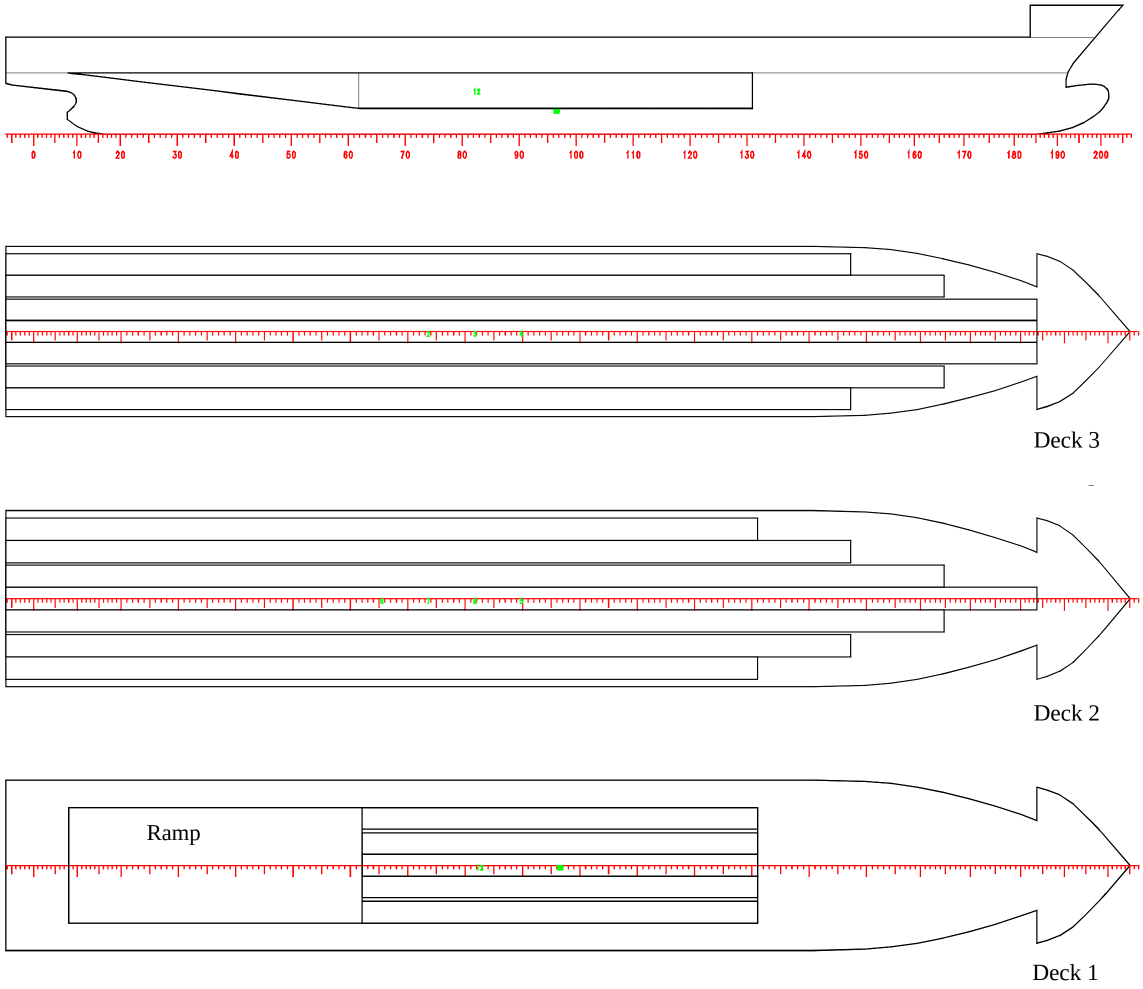

Figure 4-36. Lane configuration

The different deck heights that have been evaluated:

- trailer height of 4,5 metres on all decks
- trailer height of 4,5 metres on the tank top, while having 7 metres on main and weather deck enabling two containers high on a frame.

The IPSI ship is designed for carrying one container height on frame on the weather deck. But with some smaller amendments of the stability the ship may carry two containers high on frames on the weather deck.

Pillars may support the main deck and the weather deck, reducing the steel weight of the deck. It is desired to have a symmetric ship placing the pillars along the centreline of the ship. When designing an asymmetric ship with 7 lanes the pillars will be arranged on starboard and port sides with 3 lanes in between.

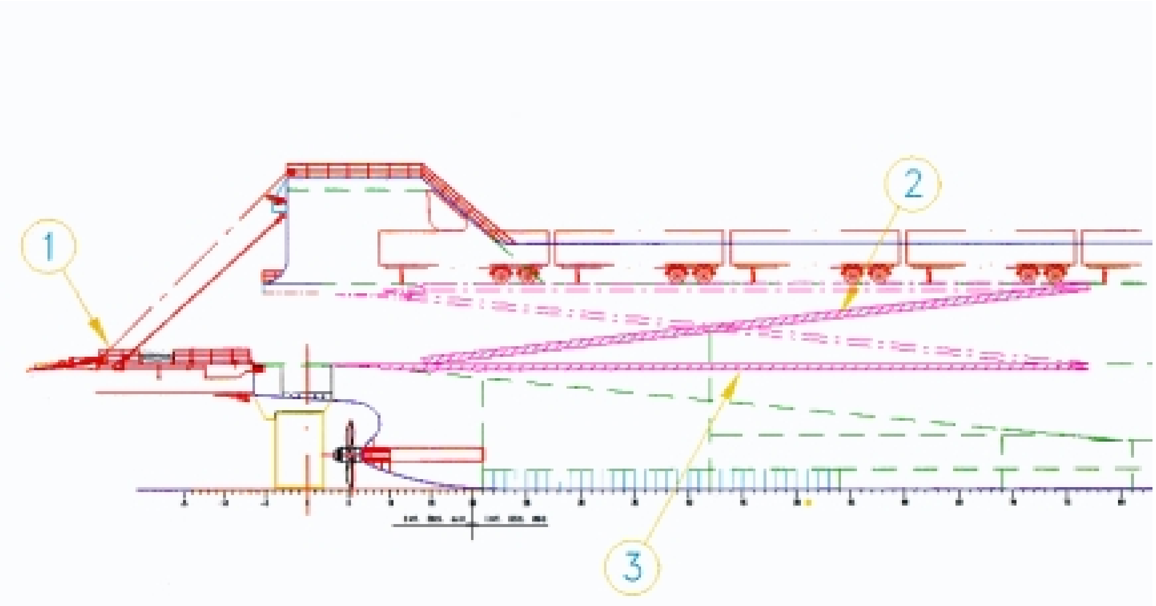

Figure 4-37. Internal ramps

Item 2 in Figure 4-37 shows that the internal ramp to the weather deck is a liftable part of the weather deck. There are two internal ramps each of 2 lanes abreast on each side of the ship. The internal ramps and the weather deck should not have curbs if the internal ramps are being used.

The advantage with the internal ramps is that it allows the IPSI ship and cargo handling concept to be used even when there is no two-level shore-based ramp.

The disadvantage with this alternative is that the weather deck and the main deck cannot be loaded simultaneously if there are curbs on the main deck. But, the internal ramp to the tank top are located in the middle of the ship making access even when loading the weather deck.

When using an internal ramp the weather deck must be fully loaded before the main deck. Similar, some of the cargo on the main deck must be discharged before the ramp to the weather deck can be lowered. This gives undesired ties on the loading and unloading operation, hence increasing turnaround time in port.

4.3.1.2 Ship form and function

Four different ships have been designed, see Table 4-28:

Table 4-28. Ship dimensions

Ship	Loa (m)	B (m)	Draught (m)	Depth (m)	TEU without tanktop	TEU with tanktop	Lane metre	Deadweight (t)
No. 1	150	23.6	6.5 - 7.1	13.6	273	293	2040	8500
No. 2	150	23.6	6.5 - 7.1	15.6	402	442	2040	8500
No. 3	115	21	6.5 - 7.1	13.1	170	182	1220	5500
No. 4	115	21	6.5 - 7.1	15.1	228	252	1220	5500

Table 4-29: Ship data

The ships will have a single-screw, mono-hull form. The family of three ships ranging from approx. 100 m to 180 m with a service speed between 16 and 22 knots. As mentioned earlier, the 180 m ship is not designed in this project.

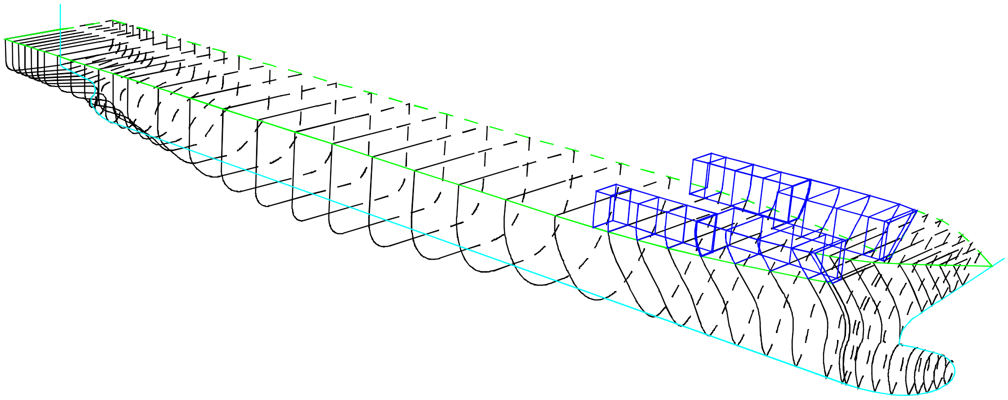

Figure 4-38. The image of ship 1

The hull forms all have a block coefficient (C_B) of 0.594 and they are originally designed for speeds in the range of 18 to 22 knots.

Length has mainly been settled from lane-metre requirements. Beam has been settled from stability (intact and damage) and deck layout requirements (number of lanes). Draught has been settled from deck height requirements and necessary propeller diameter.

A limit is reached at 7 lanes abreast. Adding the 8th lane makes an undesired stability, which gives increased accelerations. In addition the overall breath will be in excess of 26 m which exceeds the limit of several European locks.

The watertight integrity of the vessel is based on capacity requirements, space requirements and IMO damage stability requirements (SOLAS-74, Ch. II-1, Part B-1, Subdivision and damage stability of cargo ships).

The superstructures of the vessel have not been designed as part of our work. They have to be put in the foreship. The weather deck is not sheltered. On top of the weather deck, ballast tanks must be placed to enable adjustment of the stability characteristics of the vessel. These tanks (one or more) may be designed as roll-damping tanks to improve the seakeeping qualities.

4.3.1.3 Machinery

Proposing machinery was originally not within the scope of the IPSI project. However, designing a vessel without taking the machinery into account will not provide satisfactory results. Accordingly, IPSI has done a qualitative evaluation of the four different machinery options shown in Table 4-30.

Table 4-30. Alternative machinery configurations

Alternative 1	2 medium speed engines, 1 shaft
Alternative 2	4 medium speed engines, 2 shafts
Alternative 3	4 medium speed engines, 1 shaft
Alternative 4	Diesel electric propulsion, 4 medium speed engines, 2 Azimuth thrusters

The alternative machinery configurations are shown in figures 11 to 14. When comparing the alternative propulsion systems, the following evaluation criteria should be focused: Investment cost, operation- and maintenance cost, machinery layout and space requirement, reliability/availability, dynamic performance and manoeuvrability.

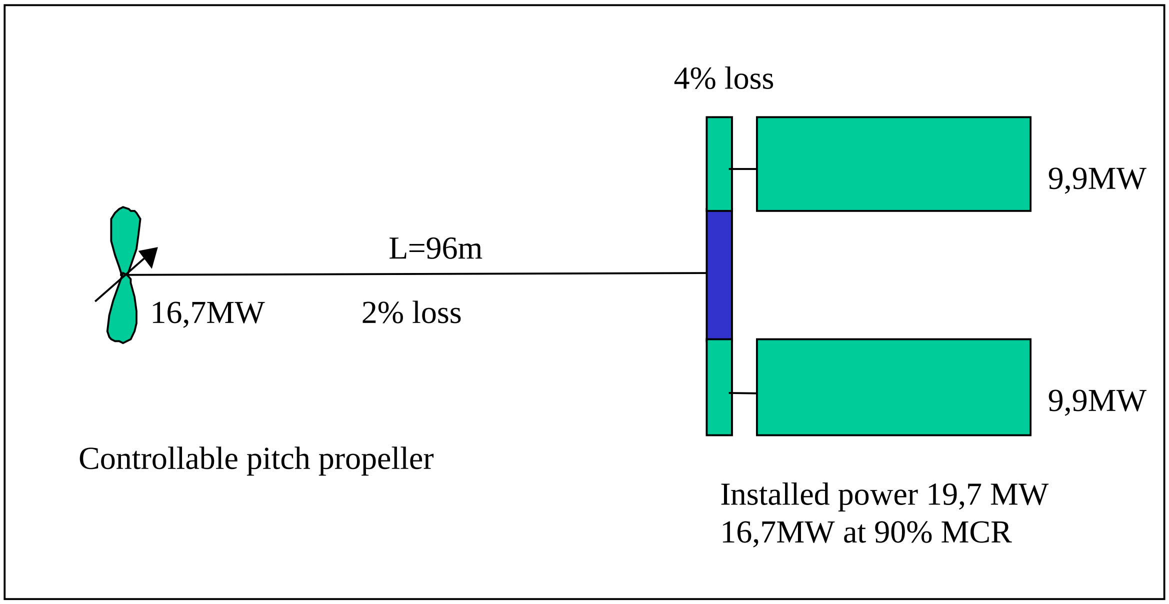

Figure 4-39. Alternative 1; Single screw propulsion system with 2 medium speed engines and 1 shaft

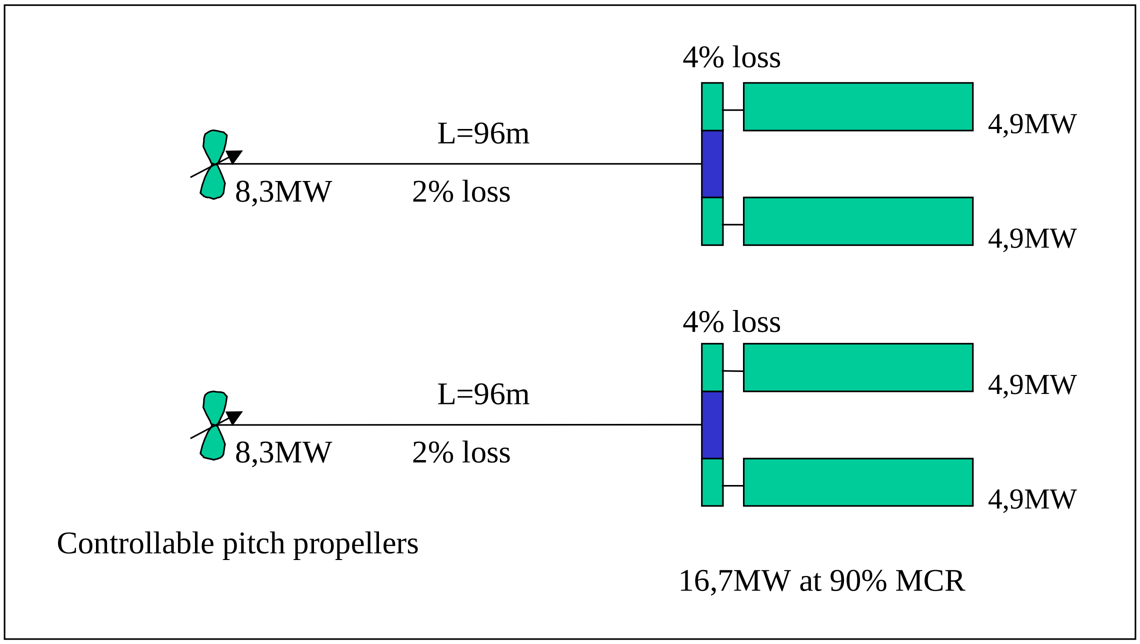

Figure 4-40. Alternative 2, twin screw propulsion system with 4 medium speed engines and 2 shafts.

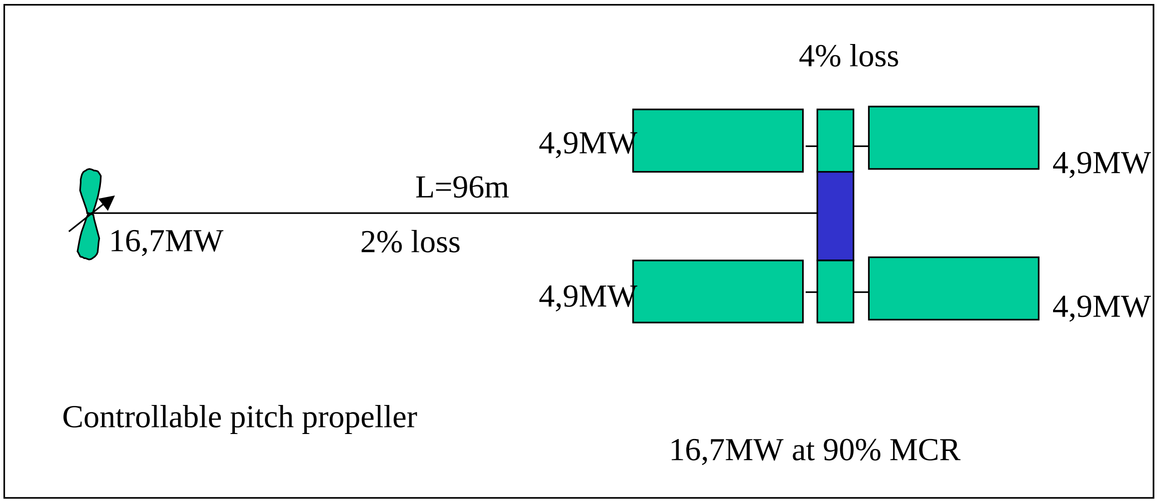

Figure 4-41. Alternative 3; single screw propulsion system with 4 medium speed engines and 1 shaft.

4.3.2 Barges

Several factors influence and restrict the design of barges. The factors may be physical, operational, organisational or economical. This chapter discusses some of the factors.

4.3.2.1 Fairway dimensions

Fairway classification is directly based on the largest class of inland vessels that are allowed to ply a given waterway. Length, width, draft and height restrictions as well as dead-weight restrictions may be found in the 1992 CEMT classification. (See Table 4-31)

Table 4-31. 1992 CEMT classification of inland waterway vessels, maximum dimensions

CClass	**Type of vessel**	**Tonnage (t)**	**Length (m)**	**Width (m)**	**Height (m)**	**Draught (m)**
I	Spits	400	38.5	5.05	3.55	2.2
II	Kempenaar	650	55	6.6	4.2	2.5
III	Dortmund-Ems	1000	80	8.2	3.95	2.5
IV	Rhine-Herne	1500	85	9.5	4.4	2.5
V	Large Rhine	3000	110	11.4	6.7	2.8
VI_b	Large Rhine	3000+	140	15	9.1	3.9

There are large class VI_b rivers in Belgium and in the Netherlands. Beyond, in Germany, is mainly river Rhine a class VI_b. Several of the side rivers to the Rhine are of class IV.

From a navigational point of view the main limitations of the waterway network are[i]:

- The depth in the River Rhine up to Cologne. During low water periods only 2.5 m of depth is available. However, most of the time vessels can be loaded up to 3.5 to 4.5 m.

- The width of the locks on the river Rhône up to Chalon-sur-sâone. The permissible beam is 11.4 m.

- The air draught on the river Rhône and the Albert canal.

- The length of the locks at the Saimaa navigation and the Trollhätte canal. The maximum permissible length is 82 m in the Saimaa navigation, and 88 m on the Trollhätte canal.

The river Rhine is a class VI_b. It is accessible by barges of the class up to Karlsruhe. At Strasbourg there is a height restriction due to two bridges, which limits the barges to 7 metres.

The waterway network in the former east-block countries is characterised by dimensions differing basically from those in the rest of Europe. There is a clear difference between Scandinavian canals and European canals. Scandinavian waterways were designed for seagoing ships while European waterways were designed for inland shipping.
The design speed of the IPSI barge VI_b, fully loaded in open waters, is set to maximum 28 km/h.

Sailing speed upstream and downstream rivers will depend on varying current conditions as well as speed restrictions and other traffic.

With a typical river speed of 5.5 km/h, the maximum speed upstream and downstream will be 22.5 km/h and 33.5 km/h respectively.

Considering typical current conditions, speed restrictions and other traffic, the following table gives an indication of possible voyage time for sailing upstream and downstream the river Rhine:

	Upstream	Downstream
Rotterdam - Duisburg	20 hrs	13 hrs
Rotterdam - Mainz	40 hrs	27 hrs
Rotterdam - Mannheim	48 hrs	32 hrs
Rotterdam - Woerth	52 hrs	35 hrs

In narrow channels, speed restrictions and shallow water effects will limit the speed even further. Typical sailing speeds may be10 km/h fully loaded and 12 km/h when empty.

Adding barges per round trip to form a convoy is a limited option because of the widespread area of different terminal locations in the seaports, i.e. Rotterdam.

With modern technical equipment such as radar and echo sounder, etc. the travelling speed of the barge can be maintained on a round the clock basis 24 hours a day. However, there exist regulations, which limit the possibilities for night sailing on some of the canals.

4.3.2.2 Barge mission

The mission of the IPSI barge is to be a part of the IPSI transport network, which aim is to transfer goods from roads to sea and river transport. By doing so the barge will help to lessen the pressure on the European road network. To fulfil this mission the barge must be an efficient player in the intermodal logistic chain. This includes the fact that the barge will have to meet the requirements of road and rail transport according to cargo units transported, reliability and quality of service.

High efficiency for the barge will be achieved through using the IPSI cargo handling technology, which is based on horizontal handling of the goods. This includes the special layout of deck and ramp and the possible use of AGVs for loading and unloading.

4.3.2.3 Barge type

As stated earlier in this report, a large investment in new barge designs is not seen as economically feasible. It is rather the desire to try to make a significant step forward in barge transport efficiency, through improvements of the present barge designs. Following from this, the IPSI barges will be of the common motorship types that can be seen on rivers and canals today.

The new feature will be that these barges will use the IPSI loading and unloading technology. It will be a RoRo barge, which there are several of operating in the Rhine. The IPSI barge will be an extension of the IPSI family of short sea vessels, hence having the special deck with lines dived by curbs and a wide ramp.

4.3.2.4 Barge size and capacity

The barges designed will be of class IV, V and VI_b. Maximum dimensions of barges in each of the different classes are shown in Table 4.32.

The competitors will be container and RoRo barges that either operates on the Rhine today or is being developed to frequent that river.

The largest containerbarge ever was put into service in April 1998[ii,iii]. It has a capacity of 398 TEU when stacking four layers high and six wide. The barge measures 134m LOA by 16,84m wide and has a dead weight capacity of 5600 tons. The barge will be deployed on a service between Rotterdam and Karlsruhe.

There are not many RoRo barges operating on the river Rhine. Some special designed car carrying barges are transporting cars for the manufacturer, but not many are transporting trailers and containers in regular schedules.

To maximise capacity inside the limitations when having a RoRo barge, the figures will be as shown Table 4-32 below:

Table 4-32. Barge design dimensions

Class	**Length (m)**	**Width (m)**	**Dead weight (t)**	**Capacity (TEU)**	**No. of decks**
IV	85	9,5	325	33	1
V	110	11,4	840	84	1
VI_b	140	15,0	2275	244	2

It has been designed a 244 TEU barge of class VI_b, and with a draught of 3.4 meters it can have two decks. The lower deck capacity is 64 TEU and the upper have a capacity of 180 TEU in two levels.

When going from class VI_b to V the capacity reduces by 160 TEU to 84 TEU. The length is only reduced by 30 m and the width by 3,6 m. As seen the differences in capacity between the three classes are very large. This is not only due to the length and width restrictions, but also the height restriction, which limits class V and IV to respectively two and one container high on one deck only.

The reason for designing a 33 TEU barge with only one layer of containers is that it can operate as a feeder, and that it illustrates the limitations of RoRo barges of smaller classes than VI_b.

4.3.2.5 Transport routes

The class V and VI_b barges are restricted to operate mainly on the Rhine and larger rivers in Belgium and the Netherlands. A barge of class IV can with its dimensions cover all side rivers of the Rhine, and it can reach almost every city in the middle Europe with connection to the inland waterways system.

The transport routes for the IPSI barge will be the rivers and canals that can be accessed by motorships of class IV, V and VI_b. The barges of class V and VI_b can be deployed on routes from Rotterdam and up Waal and the Rhine to Karlsruhe and Basle. The class IV barge can cover cities like Basle, Nancy, Stuttgart and the rivers Main, Donau, Elbe and the Ems canal. It can therefore operate as a feeder transport to the Rhine or be deployed in scheduled services on the inland waterways towards Prague or Wien.

4.3.2.6 General arrangement

Figure 4-42 shows the class VI_b IPSI barge general arrangement.

The barge is 140 meters over all, and the width is 15 meters. The cargo hold measures 118 m x 14 m on the upper deck and 106 m x 12 m on the lower.
The engine and accommodation are placed at stern. The wheelhouse must have an elevator mechanism so it can pass under the bridges.

The full width RoRo ramp at the bow makes the IPSI barge special from the other RoRo barges that already are in traffic on the Rhine. The square cargo area in the bow will therefore hang out over the water.

The Class IV and V are both designed with only one deck. The two barges are quite similar, but the class V is allowed to be longer and higher, thus increasing the capacity from 33 TEU to 84 TEU. Both of the barges have a capacity of three containers abreast even though the class V can be 2 meters wider. This is due to the fact that the width dimensions do not allow room for a fourth container.

Like the Class VI$_{b}$ barge they are self-propelled, with engine and accommodations placed at stern. They also have wide bow that makes the IPSI RoRo ramp possible.

The barge designs presented in the appendix shows the three different classes from above, port side and the front, and cross section. The class VI$_{b}$ is shown both full and empty to illustrate the ship design and the stowage plan. It is also indicated an isometric view of the cross section, and a drawing with measurements. These cross section views exemplify the general arrangements.

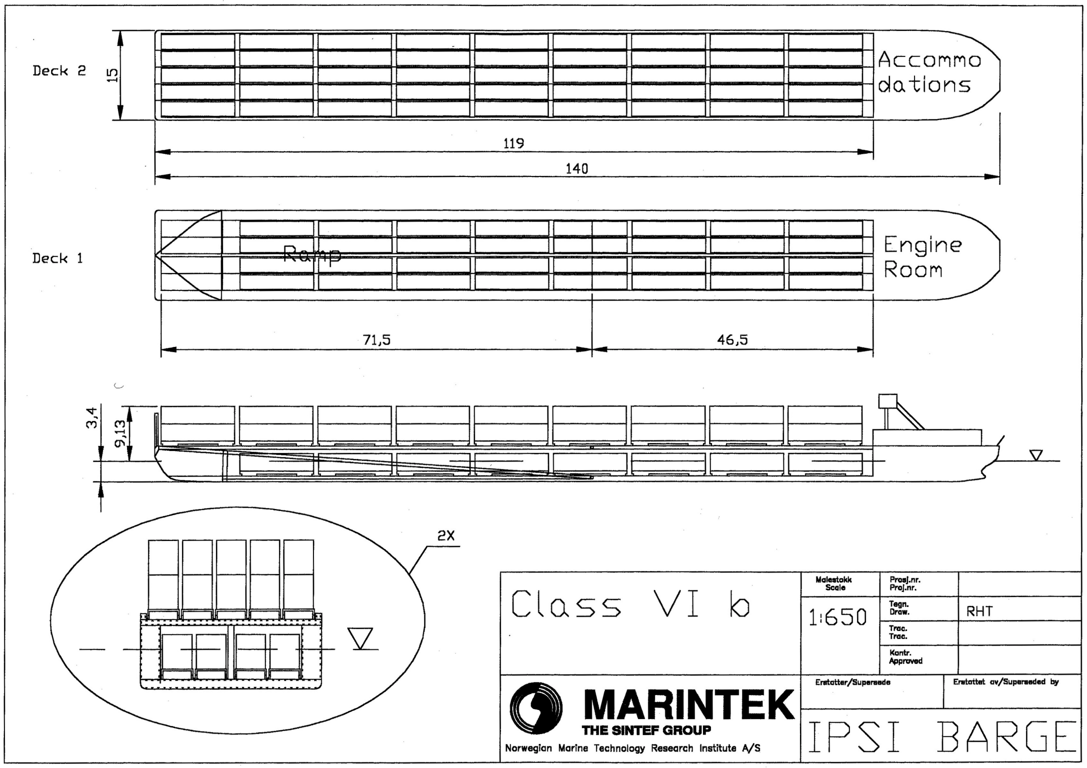

Figure 4-42. The class VI$_{b}$ IPSI barge

The optimal waterlines are shown, due to depth and height restrictions. Trim and waterline calculations have not been done pre to the drawing.

4.3.2.7 Deck layout

The cargo handling operation benefits from a deck layout where there are only straight lanes. Straight lanes mean reduced operation time, because it is possible to drive straight to the position without going through bends and narrow ramps.

By adding curbs to the deck to separate the lanes, the tugmaster can push the semitrailer or translifter at a much higher speed. In fact up to 35 - 40 km/h according to test results from STORA[iv] in Gothenburg. It is proved to be difficult and nearly impossible to drive over the curbs. Hence, the risk for damages is greatly reduced, because the trailers and cassettes are not touching each other.

All lanes can be operated at the same time, providing a large opportunity for time saving. Without curbs, only a couple of tugmasters may be on the deck at the same time. With curbs each lane will be an individual operating zone all the way from the ramp.

Using curbs and straight lanes moves the bottleneck from the deck to the ramp where the lanes are accessed.

Another benefit from the curbs is that they prevent the cargo from moving sideways inside the ship. The curbs may also be used for preventing vertical movements or overturn moment that may cause the cargo to tip over, if the curbs are fitted with securing or lashing devices.

Curbs may be moved or removed to allow cargoes that do not have standard dimensions, to be transported on the barge. The curbs are to be fitted to the deck by twistlocks.

The class VI_b's upper deck has five rows of containers stacked two-high. With nine 40' container stacks in each row, each level can carry 90 TEU. The lower deck is stacked only one high, and because of the ramp this deck is shorter. The capacity of this deck is 64 TEU. The total carrying capacity of the barge is as earlier mentioned 244 TEU. The class IV and V can carry 11 and 14 TEU in each lane, respectively.

The deck layout is illustrated in the different general arrangement drawings in the appendices. The boxes are 40' containers or trailers.

4.3.2.8 Number of decks

The IPSI barge class VI_b can have two decks, while other barges have one deck due to height restrictions because of the bridges. Even if it had been possible, the length of the internal ramp would have been so long that the capacity on the lower deck would have been limited.

The one deck version may be more suited for lolo operations, while a two-deck solution will require a RoRo operation.

4.4 Dimensioning

4.4.1 The Case

When the requirements for the IPSI terminal were developed, the capacity presented in Table 1-1 represented a key design target for the IPSI project. In our efforts to establish a realistic estimate for the investments required to develop an IPSI installation, the ability to unload and load a vessel with a capacity of 400 TEU's in less that 2 hours were the key focus.

As the IPSI terminal is supposed to be a link in a well-controlled intermodal transport chain, it is demanded that all export cargo that is provided will be loaded onto the first IPSI vessel arriving. The import cargo from an IPSI vessel should be handled and processed to inland modes before the arrival of the next IPSI vessel. This puts high demands on the IPSI terminal operations but also on the service providers on land.

For hinterland transport, three modalities are included:

- Barges for inland shipping. Only IPSI barges are considered here. An IPSI barge only carries cassettes and will be handled exclusively by the AGV system. It is required that the unload- and load operations on barges will be completed between two IPSI vessel calls.
- Trains for the rail modality. In the model no specific train timetables are applied. It is assumed that trains are available in the time period between two IPSI vessel calls. It is demanded that all export rail containers are unloaded from the train and loaded onto the first IPSI vessel and that all import containers from an IPSI ship are loaded onto a train before next IPSI vessel departure.
- Trucks for the road modality. As trucks are manned, this modality demands a high service level. Planning of truck arrivals is much more difficult than for train and barge, so a certain deviation in arrival times and even peaks in arrivals will be unavoidable. Therefore, different arrival patterns are investigated. For truck service it is demanded that 90% of the trucks will be handled within 15 minutes after arrival at the terminal for both export and import cargo.

4.4.2 AGV's Required

4.4.2.1 The Overall Model

In order to establish the number for AGV's required for unloading and loading an IPSI vessel, a detailed simulation model for the IPSI terminal was developed. The main structure of the simulation model is shown in Figure 4-43. Loading and unloading of trains takes place in the "Rail Service Centre" (RSC) and the same operations for trucks takes place in the "Truck Service Centre" (TSC).

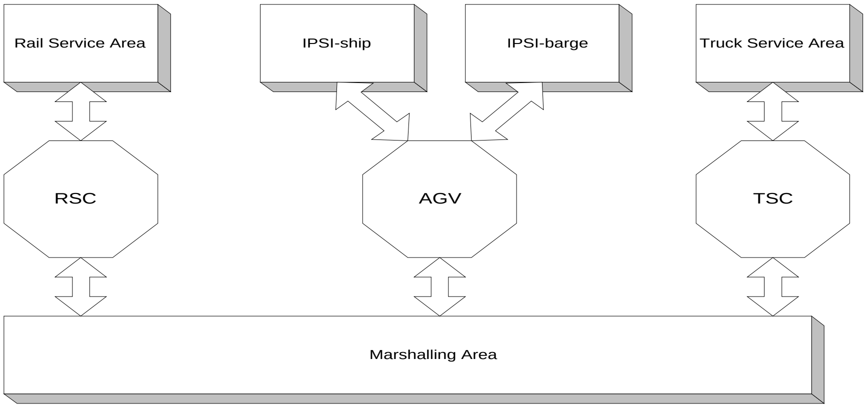

Figure 4-43. Overall structure of the detailed IPSI-model.

4.4.2.2 AGV Modelling

The movement of the AGV's is modelled down to a very detailed level, comprising two parts:

- A model of the real technical behavior of the AGV's.
  Important parameters used for an AGV are:

Length:	14 m
Width:	2.5 m
Top speed:	3 m/sec
Speed under cassette:	2 m/sec
Acceleration/deceleration:	$0.5\ m/sec^2$
Curve-radius:	20 m
Climbing speed on ramp:	2 m/sec

- A model of the traffic-control for the AGV's.
  The central controlling mechanism basically keeps an image of the AGV-positions. Every 10 metres an AGV reports its position to AGV-control. Based on this information and the knowledge of the routes and last-reported positions of the other AGV's, AGV-control determines a new route-point for the reporting AGV. The AGV receives allowance to drive to this point if the way to this point is clear.

  So AGV-control is a central controller to guarantee collision-free driving and prevention of deadlocks. Because AGV's always drive as a member of a train, no new controlling ideas (based on e.g. local intelligence) are needed. The controlling can be kept much more simple than in the case of 'free-ranging' AGV's.

  Seldom noticed, but very important is the fact, that modeling the controlling-mechanism in this way also results in a detailed specification of software-design for implementation.

4.4.2.3 Layout

A schematic view of the IPSI terminal layout used in these simulations is given in Figure 4-44.

On the left side of the illustration, TSC and RSC are drawn. Both TSC and RSC use the same pool of straddle carriers.

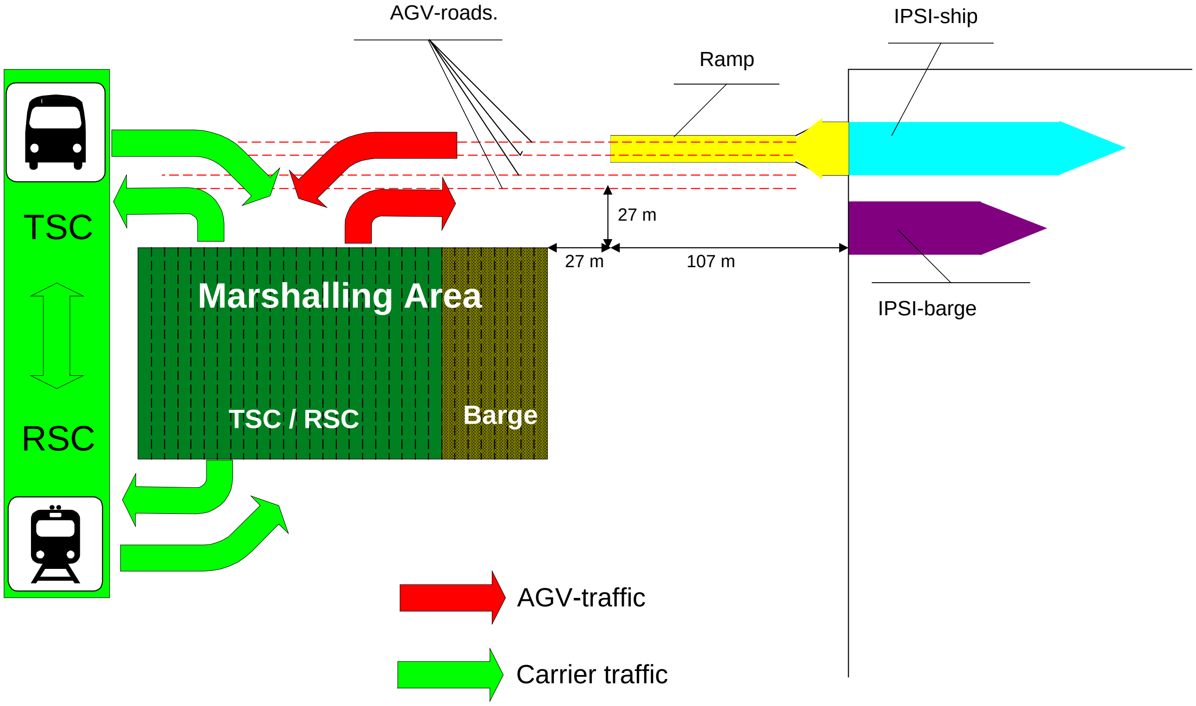

Figure 4-44. The IPSI terminal

The marshalling area is divided into rows. The left part of the marshalling area contains the rows with containers for TSC and/or RSC. The right part is reserved for containers to be delivered to or coming from the barges. The AGV's enter and leave the marshalling area only on one side, so the straddle carriers can always use the other side. In the model the following (cost-optimal) operational procedures are implemented:

- During operations each row must be exclusively reserved for the AGV-system or the straddle carrier-system. So when a row is reserved by the AGV-system, no straddle carriers are allowed to enter this row. Reservation of the next row in the marshalling area is done when an AGV-train leaves the marshalling area to go to the IPSI-vessel and plans to return to that row. Then there is enough time for straddle carriers in the newly reserved row to leave it. The row is released by the AGV-system when the AGV-train has delivered or picked up the cassettes and the last AGV of the train has left the marshalling area. Row-reservation can be simply implemented by using "stop-lights" and notification of terminal control.

- When there is an IPSI-ship at the quay the straddle carriers are allowed to enter the non-reserved rows of the marshalling area from the side opposite to the AGV-entrance. When there is only an IPSI-barge present, this restriction holds for the barge-part of the marshalling-area only.

- When there is no IPSI-ship at the quay the straddle carriers may enter the marshalling-area from both sides. This leads to shorter cycle-times, because two straddle carriers can operate in a row at the same time. Only simple control is needed to prevent mutual blocking of straddle carriers. Hence, job assignment to the straddle carriers can be optimised with respect to driving times and ‘reachability’ of the marshalling area.

4.4.2.4 Experiments and results

AGV-trains of 10 AGV’s are considered in the model. In reality the row length of IPSI-vessels varies between 7 and 11 container cassettes. For proof of feasibility the consequences are:

- The simulation must show that there is enough time left to unload and load the last (11-th) cassettes. The total handling of an IPS-ship must be significantly less than 90 minutes.

- For the cases when a shorter train is needed (rows of length 7, 8 and 9) 1, 2 or 3 AGV’s can be left in the marshalling area and sent to the next row in the marshalling area, while the AGV-train is handling the ship-row. Because the distance for a route in the marshalling area is far shorter than a route to the ship, this can always be accomplished.

A cycle is defined as one route from marshalling area to ship and back to the marshalling area again. Given this layout the mean cycle time appeared to be: 425 sec.

Looking at distances on this compact layout it becomes clear, that *this cycle time is almost completely determined by the AGV-speed under cassettes and on the ramp* (during almost 80% of the route the speed is restricted to one of these). So the maximum speed in a free area (in this case 3 m/sec) has almost no influence on this cycle-time.

Another conclusion is, that 20 train-moves can be done in 20 * 425 sec = 8500 sec. We only have 90 minutes = 5400 sec available, so we need at least 2 AGV-trains of 10 AGV’s.

The next experiment was executed with two AGV-trains. To prevent deadlocks (and unnecessary waiting) a controlling mechanism was added, that uses two “stop-lights”: one for leaving the marshalling area and one for leaving the IPSI-ship. These “stop-lights” determine the moment an AGV-train is allowed to leave. Allowance is given when the last AGV of a train passes one of these “stop-lights”.

The “stop-lights” are used only, when AGV’s interfere with each other, i.e. when working on the same deck.

Two strategies have been worked out.

A. The AGV-trains work on separate decks. So AGV-train 1 handles deck 1; AGV-train 2 handles deck 2. By routing each train to different parts of the marshalling area, the trains don’t interfere with each other. In this case the ship is handled completely in 4250 sec. During this time no trailer-traffic is allowed. So trailers have to be handled in 7200 – 4250 = 2950 sec.

B. The AGV-trains work sequentially on the same deck. First deck 1 and 2 are unloaded completely, then deck 2 and 1 are loaded completely. In this case the “stop-lights” are needed and this will extend the cycle time. This experiment shows a cycle time of 493 sec, so the ship is handled in 4930 sec. Looking at the activities per deck, each deck is occupied by AGV-traffic for about 2465 sec. So trailer traffic is allowed on each deck for 7200 – 2465 =4735 sec.

In both cases there is no problem for the AGV-system to handle the IPSI-ship within the limits. Depending on the portion of trailer load, a best strategy can be chosen.

Increasing the number of AGV’s can only be done in train-units, so in steps of 10 AGV’s. For example, doubling the number of AGV’s makes it possible to serve each deck with two AGV-trains. In this case the “stop-lights” of strategy B are needed and the resulting cycle time will be 493 sec. The IPSI-ship is then handled in 4930 / 2 = 2415 sec.

We may then draw the following conclusion: To handle an IPSI-ship according to the demands, we need 20 AGV’s. They are capable of performing the operation in (minimal) 4250 sec. or 1 hour and 11 minutes. If the trailer-portion of the shipload should increase, a strategy must be followed with a larger cycle time. But the ship will still be handled in far less than 1.5 hours.

If the number of AGV’s was increased to 40, i.e. there were 4 AGV-trains, 2 working on each deck, the loading unloading and loading can be achieved in approximately 40 minutes, provided that all the cargo is fitted onto cassettes. There are no practical reasons for extending the number of AGV-trains above 4 when unloading and loading one vessel.

4.4.3 Other Equipment

4.4.3.1 <u>Model parameters</u>

Several parameters are incorporated in the special model that was used to determine the other capabilities of the IPSI terminal. The parameters may be divided in the following groups:

1. The terminal lay out: location and dimensions of stacks, rail tracks, docks and IPSI vessel. Multipliers for terminal distances for easy modifications of terminal dimensions.
2. Equipment: Number of AGVs, number of straddle carriers, equipment characteristics: speed, acceleration and deceleration times, positioning times and picking and placing times.
3. Cargo flow characteristics: IPSI vessel cycle time, in port time, number of cassettes for import and export, TEU factor[1] for import and export, modal split (percentages of truck, train and barge for import and export), cassette utilisation and import and export arrival patterns of trucks.
4. Control variables, defining handling priorities dependent upon the state of the system. For example, if an IPSI vessel is in port and the export marshalling area is not fully filled yet, straddle carriers will give priority to loading the marshalling area above handling trucks and trains with import containers.

4.4.3.2 Performance indicators

The performance of the system is measured as a function of several input-sets. Based on the performance indicators it is decided if a specific input-set is feasible. The main performance indicators are:

- Completion time of the IPSI vessel. The absolute demand is that the vessel is fully unloaded and loaded during its in-port time. In the model the time is measured when 95% of the vessel is loaded.

- Completion time of the IPSI barge. The barge should be unloaded and loaded in the time between two IPSI calls.

- Train handling times: Export containers must be unloaded from the train and transported to the marshalling area before the next IPSI arrival. Import containers must be loaded onto the train before next IPSI departure. In the model the staying times of the train-import and -export batches are measured.

- Truck service: The truck service is measured as the 90% percentile of the truck waiting times. This percentile must be less than 15 minutes. It means that in that case the waiting time 90% of the truck is less than 15 minutes.

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[1] The TEU-factor is used to calculate the number of units to be handled. If the TEU factor is 1, there are only 20 feet containers. If the TEU-factor is 2, there are only 40 feet containers. The TEU-factor is between 1 and 2.

4.4.3.3 The central case

The average cassette utilisation was assumed to be 75% and the TEU-factors for both import and export stream were taken to be 1.7. Table 4-33 gives the flow data. Every IPSI ship delivers 100 cassettes and takes on another 100 cassettes. Every cassette has a capacity of 4 TEU’s, which means 800 TEU’s import plus export for one vessel. For three arrivals per day this means a maximum of 2400 TEU’s. 75% of this gives the 1800 TEU’s of Table 4-33. The TEU-factor of 1.7 means that for example the 440 truck TEU’s consist of 440/1.7= 259 containers or ‘units’ as is indicated in Table 4-33.

Table 4-33.

Cargo flows of the central case for 24 hours based on an 8 hours IPSI cycle. The average cassette utilisation is assumed to be 75% and the TEU-factor is 1.7

	Truck		Train		barge		Total
	TEU’s	Units	TEU’s	Units	TEU’s	Units	TEU’s
containers	440	259	560	329	800	471	1800
trailers	360	180	240	120			600
total	**800**	**439**	**800**	**449**	**800**	**471**	**2400**

4.4.3.4 Barge flow

The barge flow needs some additional explanation. In this investigation it is assumed that the IPSI barge only contains cargo for the next IPSI vessel and receives cargo from the last IPSI vessel. Consequently the barge stream does not require straddle carrier capacity! This is the big advantage of the IPSI barge concept. Figure 4-45 shows the modal split of the central case.

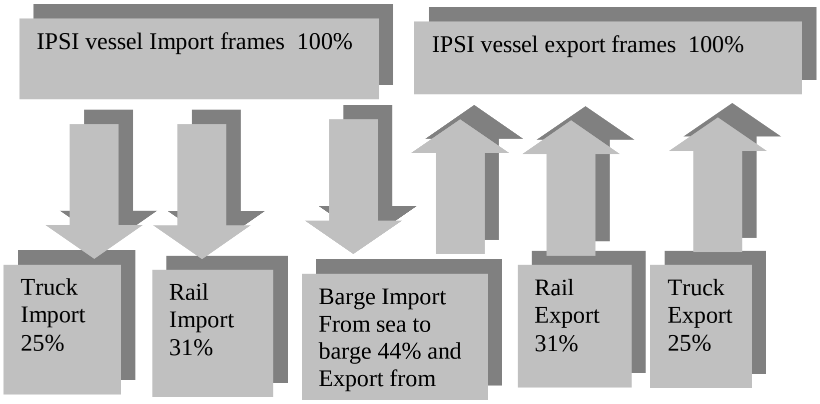


Figure 4-45. IPSI modal split in the central case

4.4.3.5 Simulation results

Variation of IPSI vessel cycle times

The results of five series of experiments varying the cycle times of IPSI vessel arrivals from 12 hours down to 3 hours are shown in Figure 4-46. The flows were according the central case and are summarised in Table 4-33.

In Table 4-34 the data derived from Figure 4-46 and some other results are given. The maximum capacity of an IPSI terminal lie between 3 and 4 hours cycle time. 3 hours is not an option in this study, because then more AGV's are needed. Hence, this is not further investigated. It is important to check if the trains are handled in time and if the IPSI vessel has been handled within 2 hours. These data are shown in Table 4-34.

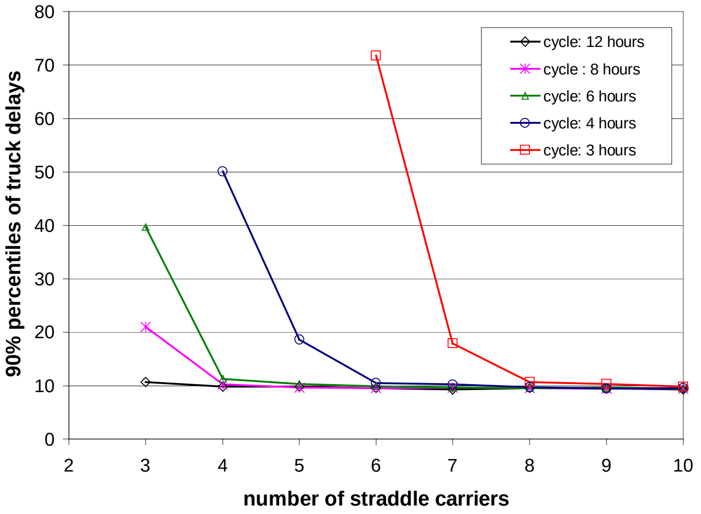


Figure 4-46. 90% percentiles of truck delays for 3,4,6,8 and 12 hours ship-cycle time

Table 4-34

Central case. Number of straddle carriers needed to obtain a service in which 90% of truck delay is less than 15 min.

IPSI Cycle	Number of straddle carriers. Av. Straddle cycle time = 6 min	Av. straddle occupation %	Av. AGV occupation % . handling of IPSI barge included	Max. Train loading time	Time needed till IPSI vessel is 95% loaded (min)	Max. number of cassettes on marshalling area
3 *)	8	80.6	33.7 *)	159	88	215
4	6	80.5	39	209	88	193
6	4	81.9	26.9	205	110	175
8	4	61.7	21.4	157	113	176
12	3	54.4	17.3	210	125	168

*) in the 3 hours run 30 AGVs were employed.

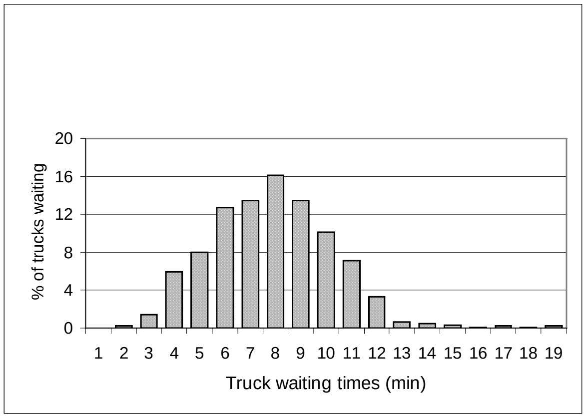


Figure 4-47. Waiting time distribution of trucks in the central case with 6 straddle carriers. The 90% percentile is 11 minutes.

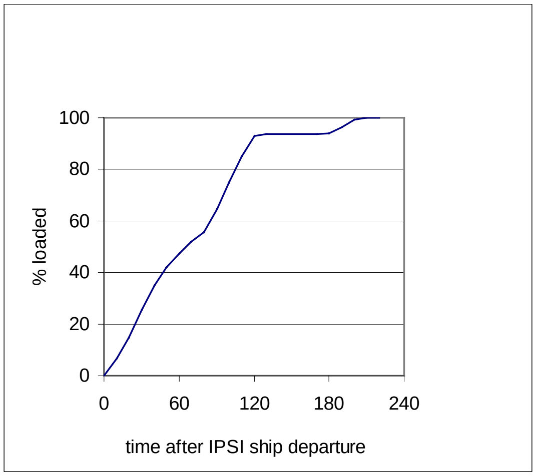


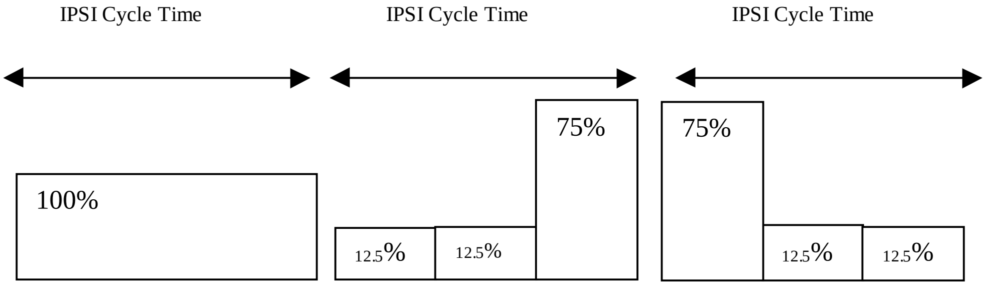
Figure 4-48. Cumulative train load with import containers in the central case with 6 straddle carriers

Figure 4-47 shows the trucks waiting time distribution and Figure 4-48 shows the loading of the train both for the central case with 6 straddle carriers and cycle 4 hours.. The number of trucks waiting appears to always be less than 10, provided that the 90% percentile requirements are fulfilled.

<u>Arrival patterns</u>

Two types of arrival patterns are used for both import and export truck arrivals. One type A is a uniform distribution and type B and C are peaked patterns for export and import arrivals respectively.

Four combinations are applied: AA, BC, AC and BA



Uniform distribution.
For both import and
export arrivals: Code: A

Peaked import arrival
pattern: Code: B

Peaked import arrival
pattern: Code C

Figure 4-49. Truck arrival patterns applied.

Table 4-35

Number of straddle carriers needed for different truck arrival patterns for IPSI cycle 6 hours				
Truck arrival patterns		#Straddle carriers	Av. straddle occupation %	
Export	import			
A	A	9	35.8	
B	C	4	81.9	
B	A	9	35.8	
A	C	5	65.3	

The arrival patterns may have a large influence on the number of straddle carriers needed to obtain the required service rate. In the runs shown above especially the uniform call pattern for import containers causes a peak just before next ship arrival. These effects have been analysed from detailed straddle carrier utilisation plots. In the simulations the peaked pattern BC has been applied. The assumption is already made that the IPSI terminal is part of a well-controlled logistic chain. Therefore we assume that it is possible to control the arrival pattern in such a way that at most one extra straddle carrier is needed to deal with fluctuations in arrival pattern.

4.4.3.6 Determination of the number of straddle carriers

The number of straddle carriers needed for the IPSI terminal is not just one figure. It depends of course on the IPSI vessel cycle and on all the other parameter settings. Still we need quantification of the equipment needed. Moreover a fixed number of straddle carriers is needed for the cost calculations to be made. It is obvious that the number of straddle carriers depends on the number of moves to be made in a certain time period. Figure 4-50 and Figure 4-51 shows the relationship between the number of straddle carriers and the number of straddle moves for an IPSI cycle of 8 and 4 hours respectively. In order to determine the equipment needed for some IPSI configuration the net number of straddle moves in 24 hours has to be calculated. Then Figure 4-50 or Figure 4-51 may be used for determination of the required straddle carriers. For cost calculation purposes a number of 11 straddle carriers will be used. This can be considered to be a rather conservative estimate.

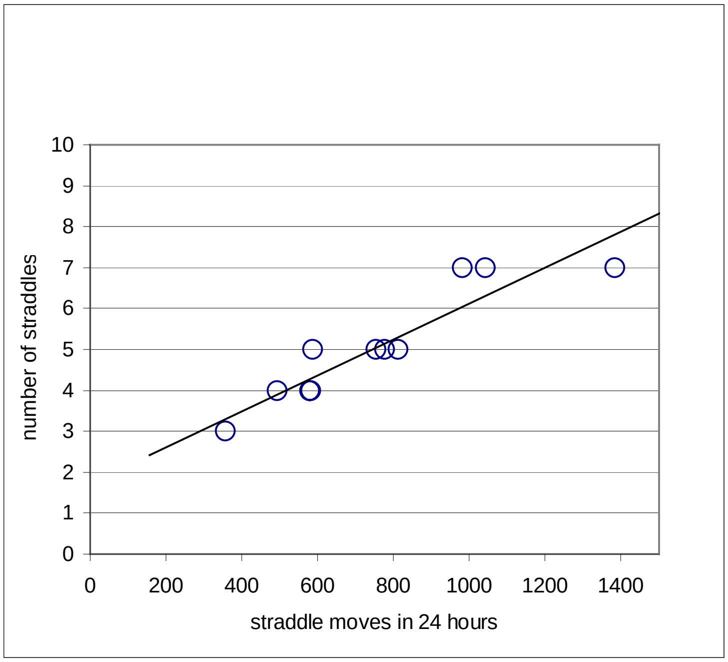


Figure 4-50. Number of straddle carriers as a function of the number of straddle moves per 24 hour for IPSI cycle 8 hours

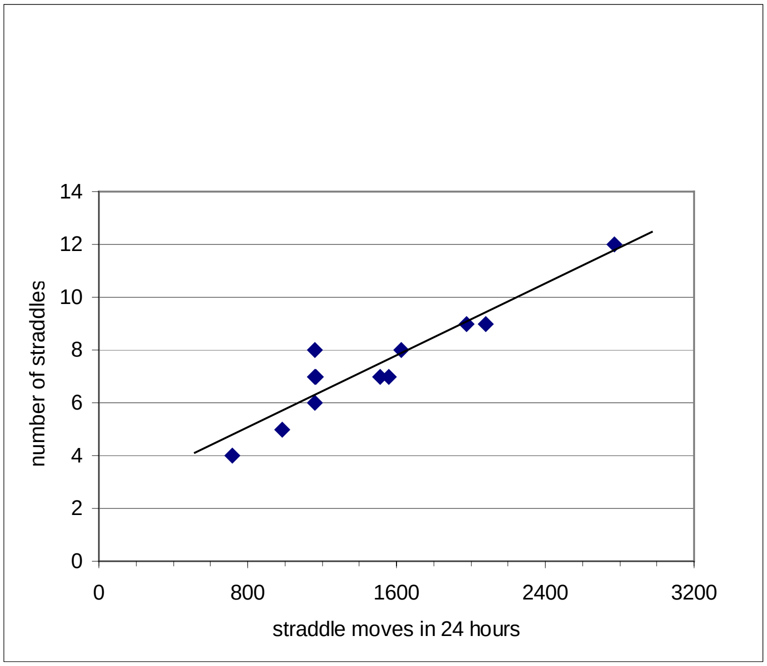


Figure 4-51. Number of straddle carriers as a function of the number of straddle moves per 24 hour for IPSI vessel cycle 4 hours.

4.4.3.7 Conclusions

Based on the simulations performed, we may draw the following conclusions:

- An IPSI terminal with a cycle time of four hours is feasible with respect to landside and seaside handling. This implies a flow of 4800 TEU per 24 hours.

- The number of cassette positions needed at the marshalling area is 200, comprising a complete import and export batch for an IPSI ship. This is logical because all cargo of an IPSI ship has to be processed in one IPSI vessel cycle.

- The number of landside equipment that is needed to meet the service requirements is determined. It depends on a number of parameters being: the cycle time of IPSI vessels, the TEU factor, the cassette utilisation, the modal split and the land side arrival patterns of trucks.

- The influence of arrival patterns of trucks on equipment requirements appears to be considerable. Therefore it is necessary that the IPSI terminal is part of a well controlled logistic chain and that it is possible to control the land side arrival patterns to minimise the need for land side handling equipment. Further research on this issue is required.

- Train batches can well be handled between two IPSI ships.

4.5 Cost

These estimates consist of the cost calculation for the IPSI terminal and for the IPSI ship. These models are then combined in the complete calculation of the IPSI system, see section 4.5.4.

4.5.1 The IPSI Terminal

As illustrated above, the IPSI terminal is a flow based terminal designed for a fast throughput and short dwell times.

The cost elements of the IPSI system are:

- Infrastructure, which is the area
- Superstructure, which is the equipment and the building
- Personnel cost that specifies the functions and number of personnel in each position
- Overhead and financial cost, which are all other costs.

Table 4-36 shows the complete cost of an IPSI terminal with a capacity of 876.000 TEU per year. (This equivalents 3 daily arrivals and departures of a 400 TEU vessel 365 days per year).

Table 4-36. Total cost calculation (in Euro) for the IPSI terminal

I.	**Infrastructure**	Area in m^2	Yearly Rent/m^2			Yearly costs
1.	Total Area	154 000	2			277 200
		No. of	Investment costs		Deprec.	Yearly
II.	**Superstructure**	Units	per unit	total	(Years)	costs
	Equipment :					
2	Tugmasters	10	100 000	1 000 000	12	83 333
3	AGVs	22	350 000	7 700 000	15	513 333
4	Straddle Carriers	11	550 000	6 050 000	12	504 167
5	Cassettes	220	8 000	1 760 000	25	70 400
6	Ramp	1	3 300 000	3 300 000	25	132 000
7	Operating Costs= 10% of 2,3,4					1 475 000
8	Mainten.& Repair = 10% of 2 - 6					1 981 000
9	Rail tracks	1	1 500 000	1 500 000	25	60 000
	Buildings :					
10	Office	1	310 000	310 000	25	12 400
11	Workshops	1	1 000 000	1 000 000	25	40 000
12	Fuel Station	1	100 000	100 000	15	6 667
13	Entrance/Exit Gate	1	50 000	50 000	15	3 333
	Software :					
14	Computer + Software	1	620 000	620 000	5	124 000
15	AGV Software	1	1 000 000	1 000 000	5	200 000
III	**Personel Costs**					
16	Twistlockers	49	40 000			1 960 000
17	AGV Controller	5	60 000			300 000
18	Straddle Carrier Driver (incl. tugm.)	65	45 000			2 925 000
19	Planner	11	60 000			660 000
20	Office Clerks	16	30 000			480 000
21	Gate Checkers	11	40 000			440 000
22	Engineers	2	60 000			120 000
23	Technicians	5	40 000			200 000
24	AGV Specialists	5	40 000			200 000
25	Straddle Carrier Specialists	5	40 000			200 000
26	Operating Costs=3% of personel costs					224 550
IV	**Overhead and financial cost**					
27	Miscelaneous = 5 % of yearly costs					659 619
28	Overhead = 10 % of yearly costs					1 319 238
29	Interests = 5 % of total investment			23 390 000		1 169 500
	Total Cost					**16 340 741**

4.5.2 Comparison IPSI and Common Container Terminals

The cost comparison of the IPSI terminals with container terminals (CT) will show whether the IPSI terminals could be competitive to the common transhipment systems.

The source of the figures of the container terminals is the study from Drewey Shipping Consultants Ltd. (DSC), "World Container Terminals", London, March 1998.

To guaranty the comparability of figures between DSC and the IPSI calculations, adjustments have been made (Table 4-37). The equipment costs will be compared without costs for M+A, buildings, rail tracks and operating costs. Labour costs will be compared inclusive overhead costs, but without operating costs, insurance and miscellaneous costs. The IPSI terminal offers a smaller buffer than the other terminals. The IPSI terminal in this example uses 2 AGV-trains of 10 AGVs each.

The Compact IPSI terminal in this table means an IPSI terminal without AGV-operations. All cargo handling in a Compact IPSI terminal is performed with conventional RoRo equipment.

Table 4-37. Cost Comparison between Container terminals, IPSI terminals and RoRo terminals

	Container terminal[1]		IPSI Terminal[2]	
(In Euro)	Small	Large	Compact	IPSI
TEU	210 000	600 000	292 000	878 000
Equipment cost*	21 500 000	68 700 000	7 000 000	21 400 000
Equipment cost/year**	1 900 000	5 200 000	500 000	1 600 000
Labour cost/year***	4 400 000	10 200 000	2 500 000	7 500 000
Labour and equipment cost/year	6 300 000	15 400 000	3 000 000	9 100 000
Employees	232	531	67	174
Calculations				
Equipment cost/year/TEU	9,0	8,7	1,7	1,8
Labour cost/year/TEU	21,0	17,0	8,6	8,5
Labour and equipment cost/year/TEU	30,0	25,7	10,3	10,4
TEU/employee	905	1 130	4 358	5 046

* Equipment without M+A, buildings, rail tracks, operating cost
** Without interest
*** Labour cost incl. overhead, without operating cost, interests and misc. cost.

[1] Drewy Shipping Consultants Ltd. World Container Terminals, London, March, 1998
[2] IPSI report D 6001, Section 7: Cost calculation of the complete IPSI system
[3] Statement from RoRo terminal operators

The differences between the throughput of the terminals should be considered. The throughput of the IPSI terminals are higher but never the less the comparison indicates interesting advantages for IPSI. The equipment costs (total investment for equipment) is extremely high for Container Terminals compared to the IPSI terminals. Furthermore labour and equipment costs per year are much higher for container terminals as for the IPSI system.

A significant difference is the number of employees required for the different concepts. An IPSI terminal needs a very small staff.

The ratios "equipment costs per year per TEU" and "labour costs per year per TEU" clearly show the difference between both transhipment systems. The ratio "labour and equipment costs per year per TEU" is most important. This indicator shows that the IPSI terminals could be very competitive to container terminals.

It can be stated that the cost comparison of the different transhipment systems indicates lower investments, less costs per TEU and a higher throughput for the IPSI concept.

Table 4-38 shows another situation. The IPSI terminals will be utilised by 75 %. However, the cost advantageous differences between the systems are still obvious.

Table 4-38. Cost Comparison of Terminals with 75% Utilisation of the IPSI terminals

	Container terminal[1]		IPSI Terminal[2]	
(In Euro)	Small	Large	Compact	IPSI
TEU	210 000	600 000	219 000	657 000
Equipment cost*	21 500 000	68 700 000	7 000 000	21 400 000
Equipment cost/year**	1 900 000	5 200 000	500 000	1 600 000
Labour cost/year***	4 400 000	10 200 000	2 500 000	7 500 000
Labour and equipment cost/year	6 300 000	15 400 000	3 000 000	9 100 000
Employees	232	531	67	174
Calculations				
Equipment cost/year/TEU	9,0	8,7	2,3	2,4
Labour cost/year/TEU	21,0	17,0	11,4	11,4
Labour and equipment cost/year/TEU	30,0	25,7	13,7	13,9
Equipment cost/year/employee	8 190	9 793	7 463	9 195
Labour cost/year/employee	18 966	19 209	37 313	43 103
Labour and Equipment cost/year/employee	27 155	29 002	44 776	52 299
TEU/employee	905	1 130	3 269	3 776

* Equipment without M+R, buildings, railtracks, operating cost

** Without interest

*** Lobour cost incl. Overhead, without operating cost, interests and misc. cost.

[1] Drewy Shipping Consultants Ltd. World Container Terminals, London, March, 1998

[2] IPSI report D 6001, Section 7: Cost calculation of the complete IPSI system

[3] Statement from RoRo terminal operators

The comparison of the infra- and superstructure between the container terminals and the IPSI terminal indicates the main difference of these transhipment systems (Table 4-39). The most expensive area in the port is the quay area where the IPSI terminal needs only a small space that can be located in common harbour areas. The draft of the IPSI vessel is on a common level and large dredging activities could be avoided. The number of equipment is low and, consequently, an extensive maintenance and repair department is not necessary. This comparison of the infra- and superstructure indicates the cost efficiency of the IPSI terminal.

Table 4-39. Comparison of the Infra- and Superstructure

	Container terminal		**IPSI**
	small	large	**terminal**
Throughput (TEU)	210,000	600,000	876,000
quay length (m)	200-250	500-750	below 100m
AGVs (pcs.)	-	-	22
straddle carriers (pcs.)	27-33	44-60	11
quay cranes (pcs.)	5-6	8-11	-
draft (m)	8-12	10-14	8
area (ha)	8	16	7
Employees	232	531	174

In the cases where the IPSI vessels are used in connection with conventional RoRo handling, no specific terminal cost is incurred, because the existing cargo handling systems for RoRo can be used to operate the IPSI vessel.

When the volume in a terminal exceeds what can be handled conventionally, the AGV technology can be put in place. There will be one investment that has to be made in order for the AGV's to operate, and that is the system for navigation and the overall control of AGV's.

This cost is in the order of 1.5 million Euro. Compared to the equivalent of a container crane, the initial investment is limited. The number of AGV's may then be increased as the cargo increases, so that the total cost picture for the operation is as in Table 4-36 for operating 20 AGV's, with a capacity of handling more than 580 TEU's per hour. The cost per AGV is estimated at 350.000 Euro per unit.

Even for the high capacity scenario when AGV's are required, the initial investment of IPSI installations is kept to a minimum (1.5 million Euro). Thereafter, the capacity can be increased by acquiring one AGV at a time – up to a limit of 40, giving a natural growth of handling capacity as the available cargo grows.

4.5.3 The IPSI Vessel

The vessel-related cost is based on the use of the 150m-IPSI ship with European crew.

The cost elements for the vessel are:

- Annual wage cost
- Fixed operating costs
- Voyage operating costs which is the fuel costs
- Annual capital costs.

Two crews of 12 people are needed to operate this vessel. All people related cost in this calculation is per position. This means that the annual wage cost for a master, including all social costs, will be 58.182 Euro, which gives a position cost of 58.182 Euro * 2 = 116.364 Euro.

Table 4-40. Annual cost for the 150m IPSI-ship

Annual running costs		
Wage costs		
Master	116 364	Euro
Chief officer	96 000	Euro
Second mate	82 908	Euro
Chief engineer	101 820	Euro
Second engineer	91 632	Euro
Steward / 1st Cook	88 728	Euro
Four able seamen	120 960	Euro
Two cadetts	31 440	Euro
Fixed operating costs		
Administration	83 345	Euro
Supplies	138 909	Euro
Sundries	37 042	Euro
Annual classification costs (incl 5th year)	20 000	Euro
Repair and maintenance	64 824	Euro
Insurance	111 127	Euro
Lubrication oil costs	159 711	Euro
Voyage operating costs		
Fuel costs	1 703 939	Euro
Total annual running costs	**3 048 749**	**Euro**
Annual capital costs		
Interests and repayments	2 697 584	Euro
Return of own capital	920 316	Euro
Total annual capital costs	**3 617 900**	**Euro**
Total annual costs	**6 666 650**	**Euro**
T/C rate	**13 901**	**Euro/day**
Finance		
Total investment costs	35 000 000	Euro
Share of own capital	20 %	
Borrowed capital	28 000 000	Euro
Own capital	7 000 000	Euro
Payback period	15	Years
Rate of interest	5 %	
Return of own capital	10 %	

4.5.4 IPSI in the Intermodal Chain

4.5.4.1 Cost Models

We have developed a cost model on the basis if the cost estimates presented in section 4.5.1 and 4.5.3, which makes it possible to compare the cost and time usage for different transport modes between specified European destinations.

The cost parameter used in the comparisons is cost is per 2 TEU. A 2 TEU unit can be one 40 feet container, two 20 feet containers, one 45 feet container or one 13,6 meter trailer unit.

These cost estimates are total system cost, which includes all cost for the IPSI-vessel and for the IPSI-terminal, and a 75 % average utilisation of the system.

The cost model for the rail- transport is based on the rebated prices from several European railway companies to their big customers in the transport industry

The cost model for road transport is based on a total cost calculation for a road transport operation in France with French drivers. When comparing with cost figures for Danish and Norwegian operations we can say that the cost that we have used in the model is conservatively low.

The cost model for the barge is based on realistic transport rates on the Rhine and on the Seine.

The cost model per 2 TEU in all modes consists of a fixed part and a variable part. The fixed and variable cost for these different transport modes is presented in Table 4-41. In addition, we have to add the collection and delivery cost to get the total door to door cost. We have assumed a road based collection and delivery service in both ends of the chain. As long as the distances are short, the fixed cost for road transport of 50 Euro in both ends will cover the cost as they are presented in Table 4-42. For road based transport there are no extra cost for the collection and delivery.

Table 4-41. Fixed and variable cost in Euro for the different transport modes

	Fixed cost	Variable cost per km
IPSI-system	220	0,15
Barge	50	0,34
Rail	100	0,4
Road	50	0,9

Table 4-42. Cost in Euro for different transport modes including collection and delivery

	Fixed cost	Variable cost per km
IPSI-system + collection /delivery	320	0,15
Barge + collection / delivery	150	0,34
Rail + collection / delivery	200	0,4
Road	50	0,9

Figure 4-52 shows total transport cost (including collection and delivery) as a function of the total distance for the different transport modes.

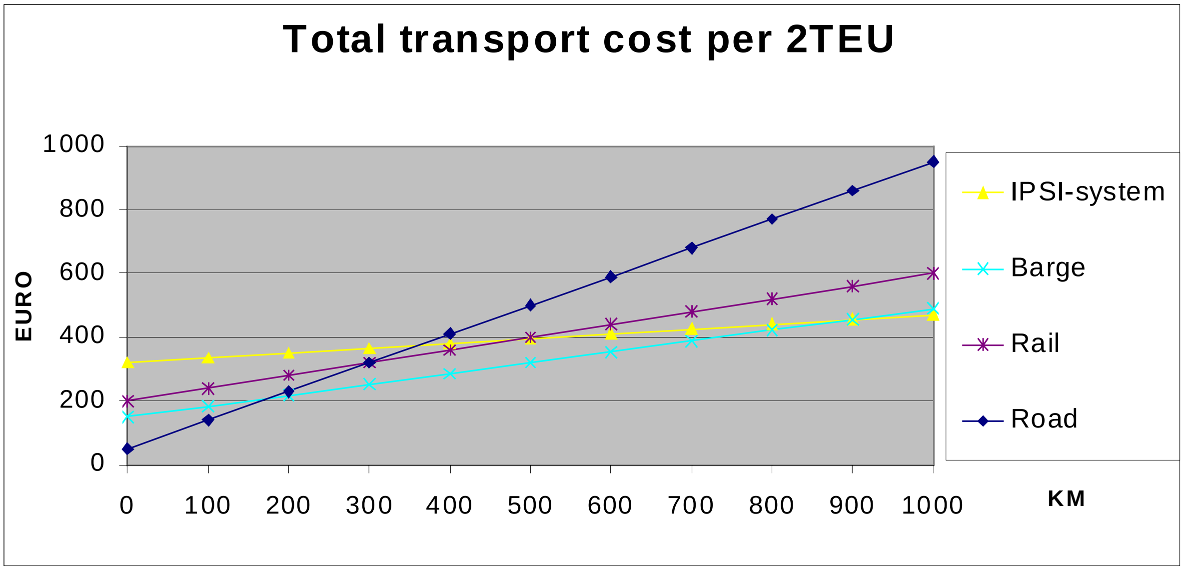


Figure 4-52. Total transport cost for different distances

4.5.4.2 Time models

We have developed a time model that makes it possible to compare the time usage for different transport modes between destinations.

The time model has fixed times in hours for container collection, terminal throughput time and container delivery. The variable part is then the time usage on the main transport leg, which depends on the distance and the speed of the transport modes that are being used. Table 4-43 shows the core time model for the different transport modes.

Table 4-43. Time model

	IPSI-system	Barge	Rail	¨Road
Container collection	1 hour	1 hour	1 hour	1 hour
Terminal handling	3 hours	3 hours	1 hours	
Main transport leg	40 km/h	11 km/h	60 km/h	60 km/h
Terminal handling	3 hours	3 hours	1 hours	
Container delivery	1 hours	1 hours	1 hours	1 hours

The total time usage with a main transport leg of 800 km for the different transport modes will the be :

Ipsi System : 8 h + 800km : 40km/h = 8 h + 20 h =28 hours
Barge : 8 h + 800km : 11km/h = 8 h + 72 h = 80 hours
Rail : 8 h + 800km/h : 60km/h = 4 h + 14 h = 18 hours
Road : 2 h + 800km/h : 60km/h = 2 h + 14 h = 16 hours

4.5.4.3 Scenarios

The cost and the time model have been used to analyse transport with different transport modes between these destinations:

	From	**To**
1	Karmøy (NO)	Karlsruhe (DE)
2	Frøya (NO)	Paris (FR)
3	Gothenburg (SE)	Zeebrugge (BE)
4	Gothenburg (SE)	Immingham (UK)
5	Immingham (UK)	Zeebrugge (BE)
6	Manchester (UK)	Milan (IT)
7	Immingham (UK)	Lyon (FR)
8	Avestad / Falun (SE)	Sheffield (UK)
9	Lübeck (DE)	St. Petersburg (RU)
10	Southampton (UK)	Le Havre (FR)
11	Lübeck (DE)	Helsinki (FI)
12	Lübeck (DE)	Riga (LU)
13	Barcelona (ES)	Milan (IT)
14	Barcelona (ES)	Napels (IT)
15	Bilbao (ES)	Gothenburg (SE)
16	Bilbao (ES)	St. Petersburg (RU)

Table 4-44 gives the transport cost for 2 TEU with different transport modes or combination of different transport modes between these destinations, and
Table 4-45 gives the time. An example of a detailed estimate of cost and time for each of the transportation alternatives analysed is given in Figure 4-53, showing transport from Barcelona to Milan.

Table 4-44. Transportation costs (in Euro) of 2 TEU containers (one way) between different sources and destinations

Transport means:			Ship	Ship & Barge	Road & Ship & Barge	Ship & Road	Ship & Train	Road & Ship & Train	Train	Road
Case	From	To								
1	**Karmoey**	**Karlsruhe**		635		906	704			1 687
2	**Froeya**	**Paris**			985	1 046		1 037		2 919
3	**Gothenburg**	**Zeebrugge**	363						796	1 641
4	**Immingham**	**Gothenburg**	360						1 014	2 346
5	**Immingham**	**Zeebrugge**	292						429	1 030
6	**Manchester**	**Milan**				1 330		1 015	861	1 802
7	**Immingham**	**Lyon**				906	685		686	1 368
8	**Avestad**	**Sheffield**				893		751	1 175	2 744
9	**Lübeck**	**St. Petersburg**	445							1 670
10	**Southampton**	**Le Havre**	270							778
11	**Lübeck**	**Helsinki**	402							2 008

12	**Lübeck**	**Riga**	380							1 243
13	**Barcelona**	**Milan**				474				1 025
14	**Barcelona**	**Napels**	436			1 006				1 558
15	**Bilbao**	**Gothenburg**	539			1 351				3 140
16	**Bilbao**	**St. Petersburg**	755			2 497				3 863

Table 4-45. Transportation time (in hours) between different sources and destinations

	Transport means:		Ship	Ship & Barge	Road & Ship & Barge	Ship & Road	Ship & Train	Road & Ship & Train	Train	Road
Case	From	To								
1	**Karmoey**	**Karlsruhe**		96		41	41			32
2	**Froeya**	**Paris**			83	62		62		50
3	**Gothenburg**	**Zeebrugge**	32						28	27
4	**Immingham**	**Gothenburg**	31						38	37
5	**Immingham**	**Zeebrugge**	17						14	12
6	**Manchester**	**Milan**				131		40	32	30
7	**Immingham**	**Lyon**				34	34		24	23
8	**Avestad**	**Sheffield**				40		41	45	44
9	**Lübeck**	**St. Petersburg**	45							32
10	**Southampton**	**Le Havre**	13							12
11	**Lübeck**	**Helsinki**	37							38
12	**Lübeck**	**Riga**	33							24
13	**Barcelona**	**Milan**				29				20
14	**Barcelona**	**Napels**	42			39				30
15	**Bilbao**	**Gothenburg**	64			57				54
16	**Bilbao**	**St. Petersburg**	102			82				66

The alternatives with lowest cost are those that involves either pure Ship transportation (case 3, 4, 5, 9, 10, 11, 12, 14, 15 and 16) or a combination of Ship and Barge (case1 and 2), Ship and Train (case 7) as well as Road, Ship and Train (case 8).

The only exception is case 6 (from Manchester to Milan), where Train is the lowest cost alternative, because the voyage through Gibraltar (from Southampton to Genoa) makes it difficult for the waterborne alternative to compete in this case.

As long as the distance for transportation is comparable for the different transportation modes, transport by semitrailer and train is the fastest alternative. Small deviations between semitrailer and train is caused by the assumption that loading and unloading of trains takes more time. Both mean speed and distance for semitrailer and train, for this analysis, is assumed equivalent (assumed speed is 60 km/hr).

Transport by ship may compete also with respect to time, as long as the distance by sea is much shorter than distance by land. Such shortcuts may be observed for the IPSI route between Gothenburg and Immingham (case 4 and 8) and between Lübeck and Helsinki (case 11).

As long as a barge is involved, time will be considerable higher (1,5 to 3 times) because of the slow barge speed. In return, however, these alternatives give the lowest cost.

13a: - By Ship and Road (ship from Barcelona to Genova /via Marseilles)
13b: - By Road

Cargo transport cost and time between destinations (2 TEU)

Case no 13 - From Barcelona to Milano

Case	Leg	Transport mean	From	To		Distance (km)	Time (hrs)	Cost (Euro)	Mean values (km/hr)	(Euro/km)
13a	I	Ship	Barcelona	Genova		**Min. Cost alternative:**				
	II	Semitrailer	Genova	Milano		**898**	**29**	**474**	**31**	**0,53**
13b	I	Semitrailer	Barcelona	Milano		**Min. Time alternative = Reference case:**				
						1061	**20**	**1025**	**54**	**0,97**

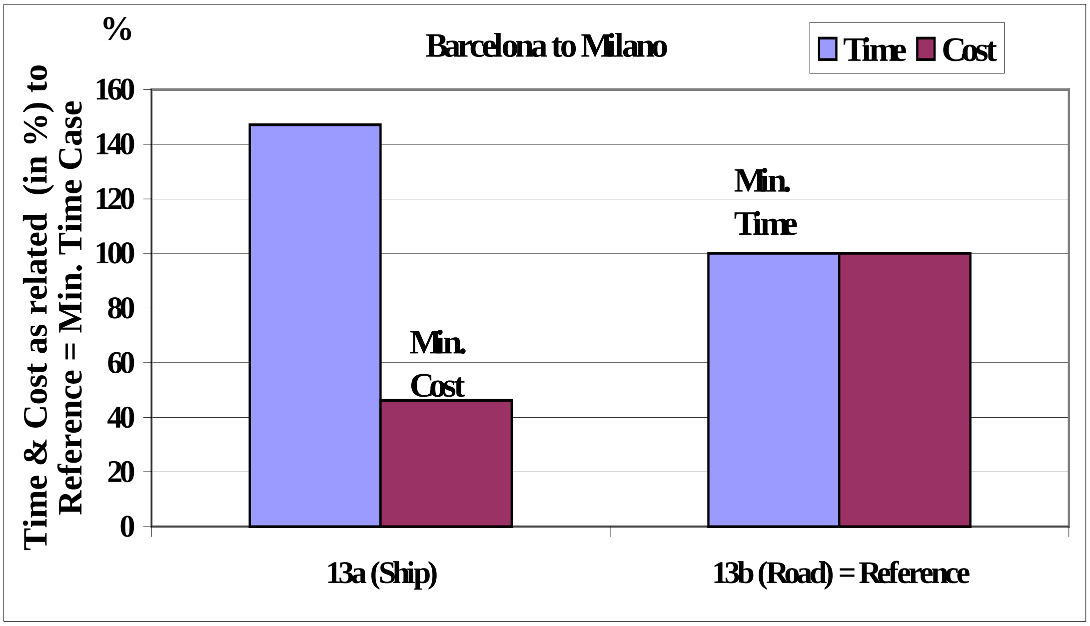
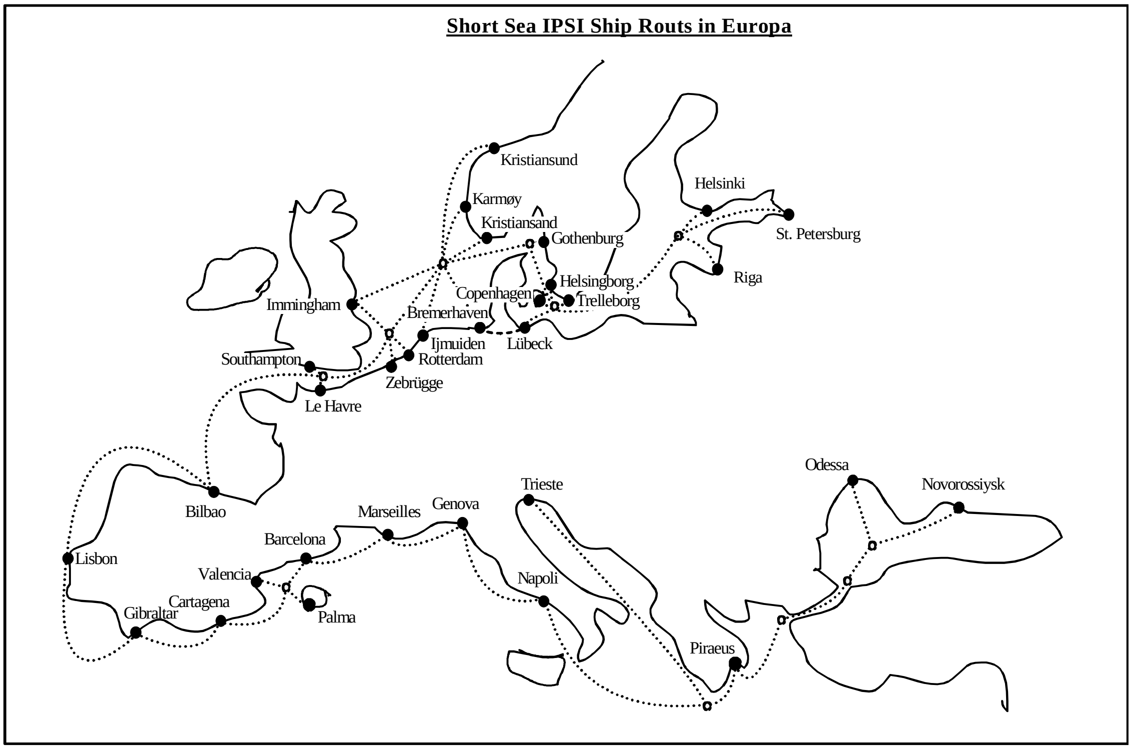


Figure 4-53. Case 13: Barcelona to Milano.

Figure 4-54 shows the potential IPSI sea routes that have been analysed.



Short Sea IPSI Ship Routs in Europa

Figure 4-54. Potential Short Sea Ship routes in Europe evaluated in the IPSI project.

5. CONCLUSION

The IPSI terminal and vessel concept has been shown to have capabilities that may make it an efficient hub in intermodal chains.

Furthermore, the cost of vessel and operation combined with the performance of the cargo handling equipment compared to conventional container feedering, clearly makes the IPSI concept a commercially viable alternative for this type of operation. If the IPSI concept was attempted for container feedering, we could achieve the following benefits also for container shipping:

- The expensive equipment in ports like Gioa Tauro and Rotterdam could be dedicated to handle the cargo from large, expensive intercontinental container ships. A cheaper and more efficient technology could transfer cargo onto a RoRo vessel for feedering, either directly or via a storage area.

- By using IPSI technology for container feedering, we had created an "open" solution. By open we mean a solution that could combine the feedering of intercontinental containers with intra-European transport. Such an integration would open up great possibilitites for new waterborne transport services in Europe, attracting cargo form the road.

The handicap of the IPSI is essentially the use of cassettes for handling containers and other unitised cargo during loading and unloading. If generally used, management of standard cassettes will be required. This, however, is similar to managing containers, and should not discourage the real life testing and evaluation of the IPSI concept.

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