INNOVATION in Forest Products Shipping

The Reels-on-Wheels system

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INNOVATION IN FOREST PRODUCTS SHIPPING

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## LITERATURE
1 INTRODUCTION

Shipping is one of the most innovative sectors in the economy, witnessing the multitude of new transportation- and ship-concepts which have been developed over the last four decades. Supertankers, bulkcarriers, containerships, chemical tankers, gas ships, roll-on/roll-off ships, are just a few examples of the creative energy that is generated within the sector.

Some impulses for innovation are derived from technological innovations, but the majority comes from market forces. The shipowner or operator seeks new ways to provide a better quality service at a lower cost. This search for continuous improvements will never come to an end, and can be stimulated by looking for opportunities to innovate in the transport chain.

At the Faculty of Mechanical Engineering and Marine Technology of the Delft University of Technology, engineering students are not only taught the basics of their profession, but also learn to develop a positive attitude towards technological change and innovation. The curriculum of the University contains several courses in creative problem solving and opportunity search, part of a wider designers-package.

Also in shipping, a special course on Innovation helps the students to understand the innovation process, so they become familiar with its workings. Especially during their master thesis project the marine technology (former naval architecture) student gets an opportunity to show that he or she can handle the complexities of markets, economics, operations, technology and creativity of shipping and shipdesign.

Some of the students do their thesis work abroad, which was also the case with Remko van der Lugt. He wished to write a thesis on the creativity techniques used in an innovation process of shipping. Kvaerner Masa-Yards Technology of Turku, Finland represented by Kai Levander and Sauli Eloranta was the ideal environment for Remko to work in. This engineering consultant has an impressive record of shipping-innovation and were explicitly interested in the use of creativity techniques, and were willing to accommodate him, for which we are grateful.

The subject matter of his master thesis was provided by Kvaerner Masa-Yards Technology, as a study of the Finnish forest products industry had just been published (early 1992). It outlined the relatively high logistical costs for the Finnish forest products industry, which could threaten its competitiveness.

We decided to search for innovative ways to reduce these costs substantially by looking at the total logistical chain of forest products in a holistic way.
In order to stay with two feet on the ground, Wagenborg Shipping of Delfzijl, Netherlands was asked to put their know-how at our disposal, as this company is probably the largest operator of ships on the Baltic Sea. We are indebted to Koos Veldman, not only for his intellectual input, but also for his financial support.

This study describes the process of innovation in forest products shipping, which resulted in a, to our opinion, very promising, new concept: The Reels-on-Wheels system.

In order to make such a system work, the different parties in the logistical chain have to shed their traditional boundary thinking. Substantial innovations can only take place if the sectors act as one, and not individually.

More research is required to develop the RoW-concept further. In order to diffuse the RoW-innovation most effectively, we have chosen to publish the master thesis report in bookform, and to present it to the collective forest products industry executives, during the PPI Transport Symposium 10, 25-27 October 1993 in Antwerp.

We hope and wish that the industry will embrace the RoW-concept and spend some money on the follow-up studies, which will be required to make it "ripe for the market".

We kindly invite comments and suggestions on this book, which you can direct to:

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2 SUMMARY & CONCLUSIONS

This book contains a study into the potential for innovation in the logistical chain of forest products, especially paper reels. The parts that make up the chain, like hinterland distribution, terminal storage and handling, shipping, have been optimized in the past to the extent that no major improvements can be expected for the entire logistical chain. The only way to achieve a major reduction in the logistical costs of forest products distribution, is to innovate the chain as a whole.

This study attempts to take a fresh look at the logistical chain, which results in a radical new and fully automated transport system of paper reels. The objective of the study is not only to develop new shipping concepts, but also to demonstrate the explicit use of creativity techniques in the design process.

Chapter 3 explores the existing logistical chain of paper from Finland to the North West Continent of Europe. Paper has been selected as it seems a fertile ground for innovation.

The economic rationale for the Finnish paper industry behind the innovation in the logistical chain is the worsening competitive position. As logistical costs are approx. 400 Finnmarks per ton, and thus represent a major cost-element, a substantial reduction of these costs may be crucial to the longterm competitiveness of the sector.

Central to the innovative concept in this study is the so-called Reels-on-Wheels system, as illustrated in figure 2.1
The reels are transported horizontally, with axles shoved through the reels and wheels connected to these axles. By use of a system of rails the reels are moved between the various means of transportation. By giving the rails a small inclination, the reels roll down the track, without the need for any machinery. This way, a very uncomplicated, robust, way of automatic cargo handling is achieved, making use of the forces of gravity.

Inland transportation in Finland takes place with trucks that are provided with rails. The warehouse in the Finnish harbour consists of a number of rail-tracks. It is situated directly to the quay. The sea-going vessel also has an internal structure of rails on which the reels roll. The inclination of the rails is achieved by ballast tanks in front and stern. Connection between rails is made by use of chain-conveyors.

At the W-European sea-harbour the ship discharges its load directly onto an inland barge, which is also provided with an internal structure of rails. The barge is brought up the inland waterway by a pusher-tug. From the inland harbour, situated in the centre of the market-area, the distribution takes place. The barge has a warehousing function. Trucks are loaded directly from the barge. The lorries transport the paper reels up to the printing houses.

*Figure 2.2 Reductions in logistical costs (Logistical costs set out against covered distance from the papermill)*
Summary and Conclusions

With this system, handling costs are reduced to a large extent. Also capital costs will be reduced because of the smaller amount of reels that is in the pipeline. The use of the inland barges reduces the hinterland distribution costs.

The new RoW-concept should be able to result in an overall reduction of some forty percent of the logistical costs of paper reels, as illustrated by figure 2.2.

Due to the limited time available, the study is focussed on the development of the reels’ transshipment system, the ship is designed around the optimal hold configuration. The ship design approach that is followed is market-driven, i.e. the freight-earning part of the ship, its hold, is central to the design.

In order to design an optimal hold configuration, more knowledge had to be gained on the details of the rails-wheels-axle system on which the reels are moved through the system, without human interference. The next step concerned the determination of the design parameters based on the service between Finland and the North West Continent, such as the approximate deadweight capacity and speed.

Based on the foregoing information, different hull-forms were generated and combined with the hold-requirements into a large number of R-o-W concepts. One design has been selected and developed in more detail into a conceptual design.

The study is concluded with a brief economic evaluation and an evaluation of the innovation process.

S-CURVE FOR FOREST PRODUCTS CHAIN

The S-curve is a graph of the relationship between the effort put into improving a product (or process) and the results that are achieved through that investment. Initially, as funds are put into developing a new product, progress is very slow. When the key-knowledge necessary to make advances is put in place, the performance rushes upward. Then, as funds are continued to be poured into the development of the product, it becomes more and more difficult and expensive to make technical progress. The product is closing in on its limits. It is not possible to reach beyond this limit. To bring the performance to a higher level, one must look for a new product with a higher limit. A new S-curve represents this product in the graph, as shown in figure 2.3. However, it is possible that a new product, with a new S-curve, bears an even lower limit than the present one. Therefore the choice where and when to change must be carefully evaluated. Change does not automatically guarantee higher performance.
The logistical chain of paper is obviously closing in on its limits. Large investments in part-innovations bring only small benefits. To reach beyond the performance limits of the present chain, a logistical chain has to be developed that brings a conceptual difference compared to the present one. In order to create substantial improvements, the jump has to be made to a new S-curve. When a new curve is started up, firstly the necessary key-knowledge has to be gathered. Therefore, in this part of the curve, the performance will remain low. But, when that has taken place, performance will outgrow the present limit.

Figure 2.3 S-curves for the forest products logistical chain
PROCESS LEADING TO REELS ON WHEELS IDEA

Most of the contemporary innovative ideas make use of larger units, like cassettes, containers, etc. In this study, exactly the opposite direction is chosen. The field of continuous flow logistics was explored in more detail.

The shape of reels, cylinders, is looked at. ‘What benefits does this shape bring?’. Well, among others, a cylinder can roll. Why not make use of this opportunity the shape of the reels brings?

An analogy is found in a can-dispenser, figure 2.4. When a can, which also has a cylindrical shape, is taken out of the dispenser, the inclinations of the shelves take care of filling up the empty slot. A system like this can be implemented in, for instance, the transshipment process. The paper carrier is filled by making use of the force of gravity.

Gravity can be exploited to an even larger extent. An analogy is found in a marble game with lanes with altering inclination. The marble rolls down the lanes. With a similar hold-construction (figure 2.5), the hold can be loaded in a continuous process, using gravity to the maximum extent.

Figure 2.4 Can dispenser

Figure 2.5 Implementation of the marble game
However, with reels rolling down the tracks, the reels would have to fall from one lane to another, a distance of about 2 metres. This would imply unacceptable forces on reel and construction. The distance can be reduced by decreasing the diameter of the reel. Wheels at the sides of the reel, with a connecting axle through the inside tube, is a more elegant solution. The wheels roll on rails, so that decks are made redundant.

The 'Reels on wheels'-system is born.

In the following, it will be referred to as 'RoW'-system. The hold interior, based upon the marble game did not prove to be feasible. But the RoW idea was continued with, because of its additional benefits. The entire logistical chain can be simplified by introducing this system. Horizontal internal transport is taken care of by the inclination of the rails and vertical internal transport by chain-conveyors. The total concept is shown in figure 2.6 (next page).

The logistical chain starts at the papermill, where the reels are put on axles. The so derived RoW-units are loaded on lorries, with rails in the hold. The lorry brings the RoWs to the harbour, where a chain-conveyor loads them into the warehouse. The warehouse consists of a construction with various lanes of rails, with chain-conveyors on each end. When a vessel arrives, it is loaded by the second chain-conveyor. The inclination of the rails in the hold is obtained by waterballast. In the W-European harbour, the paper is discharged into a river- barge, which takes care of the further transport to the centre of the consuming industry, figure 2.7. This barge also has a ware-housing function. It discharges its load directly into trucks, which take care of the final distribution to the printing houses.

Figure 2.7 Transshipment from RoW carrier to inland barge
Figure 2.6 Concept of sea-transport and transshipment
THE INNOVATION PROCESS

The standard procedure in ship-design is a process of iterations, following a predetermined course of action. By repeating this sequence over and over again, the design approaches the optimal situation step by step.

The disadvantage of this iterative process is the absence of structural new ideas in the phase of starting up. On the other hand, an iterative approach makes it possible to handle complicated matters, such as the design-process of a ship.

The objective of the intended innovation-process in this study is to eliminate the disadvantages of the iterative process, while keeping its benefits of managing complex problems. Or, from the opposite point of view, to introduce originality into the start-up of the iterations. Thus, the iteration process is only activated after that the initial idea is sufficiently elaborated, so that the process is unlikely to slide back to a solution of marginal creativity.

Therefore it is imperative to start with the design of the crucial part of the ship, the cross-section of the cargo hold. Once this part is optimal, the consequent iterations in the design process will not cause a fundamental change in this basic concept.

The next step will be to determine the optimal hull & machinery configuration of the ship. In other words, the innovation process of the ship is such that:

The ship will be designed to envelop the cargo hold.

The standard procedure of ship design is to decide upon a hull-form, often based on comparable ship-types, and thereafter to design the hold into the vessel. Then, the focus remains on the ship’s technical characteristics, rather than on the money-generating part.
CONCLUSIONS & REMARKS

INNOVATION PROCESS

- More than one person has to be involved in the innovation process in order to maintain the openness of mind that is required. One person faces many deadlocks in the process and a second opinion can trigger the innovation process.

- Sketching and drawing skills are of primary importance for the designing engineer. It is the most direct way of communication available. Courses in sketching should be part of the basic education for every design engineer, such as the engineer in marine technology.

- In the phase of orientation, divergent creativity techniques give best results. In a further stage, the serial approach is most suitable. At present, the study at the Faculty of Marine Technology focusses on the second, optimizing part of design and not on the development of new concepts. If this is to change, students should be equipped with knowledge of the various divergent creativity techniques.

- Regulatory constraints, imposed by the authorities, should be neglected temporarily, in order to arrive at an original conceptual design. In a later stage of the design the concept can be optimized for these constraints, without deviating from the merits of the concept.

REELS ON WHEELS SOLUTION

- The costs of the transshipment part of the logistical chain will be reduced to a large extent. This influences the total logistical costs, as transshipment makes up some 30% of the total costs.

- The total cost-reduction introduced by the R-o-W system will probably be even higher, because of the integral approach on the logistics, in particular if the inland barges are included in the distribution system.

- The R-o-W system provides a possible direction in which the forest products logistical chain might turn in the future. It is not meant to be a system that will be introduced in the market in the next couple of years.
PROBLEM DEFINITION

The logistical costs represent about 17% of the total costs of paper. Reducing these logistical costs would provide the papermills with a better competitive position. Present attempts to cut-back on these costs are primarily based on optimizing the various parts of the chain. These attempts have had little effect.

By introducing an integral approach, looking for conceptual innovations that bring benefits to the entire chain, major improvements can be achieved.

The Reels-on-Wheels system gives a good example of how the logistical chain could look like if innovations of the conceptual design of the total chain are considered. To underline this, the R-o-W concept is expected to reduce the total logistical costs by some 40%, as the graph in figure 2.8 illustrates.
3  FOREST PRODUCTS SHIPPING FROM FINLAND: OVERVIEW

The export of forest products from Scandinavia to continental Europe requires a chain of logistical activities, which costs determine to a large extent the competitive position of the exporters involved. Logistical costs make up some 17% of the total production costs of paper. In the past, many innovations have been introduced into the chain. These part-innovations have reduced the overall cost per ton. In order to be able to maintain the competitive advantage the forest products producers and the various transport-operators have to innovate in new systems. This creates difficulties as all the vested interests are looking at their own, often sub-optimal, solutions. The producers have contracted out the logistics as they are reluctant to invest in activities which they consider not to be their core-business.

The only way to lower the overall logistical costs considerably is to look for innovations that involve the total chain, while the separate links can only be improved marginally. Therefore, in this project, the system as a whole will be considered, and improvements to it, without taking into account borders between the links.

The study started with a literature search completed with information, generated from meetings and visits to stevedoring terminals, forest products ships and papermills, in order to come to a clear problem definition. Various solutions are generated with the use of diverse creativity methods, which are described in detail.

The goal is to demonstrate to the parties involved in the forest products chain that the benefits of a joint effort outweigh an individual approach. This is done by creating an example of how an integral logistical system could look like. It is not the intention to produce a system, that is technically detailed and ready for introduction in the market.
BUILD-UP OF LOGISTICAL COSTS

The costs of the logistical chain, with a total of about 380 Finnmark can be allocated to the various links of this chain. Figure 3.1 shows the logistical costs as a function of the covered distance from the papermill. It makes it possible to establish an order of magnitude for the various cost components. However, it is too rough to build exact figures on. It is noteworthy that the 1000km sea-leg represents only 13 percent of total logistical costs.

Solutions which reduce the costs in only one link have relatively low impact on the costs of the entire chain. Only solutions that involve the complete chain can generate substantial benefits.

Figure 3.1 Logistical costs [FIM/t] set out against the covered distance from the factory [km]
THE S-CURVE

The S-curve is a graph of the relationship between the effort put into improving a product (or process) and the results that are obtained from that investment. Initially, as funds are put into developing a new product, progress is very slow. When the key-knowledge necessary to make advances is put in place, the performance rushes upward. Then, as funds are continued to be poured into the development of the product, it becomes more and more difficult and expensive to make technical progress. The product is closing in on its limits. It is not possible to reach beyond this limit. To bring the performance to a higher level, one must look for a new product with a higher performance limit. A new S-curve represents this product in the graph. However, it is possible that a new product, with a new S-curve, bears an even lower limit than the present one. Therefore the decision which technology to choose must be taken with care. Change does not automatically bring a higher performance. The S-curves are shown in figure 3.2.

Figure 3.2 S-curves and their limits
The logistical chain of paper is obviously closing in on its limits. Large investments in part-innovations bring only small benefits. To reach beyond the performance limits of the present chain, a logistical chain has to be developed that brings a conceptual difference compared to the present one. To be able to bring substantial improvements (= cost savings) the jump has to be made to a new S-curve. Initially the performance will remain low, as a new curve is started. The necessary key-knowledge has to be gathered first. But, when that has taken place, performance will outgrow the present limit, providing that a product with the right S-curve is chosen. Many examples in industry and shipping are available to illustrate these graphs. (Richard N. Foster, Innovation)

The objective of this study is to create ideas for the development of a new performance S-curve for forest products transport. This is done by using an integral approach instead of looking at parts of the logistical chain individually. This way a reduction in costs of up to 40% could become feasible.
THE INNOVATION PROCESS IN BRIEF

Every creativity-process and innovation has a different character and can be described in a different way. Still, in every innovation process a common structure can be distinguished. Following this structure prevents the designer from focussing too much on one solution. As this single solution fails it is not hard to take a step back and head for another direction.

DESCRIPTION OF THE PROCESS

The structure followed in this study is based on succeeding divergent and convergent phases. The divergent phases are the creative parts, in which ideas are generated. Criticisms and judgements are postponed. Otherwise the window through which the problem is being looked at is too narrow, so that possible solutions fall out of the range of vision. In the convergent phases the evaluation and judgement take place. Here the ideas, worth looking at further, are selected. With the whole field of view in mind, an informed choice can take place.

The different phases of the process are listed below, and are summarized in figure 3.5.

Present market situation. This phase is meant to get to know the present situation and the problems in the market.

Generation fields of solution. Global directions of solution are generated. It doesn't provide ready feasible solutions. Ways to look at the problem are found, basic ideas that put the problem into a broader perspective.

Evaluation. The best (most feasible, strange, other viewpoint, etc.) fields of solution are chosen to continue with. The rest is not disposed of, as they might be useful when the choice appears unusable at a certain point.

Generation of ideas. From the fields of solution that are selected, a broad range of ideas are generated. These ideas are not to be judged upon, yet, as this would limit the perspective, while the optimal solution might lay beyond the range of the perspective of that moment.

Evaluation. A couple of solutions, most promising or most striking, are selected.

Bottleneck/constraint analysis. This is a negative creative phase. It is a divergent part of the design process. Possible bottlenecks and constraints are generated for the remaining ideas.
Evaluation. A selection is made between ideas with bottlenecks that can be overcome without too much effort and the ideas with too many or too complicated bottlenecks.

Solving the bottlenecks. Again, a divergent phase. This part is a small problem solving exercise itself.

Evaluation. The remaining ideas are considered. If the bottlenecks are solved to satisfaction, the idea proceeds in the design-process. If not, the idea is put aside. If the number of selected solutions becomes too small, earlier rejected ideas can be taken up again to continue with.

Elaboration. The ideas are elaborated into conceptual designs, with real dimensions and qualities. These can still be optimized, but from here the essence of the concept does not change.

Economic evaluation. Comparison of the different conceptual designs in economic terms. Here the final solution is chosen. Not always the most economic alternative is chosen. Other criteria such as the environment, political factors, etc., should also be taken into account.

Design development. Making the concept into a production-ready design and also, ready for the market in which it is to be launched. The work to be done is, for instance, final drawings, calculations, etc.

CREATIVITY TECHNIQUES

In order to improve the quality, quantity and open-mindedness of the generated solutions, creativity techniques are used. As an objective of the project is to find suitable techniques for the maritime engineer to use by himself, a limitation is made in the choice of techniques. Techniques that require more than one person are eliminated. This may limit the broadness of the ideas, but it is of interest to notice which techniques bring the best quality of solutions, when used by one person.

Figure 3.5 Structure of an innovation process
The literature on creativity techniques is extensive and therefore only a few techniques are mentioned and illustrated here, such as looking for analogies.

ANALOGIES

The idea behind this technique is that, very often, the present problem has been faced before in a somewhat other way and has been solved, one way or the other. The implication is, that finding a solution would just require to identify this problem and solution, and to transpose it to the new situation. This avoids "inventing the wheel for the second time", which makes the design-process considerably more efficient. Some examples may illustrate this technique.

Direct analogies can be found in:

- **The existing technology.** Keeping close to the technology of the actual problem makes the translation-step relatively easy. The perspective remains narrow, so it is questionable if the solution is optimal.

  Example: When looking at the disembarkement of passenger-ferries, one could look at the discharging of self-unloading bulk-carriers and look at the way discharging problems are dealt with.

- **Adjaent technologies.** This is not a step too far away either. But if a solution can be found here, it is fairly easy applicable.

  Example: If a new kind of protection-system for very sensitive cargo has to be designed one can look at, for instance, the protection of eggs during transport.

- **Nature.** The method of using nature to find analogies is also known as 'Bionics'. Nature is the oldest technology available. The evolution has, in a way, optimized all species. Therefore it has to be the most experienced tutor available. However, the translation-step asks for a lot of flexibility and imagination.

  Examples:

  - Sonar *came from* Dolphins
  - Radar *came from* Bats
  - Velcro *came from* Burdocks
  - Jet propulsion *came from* Squid
  - Submarine depth control *came from* Swimbladder of fish

A number of other examples are available. It has proven quite a powerful tool for the discovery of useful concepts.
Although the creative process does not start until after the termination of the exploratory phase, a new method, which facilitates the formation of an overall picture is used.

This method is called ‘mindmapping’, developed by T. Buzan. It was developed to overcome the disadvantages of the traditional way of making notes, which is writing in a notebook, page after page from the upper left side to the lower right. Just like the structure of this report. The disadvantages are that before writing things down, they first need to be ordered and organized in the mind. Making corrections or adding pieces of information is hard to accomplish. A lot of time is lost while searching for words or parts of sentences just for the connection of important words. All information has to be written down in correct sentences, which is quite a time-consuming operation. Finally, the division in different pages does not help obtaining an overall picture.

The idea behind mindmapping is that all information, read, seen or heard, is stored in some place of the brain. But, usually, the location where it is stored is forgotten. Knowing this, the making of notes that cover the whole subject becomes superfluous. It is sufficient to keep track of the locations in the brain, where the different batches of information are stored. A map of the mind can do just that.

Figure 3.6 shows a mindmap of the forest products transportation project.

The technique of mindmapping consists of putting the notes down on paper in an organic structure, starting with the object of study eye-catching in the middle of the paper. From here branches are made, with only key-words along the ramifications, one word each. This word unlocks a certain quantity of information in the brain. It functions as a reference to the place where this information is stored, so that it can be brought up to the surface. It is of no importance where the trees are situated on the paper, as long as they start in the middle, connected to the object.

Unlike the traditional way of making notes or subtractions, both sides of the brain are used which, obviously, provides a larger capacity. The left side of the brain is the part that organizes and brings structure into things. This is the part that is primarily used, while writing things down in the normal way. In mindmapping the use of arrows, codes, ramifications stimulate the activity of the left-hand brain.
Figure 3.6 Mindmap on forest products logistics
The right side of the brain is the creative part. It also provides overview and makes associations. This part is stimulated in mindmapping, by using different colours, typefaces, kinds of lines, etc. Also drawings and graphs are, for the greater part, right-hand brainwork.

The use of drawings and sketches is stimulated, because a drawing can display a large quantity of information in a short period of time. Also the consumption of the information is speeded up by the use of the right-hand processes images faster than other symbolic information. To put those into words is an extra translation-step, for which there is no need when making pictures of those images.

In the mindmap, adding information, or making corrections is quite easy, for the structure is meant to grow in an organical way. So if one tree is covered for the moment, it is no problem to switch over to another tree. The continuation with the first tree can happen anytime afterwards.

If the growth of the organic form is stuck, use can be made of the ‘kid’s kit’, the questions a toddler asks its mother all the time:

Who?
What?
How?
Where?
Why?
When?
With what?

When these questions are covered in the branches, a good overview of the matter is obtained. They make sure that no important subjects are overlooked.
FOREST PRODUCTS MIX

The name ‘forest products’ covers a range of products, which all have in common that they are based on the same material: trees. Logs can be transformed into the following groups of intermediary- or end-products: Wood; Woodpulp; Paper; Boards. A first division can be made in the kind of basic material that is used:

**Softwoods** or coniferous woods like fir, pine, spruce, etc. Best known producers are Canada and Scandinavia, while the former Soviet-Union is a major producer, who has just entered the open market. Also Chile and New Zealand are growing fast, with extremely efficient production-methods.

**Hardwoods** or non-coniferous woods like maple, oak, teak, etc. These are, for the greater part, produced in developing countries, which brings its own logistical problems. This is of interest, because the market asks for major improvements. In the coming years, major changes are bound to take place in this trade. However, it is beyond the aim of this project.

WOOD

A sub-division can be made into logs, sawnwood and pulpwood.

- **Logs.** Logs or lumber are not mechanically transformed in any kind of way, except for the branches that are cut of. Logs usually are trees of good quality and correspond to the required dimensions. The trade of logs is rapidly diminishing, as the producing countries are trying to increase the amount of added value put into the exported products.

- **Sawnwood.** Timber or sawnwood are high-value beams and boards, made out of logs of good quality. In Scandinavia timber is usually exported in length-packages. These are packages of sawnwood of same length. This gives rectangular parcels which are much easier to stow than boards or beams separately, like it used to be some twenty years ago. The packages are often shrink-wrapped to reduce damage by weather influences.
INNOVATION in forest products shipping

- **Pulpwood.** The logs that do not meet the requirements above become pulpwood. So do the waste products from the timber-production: sawdust and woodchips. Pulpwood is used to produce pulp, but can also be used in the production of panel and board products.

**WOODPULP**

Woodpulp is an intermediary product which is used to produce paper, or in the chemical industry to produce a whole range of different products. For some of these products, the connection with forest products is somewhat hard to establish, for products like handles for tools like screwdrivers, linings of blazers, spectacle-frames, etc. are made out of chemical pulp. The cargo is sensitive to damage, mainly by contamination of the material by rust, paint or dirt. It is produced in sheets or blocks. However, the sheet form is more common. Woodpulp is either transported in reels or in packages of sheets. In the last case, eight of these are combined to one bigger unit.

**PANELS AND BOARDS**

The export of panels and boards has increased over the past years. It is a group of value added products, which often makes use of the sawmill waste, like sawdust and woodchips. The following division can be made:

- Veneer sheet, thin wood sheet for use in plywood, furniture, etc.
- Plywood, three or more layers of veneer sheet glued together.
- Particle board, made out of chips and/or strands, agglomerated by the use of organic materials.
- Fiber board, building board with added material, for example: plasterboard, containing gypsum.

The transport of these boards has to be done with care, for most of the adhesives dissolve in water. Also mildew damage is not uncommon.
PAPER

In this part of the chapter relevant information on the logistical chain of paper from Finland is discussed.

A large variety of paper and paperboard products is exported. The following product-groups can be distinguished:

- **Newsprint.** Thin, uncoated, paper on which newspapers are printed. Groundwood paper, newsprint with a better printing quality is used for telephone directories, etc.
- **Uncoated paper.** Copier paper, books, etc.
- **Coated paper.** For magazines, catalogues, etc. Coated with china-clay. The shiny surface is obtained by a process of polishing.
- **Wrapping paper,** paper bags.
- **Kraftliner.** Thick, rough, paper for the production of corrugated cardboard, cardboard boxes, etc.

Paper is vulnerable cargo. It is packed either on reels, or on pallets with boxes of sheets, especially the more expensive kinds like copier paper. This last form is of increasing importance, while the paper producing countries try to increase the added value put into their export products.

<table>
<thead>
<tr>
<th>Weight pallet</th>
<th>≈ 1500 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price pallet of copier paper</td>
<td>≈ fl 5000,- (Dutch guilders)</td>
</tr>
</tbody>
</table>

This type of cargo is very sensitive to damage. If a box is even slightly damaged, it cannot be sold anymore.

The transportation of paperreels remains most important. The major volumes are transported in reels, either as an intermediary product to be processed to paper sheets like copier- or writing-paper, or as a basic material for the printing houses. A price-indication is given for the different product-groups:

<table>
<thead>
<tr>
<th>PAPERTYPE</th>
<th>gr/m²</th>
<th>PRICE {fl/m³}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newsprint</td>
<td>45</td>
<td>1480</td>
</tr>
<tr>
<td>Uncoated (reel)</td>
<td>60</td>
<td>1470</td>
</tr>
<tr>
<td>Coated (reel)</td>
<td>60</td>
<td>1590</td>
</tr>
<tr>
<td>Kraftliner</td>
<td>150</td>
<td>1560</td>
</tr>
</tbody>
</table>

The prices per cubic metre of the types of paper are not significantly differing. Therefore the assumption can be made that the price of paper, no matter what type, is about 1500,- fl/m³
FOCUS ON PAPER

Wood, woodpulp and boards can be transported very effectively, in an uncomplicated logistical chain. Here, not a lot of improvements can be expected, as the box-like shape of the cargo-units already makes stowage and handling relatively efficient. The logistical chain of paper however, seems to be more suitable for improvement. Reducing labour for handling and damage can bring large cost reductions. Also the inland transportation in W-Europe, which now is usually done by trucks, is a cost-item. Small changes in efficiency could bring major improvements.

It is expected that innovation in the paper chain will bring the largest returns. Therefore the study focusses on this logistical system.

PAPER DAMAGE

Paperreels are quite damage sensitive. Most common causes of damage are:

- When the reels are transported in vertical position, if the reels are put down under an (small) angle. Then the bottom flat side of the reel is dented, which creates a lot of damage.

- If the reels are moved by clamp-trucks, and the clamp does not grab the reel parallel, the clamp dents the outside layers.

- When the clamp-truck is approaching the reel, sometimes the clamp hits the reel. It then cuts into the paper, which can cause quite a deep penetration.

- When the surface on which the reels are put down is not totally flat, the roughnesses are pushed into the paper.

\[ \text{Figure 3.9 Reel damage by clamptrucks} \]
The outside layers of the reel, which are exposed most, represent a large volume of the paper on a reel. This can be illustrated by the following example, a reel of newsprint with a quite common, small damage with a penetration depth of 2 cm:

<table>
<thead>
<tr>
<th>Reel:</th>
<th>Length</th>
<th>Diameter</th>
<th>Weight</th>
<th>Penetration depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.00 m</td>
<td>1.00 m</td>
<td>2 t</td>
<td>0.02 m</td>
</tr>
</tbody>
</table>

Cross section area  
\[ \text{Cross section area} = \frac{1}{4} \pi D^2 = \frac{1}{4} \pi 1^2 = 0.75 m^2 \]

\[ \text{Damaged cross section area} = \frac{1}{4} \pi [1^2 - (1 - 2 \times 0.02)^2] = \frac{1}{4} \pi (1.002 - 0.962) = 0.06 m^2 \]

\[ \text{Damage percentage} = 8\% \]

\[ \text{Price of newsprint} = 1500, - \text{fl/t} \]

\[ \text{So, damage costs} = 8\% \times 2 \times 1500 = \text{fl 240,-} \]

In a printing house the damaged reels can cause down-time and damage to the machinery, if the damage is not noticed. These damages cost many times the price of the lost paper. Which is no surprise, as the printing speed of the large machines is about 1200 metres a minute (70 km/h).

When the reel is not too heavily damaged, the reels are still sold to the printing houses, at a discount. This appears, for the papermill, to be economically more attractive than taking care of the repair-work before delivery to the printing-house.
PRESENT EXISTING PAPER CHAIN

The present situation in each link of the chain is discussed.

INLAND TRANSPORT FINLAND

The transport of the paper from the mills to the harbour is done by either lorry or train. In the interior of Finland a tremendous amount of rivers and lakes is situated. When thinking of inland transportation, it appears to be quite obvious to use these waterways. However, the rivers and lakes are usually frozen for several months a year. This makes the inland waterways not a year-round transport route. Consequently, all paper is transported by rails or road.

Part of the papermills is situated close to a sea-harbour. Then, the logs have to be transported from the forest area to the papermill. This used to be done by dropping the logs into the river and to allow the current to take care of the transport. Nowadays the logs are transported on lorries, because of the bigger reliability and the better quality of transport.

In a number of ports along the coast, forest products can be handled. The goods do not have to be transported over land from a papermill in the north of the country, to a harbour in the south. A port closeby can be chosen.

The major forest products ports in Finland, with their yearly total export volumes of paper in 1991:

<table>
<thead>
<tr>
<th>Port (North to South-East)</th>
<th>Export (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kemi</td>
<td>455.000</td>
</tr>
<tr>
<td>Oulu</td>
<td>235.439</td>
</tr>
<tr>
<td>Rauma</td>
<td>1.636.546</td>
</tr>
<tr>
<td>Hanko</td>
<td>182.428</td>
</tr>
<tr>
<td>Helsinki</td>
<td>338.992</td>
</tr>
<tr>
<td>Kotka</td>
<td>1.472.894</td>
</tr>
<tr>
<td>Hamina</td>
<td>1.566.834</td>
</tr>
<tr>
<td>rest</td>
<td>536.684</td>
</tr>
<tr>
<td>Total</td>
<td>6.424.817</td>
</tr>
</tbody>
</table>
Figure 3.10 Finnish paper exports & papermill capacity
FINNISH HARBOUR: LOADING

Forest products form the major business of most Finnish ports, as it is the largest export volume of goods. The harbours are, with a few exceptions, compared to West-European standards very small. Harbour-workers are employed on a fixed basis by the stevedoring companies. This makes stevedoring in Finland quite a costly operation, because the amount of work that is to be done is not constant every day. Sufficient harbour-workers have to be employed to cover the maximum amount of work. Even when there is no work to be done, these labourers still have to get paid. To overcome this problem, two directions are generally accepted:

- Separation of the stevedoring-work from the presence of a ship. This makes it possible to have a continuous amount of work that has to be done daily.
- Automatic cargo handling. Application of this concept makes harbour-workers, more or less, redundant.

When a truckload of paper enters the harbour, the truck drives into the warehouse, where it is discharged by clamp-trucks. The paperreels are stacked on top of each other in an upright position.

When a ship is loaded, clamp-trucks put the reels on roll-trailers (Mafi) or cassettes (Rolux). At present, most stevedoring companies use Mafi-trailers, but Rolux-cassettes become more and more popular, because of less capital costs and maintenance costs, as a smaller amount of wheels is involved. After being loaded, the trailer is pulled to the ship by a Tug-master truck.
TRANSSHIPMENT METHODS

At the quay, the paperreels are loaded into the vessel. At the moment three methods are commonly used: LOLO, STORO and RORO.

LOLO

Figure 3.12 Loading with the LoLo-system

Lift on Lift off is the oldest transshipment method. The reels are lifted onboard from the trailer by a crane, which is either installed onboard the ship or on the quay. The connection of the reels to the crane can be provided by friction clamps or vacuum clamps.

- **Friction clamps.** The reel is held by use of its own weight. This system is quite slow, but very flexible, a lot of different sizes can be handled. A scissor-like construction takes care of the required pressure on the clamps, so that sufficient friction is generated.

Figure 3.13 Friction clamp
Vacuum clamps. A ship-borne gantry crane is used. The connecting installation consists of a set of (4-8) vacuum caps. These caps are placed on top of the reels by the crane-driver. Then the vacuum is created, so that the reels can be lifted. To maintain the vacuum, the inside tubes of the reels need to be closed by use of well-fixed plugs.

Figure 3.14 Vacuum-clamp installation

For every reel-size a different size of caps is needed. Consequently, the ship carries a number of installations (about five). The method does not require any harbour-workers onboard the ship or at the quay, except for the Tug-master driver and the crane-driver.

When a large quantity of similar size reels are moved, this method is very fast and gives very little damage. But if a lot of different reel-sizes have to be transshipped, the stowage can not be done efficiently. Then, the big, expensive, gantry-crane has to move the reels by use of gravity-clamps. Quite inefficient, as the expensive crane can move only two reels at a time.
The ships on which the LoLo method is used, are often uncomplicated, old-fashioned dry cargo ships. Square holds with flat walls and floor make stowing easier and give less damage to the reels. These ships are very flexible, easy to bring into action in other trades. However, the ships on which the vacuum system is used are purpose-built, which gives them less flexibility, due to the high invested capital.

The No.1 hold is often not square-formed. In order to be able to stow paperreels in this hold, use is made of a system of adjustable boxes.

![Figure 3.15 Cross-section of No.1 hold](image)

The major disadvantage of the LoLo-method is the danger for damage to the reels. The following types of damage occur:

- **Lifting damage.** The reels can hit the walls of the ship when lifted.
- **Clamp damage.** When the clamps are not positioned right onto the reel.
- **Water damage.** The hatches often can not be closed totally watertight. Due to the flexibility of the ship openings occur, through which water can enter the holds.
- **Mildew damage.** Due to the moist atmosphere in the holds the reels can get mouldy.
The Stowable Roll-on Roll-off method came into practice to overcome most of the problems of the LoLo transshipment. Use is made of Roll-on Roll-off ships. These can be taken from another trade or purpose-built. Usually, a simple stern-ramp gives access to the main-deck.

The trailer-tugmaster combination drives through the ramp into the hold. Here, the tugmaster disengages from the trailer, and takes an empty trailer back to the warehouse. In the hold, two clamptrucks take the reels from the trailer and stow them on deck. When the loading is finished, the outside reels are lashed by use of ropes, straps and/or nets. Also airbags are used for stowage purposes.

To prevent the reels from damage, the decks need to be totally flat. Lashing points are retracted so that a flush-deck is obtained. The sides of the hold are flat as well. The condition of the air is controlled by big deck-fans, which are compulsory on RoRo-ships, to relieve the cargo-space from exhaust-gases. The decks are totally concealed and the stern ramp functions as a watertight door. This takes care of the problem with intruding sea-water.

Access to the lower, and possibly the upper, deck is obtained by a hoistable ramp, lift or sideloader. In the first two cases, the trailer is brought to the deck in question, from where the stowage is done by clamp-trucks.
In the latter case, the trailer is positioned on the quay close to the sideloader. A clamp-truck puts the reels on the sideloader-platform, which transports the reels up or down. In the hold, a clamptruck takes the reels from the platform and stacks them close together. The sideloader can also function as an additional access to the main-deck. A ship with stern ramp and sideloaders can be worked on by multiple gangs, so that the port-times can be reduced considerably.

Figure 3.17 Sideloader handlings

Disadvantages of the Storo system are:

- The reels still have to be handled by clamp-trucks a number of times, with the related danger for damage.
- The method is very labour-intensive. A full gang is needed for the stowage. The port-times can be reduced, but with a lot of extra expenses due to the extra gang that is required.
- The sideloader installation is capital-intensive and vulnerable. When the sideloader breaks down, the access to the lower and upper deck is blocked, which can cause major down-time to the vessel.
The Roll-On Roll-Off method makes a more universal system for transshipment. The paperreels are lashed on a trailer or cassette in the warehouse. Then the trailer is driven to the ship. Via a stern-ramp the trailer enters the main-deck. From here a hoistable ramp or lift gives access to lower- and upper-deck. The trailer is put into place, whereupon the tugmaster disengages and drives back to the warehouse to pick up a new trailer. The trailer is lashed to the deck to prevent it from shifting.

The only time the reels have to be moved by a clamp-truck is when they are put onto the trailer. After that, the reels do not have to be touched any more until the European warehousing. The bigger unit increases productivity and reduces the port turnaround time.

The RoRo system also has the added advantage to carry road-trailers. In this case, the reels do not have to be touched from the papermill till the consuming industry. The smaller amount of handlings implies a reduction in damage.

Disadvantages of the RoRo method are:

- This ship type requires a lot of investments, also for the trailers or cassettes.
- The lashing of the trailers is expensive, because it demands a lot of labour. It takes about 10 minutes with 4-5 man to lash a trailer or cassette. This problem can partly be overcome by using new lashing methods. It is claimed that, by use of the Wisa-fix method, lashing can be done in 5 minutes by only 2 labourers.
- In the holds, a lot of cargo-space remains unused. Cassettes and trailers cannot be stacked on top of each other. Also, a lot of extra weight of the equipment has to be carried, which reduces the payload.
MARITIME TRANSPORT

For the continuous flows, the shipping companies maintain liner services. Almost all ships that operate in these services are purpose-built RoRo and StoRo vessels. The balance is shipped by tramp-vessels, usually LoLo dry cargo ships. The liner services are usually on a weekly to two-weekly schedule, with often multiple ports of call in W-Europe.

To obtain an impression of the flows of paper, a map was made of Finnish exports of paper to Western European countries, shown in figure 3.19.

Figure 3.19 Finnish paper exports to W-European countries (*1000 tons)
NORTH WEST CONTINENT: DISCHARGING

As ports in NW-Europe usually are bigger than the Finnish ports, a pool-system of harbour-workers can be created. A stevedoring company just has to pay workers for the job that has to be done. Though, the stevedoring companies are facing another problem: The average age of the harbour-workers is very high (Rotterdam: 52 years). In the coming years, a lot of them will retire and few young men are willing to fill in the vacancies. So, also at the W-European harbours new ways must be found to either make the work more appealing or decrease the need for port labour.

The discharging operations are similar to the loading in Finland, but reverse. As an example the StoRo operation is taken. Clamp-trucks put the reels on trailers, the trailers are driven from the ship to the warehouse by tugmasters, in the warehouse the trailers are discharged and the reels are stacked by clamptrucks in the warehouse. Clamptrucks also load the arriving lorries.

Some figures on European transshipment, derived from Rotterdam harbour, illustrate the cost element:

Hourly costs of the different components, needed for transshipment:

- Crane
  - ft 200,-
- Tugmaster
  - ft 180,-
- Clamptruck
  - ft 125,-
- Harbour worker
  - ft 60,-
- Overhead costs
  - 20%
- Fixed charges
  - 5%

For a StoRo operation the following composition of these elements is needed.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (fl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Clamptrucks in the hold</td>
<td>2 * fl 125,- = fl 250,-</td>
</tr>
<tr>
<td>2 Tugmasters</td>
<td>2 * fl 180,- = fl 360,-</td>
</tr>
<tr>
<td>2 Clamptrucks in the warehouse</td>
<td>2 * fl 125,- = fl 250,-</td>
</tr>
<tr>
<td>8 Harbour workers: 6 drivers</td>
<td>6 * fl 60,- = fl 360,-</td>
</tr>
<tr>
<td>2 Supervisors</td>
<td>2 * fl 100,- = fl 200,-</td>
</tr>
<tr>
<td>Overhead costs and fixed charges:</td>
<td>25% = fl 355,-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>fl 1775,- /hour</td>
</tr>
</tbody>
</table>

In an optimal situation, with a StoRo-operation, a production of 200 tons an hour be made, but due to delays an average production of 150 t/h is normal. So the costs per ton up to the warehouse are:

\[
\frac{fl 1775,-}{150 t} = fl 11.83 /ton
\]
Assumption of the productivity during the loading of the lorries is 100t/hr. For this are needed:

2 Clamptrucks  \(2 \times \text{fl 125,-} = \text{fl 250,-}\)
2 Drivers  \(2 \times \text{fl 60,-} = \text{fl 120,-}\)
1 Supervisor  \(1 \times \text{fl 100,-} = \text{fl 100,-}\)

Overhead costs and fixed charges:  
25%  \(\text{fl 470,-}\)

TOTAL  \(\text{fl 587,50}\)

With an assumed productivity of 100 t/hr the costs per ton of the loading of the trucks become:

\[
\text{fl 587,50} \div 100 \ t = \text{fl 5,87 /ton}
\]

Thus, total transshipment costs per ton are:

\[
\text{fl 11,83} + \text{fl 5,87} = \text{fl 17,70 /ton}
\]

This is without the contribution margin, to pay for the investments in the terminal.

WAREHOUSING

The W-European terminals fulfil the main warehousing function of the logistical chain. Especially kraftliner is shipped to the European port without being sold yet. Consuming industries often need reels on very short notice. Then it can be sold from the warehouse, without having to pass through the whole logistical chain before arriving at the consumer. For newsprint exists a more continuous need, the amounts of paper needed are better predictable. Therefore, newsprint is usually sold, before it enters the chain.

The estimated average time a reel spends in warehouses in the entire chain is about 5-10 weeks. Apart from the warehousing costs this also involves an amount of capital costs that cannot be ignored.

Example:

| Reelweight | 2000 kg |
| Material | Kraftliner |
| Reelvalue | fl 1465,- a ton |
| Warehousing costs | fl 1,50 a ton a week (Rotterdam) |

Assumptions:  
Interest: 8 % a year  
Warehousing time: 8 weeks

Total warehousing costs:  
\[
(1,50 + \frac{2000 \times 8\% \times 1465,-}{1000} \times 8 \text{ weeks}) = \text{fl 30,-}
\]

This implies warehousing costs that are about 24% of the total costs of the logistical chain (= fl 127,-).
INLAND TRANSPORT W-EUROPE:

The paper can be transported from the warehouse to the consuming industry by three modes of transport:

- **Roads**: Trucks are most commonly used, because of their high flexibility. However, it is the most expensive way of transportation. Furthermore, the increasing traffic congestion and environmental regulations will make this kind of transportation less favourable in the years to come.

- **Railways**: Trains are fast, but not very flexible, because of the rails that are needed. Governmental subsidies make transport by train more feasible. Large volumes of cargo are needed to fill up a train so that the transport becomes economical.

- **Inland waterways**: Inland barges are the cheapest form of transportation. At present, very little use is made of inland waterways for the transport of paper. Small speeds, little flexibility and the requirement of large batches of cargo are factors that make barges less attractive. If these disadvantages can be overcome, a large cut-back in costs can be expected.
CURRENT INNOVATIVE PROPOSALS

Current innovative proposals have been developed with the following objective:

SOLVING THE TRANSSHIPMENT PROBLEMS

The principal cause of the high costs of transshipment are the labour-costs. These can be reduced in three ways:

Intermodal units. Because of the larger units that have to be moved, less handleings are needed, which implies a cut-back in the need for harbour workers. An additional advantage of the intermodal unit is its protective function. The reels do not have to be grasped themselves, so less damage-causing clamp-handleings are needed.

Examples:

- Efforts have been made to make the Rolux cassette into an intermodal unit, thusfar unsuccessful. Special road-trailers and bogies for transport on rails were developed.

- Small volumes of paper are transported in ordinary containers. Containers are not ideal for paper, as a lot of cargo-protecting material has to be used during the lashing. Because of the non-standardized paper-sizes, the containers cannot be stuffed efficiently. This results in a low payload factor.

Figure 3.20 The Rolux intermodal unit
Transshipment units. The paperreels are put onto cargo-carrying units, so that the transshipment is less labour-intensive. The purpose is to make the work that has to be done independent of the presence of a vessel, so that the work is spread more continuously during the week.

Examples:

- **The Ahlmark concept.** Using giant containers. These units are loaded during the week. When a ship arrives, the containers are loaded into the ship by use of a ship-borne gantry-crane. The containers have a warehousing function as well. When loaded, they can be stacked at the quay-side.

  ![Figure 3.21 The Ahlmark system](image)

- Also designs have been made, which use large flats as transshipment unit, the so-called ‘super-pallets’. An advantage is the accessibility of the cargo-space, the super-pallet can be loaded from all sides, while the container has just one entrance. But, a flat does not protect against the weather.

Automatic cargo handling. Replacing the labourers by machines makes stevedoring operations possible 24 hours a day, 7 days a week. This makes an optimal schedule for the sea-ship possible. Also manning costs will decrease dramatically. However, this will have to weigh up against the higher capital costs and maintenance costs involved.
Examples:

- Radio-controlled trailers, or trailers that drive a certain predestined route autonomously.

- The Mongstad Engineering system. Trolleys take care of the transport from ship to warehouse, possibly with automatically loaded loading platforms. This system is shown in figure 3.22.

Figure 3.22 Mongstad Engineering automatic cargo handling system
PROBLEM DEFINITION

After this overview of the logistical chain, the problem definition of this study is put down as follows.

The objective of the study is to come to a substantial reduction of the overall logistical costs by use of an integral approach. As a case-study the logistical chain of paper products from Finland to Western-Europe is selected. During the process of idea-generation, the following ambitions will be attempted to achieve:

- The system will be kept simple. As little as possible mechanical and electronic systems will be used, in particular onboard of the vessel. These parts tend to break down, due to the moist and salty environment.
- Because of the vulnerability of paperreels, good damage-preventing capabilities are required.

Figure 3.23 Ideal solution: Logistical costs against the covered distance.
Value analysis shows the direction of the most profitable direction for innovation:

- **Capital costs** \( (\approx 70 \text{ FIM/t}) \). Can be reduced by cutting down the time the paper spends in the warehouse.
- **Inland transport Finland** \( (\approx 50 \text{ FIM/t}) \). Is not expected to improve, with regard to the current constraints.
- **Loading of the sea-going vessel in the Finnish harbour** \( (\approx 60 \text{ FIM/t}) \). Handling costs can be reduced substantially by decreasing the labour content.
- **Maritime transport** \( (\approx 50 \text{ FIM/t}) \). The sea-going vessels have been optimized to a large extent. Small improvements are still possible, but it is not worth focussing on in the framework of this study.
- **Discharging of the vessel at West European harbour** \( (\approx 45 \text{ FIM/t}) \). Transshipment solutions from the Finnish port will also bring a benefit to the stevedoring costs in W-Europe.
- **Distribution W-Europe** \( (\approx 105 \text{ FIM/t}) \). Here, major benefit can be gained, possibly using inland waterways.

In the next phase of the study, we will look for an integrated system, that reduces in particular the capital-, transshipment- and distribution costs.

*Figure 3.24 Estimated reduction of logistical costs [FIM/t]*
INNOVATION in forest products shipping
4 GENERATION OF POTENTIAL SOLUTIONS

RESTRUCTURING THE CHAIN

There are many ways to reduce the costs in the logistical chain. Not only technical solutions are considered, as the following paragraphs will illustrate. First the benefits that could come from restructuring the logistical chain of forest products are looked at.

IDEA 1 DISTRIBUTION FROM THE MIDDLE OF THE MARKET AREA

At the moment, large batches of paper are transported to the European ports. From here, these large quantities are split up into truckloads, which are transported to the consuming industries. The distribution takes place from the port-side warehouse.

The division of the large batches into small units can be postponed by using inland waterways. Then, the distances the lorries have to cover to get to the consuming industries can be reduced.

Two contradictory concepts about the logistical system can be followed. The first is the main-port idea. By having one, strategically situated, harbour taking in all cargo that is destined for W-Europe, inland transport can be used very efficiently. Trucks can be avoided by using inland barges or trains, which require larger batches of cargo. The benefits of the cheaper inland transportation have to weigh up to the larger distance that has to be covered.

The purport of the second idea is to keep the sea-leg as long as possible, as the maritime transport is the cheapest way of transportation available. Because of that, the port closest to the consuming industry should be taken, thus maintaining a lot of smaller harbours along the coast.

Distribution from the centre of the market area could combine the advantages of both concepts. It is in a way a mainport-system, as the distribution takes place from one point. Also the leg where ships are used is kept as long as possible, which fulfils the second concept.
IDEA 2 RE-ARRANGING THE LOCATIONS WHERE VALUE IS ADDED

Generally speaking, when value is added to a product, logistical costs increase. The transportation has to be done with more care to decrease damage. If value is added further up the chain, a cut-back in logistical costs is expected.

It looks as if the quality costs are dependant upon the area under the graph of added value against the covered distance, as shown in figure 4.2. If this area is reduced, the quality costs will probably decrease.
According to this graph, the cheapest logistical system would be obtained when the industry transports logs to Europe, where these are processed into paper, the way it used to be a couple of decades ago. It is doubtful if a system like this is desired. Besides the logistical costs, a lot of other factors play a part in the process of decision making:

- **Production costs.** The gain in logistical costs has to weigh up against the increase in production costs, if that is the case.
- **Political demands.** In contrast to the described concept, at the moment papermills are trying to put in the product as much added value as possible. This is for the benefit of the national income. An example is the increase in exports of pre-cut palletized paper-sheets.
- **Invested capital.** The papermills are presently situated in Finland. Changing the current system requires a lot of investments in Europe. Production capacity in Finland will become redundant. So high costs must be incurred to re-arrange the production capacity from Finland to Europe. These costs must also be taken into account.

Obviously, this idea is not feasible, for the negative effects will outweigh the benefits by far. But, when putting it in a less extreme form, it might be useful, and this is actually happening in the paper recycling sector.
INNOVATION in forest products shipping

IDEA 3  ANALOGIES WITHIN SHIPPING

The following analogies within shipping can be made:

- **General cargo or breakbulk.** This is the present perception of paper logistics. It stands for a, merely former, way of transportation. It has proven to be a quite inefficient way of transport. The task is to get paper out of this general cargo system and into another system.

- **Unitized parcels.** A distinction must be made between units, meant to lower the stevedoring and warehousing costs, transshipment units and units that cover the whole logistical chain, intermodal units.

  A quite obvious and dominating intermodal unit is the container. What can be learned from container operations for the unitization of forest products?

  For the transshipment unit, existing analogies are the barge carrier and the tug-barge system. Also the concept of floating warehouses of Kvaerner Masa is looked at. However, this is still just an idea, not yet proven in the market place.

- **Bulk.** Bulk transport is usually based on continuous flow technology. The process-like approach to this logistical system might be worth looking at, when searching for analogies for the forest products chain.

  Taking one step further away from the maritime transport, looking at liquid bulk logistics, pipe-line transportation comes into view. What would it look like if forest products transportation could take place in a pipe-line kind of way?
IDEA 4  INTERMODAL UNIT

The intermodal unit is looked at by way of a progressive abstraction. The question that is posed in this context: "What is the core function of a cargo-carrying unit, when used for paperreels?"

Answer: "To connect paperreels to each other, so that one bigger unit is obtained."

This definition highlights a strange phenomenon. At the papermill large reels are cut and re-rolled into smaller reels. Putting together these reels into a bigger unit, means, in a way, the reconstruction of the large reel. This seems to be a waste of energy. It appears much more efficient to transport the large reels, and do the re-cutting further up the logistical chain.

The comparison between a container, filled with reels and a giant reel is shown in figure 4.3.

Figure 4.3  Comparison container to giant reel
GIANT-REEL TRANSPORTATION

The machines that produce the paper are put in a straight production line with a length of about 500 metres. At the end of this line, the produced paper is rolled onto a giant-reel, as shown in figure 4.4, with approximately the following dimensions:

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Length</td>
<td>≈ 8 m</td>
</tr>
<tr>
<td>Diameter</td>
<td>≈ 3 m</td>
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<tr>
<td>Weight</td>
<td>≈ 30 t</td>
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</tbody>
</table>

When the reel is full it is lifted to another machine, where re-cutting into smaller units with dimensions required by the printing houses takes place. Afterwards a protective cover is put around the reels. These last activities bring only small contributions to the value of the paper. It would not make a large difference if these activities were performed somewhere else.

Then, the re-cutting has to take place as far up the chain as possible. The location in question is the W-European warehouse. From here the distribution takes place, in small parcels.

The transport of the giant reels brings its own complications. Transport in a vertical position is impossible at the moment, as the biggest available clamp-trucks can carry only 5 tons. Also, a reel of this dimensions would deform, bulge out. If the reels are transported in a horizontal position, they tend to become pear-shaped. If the reel is transported, hanging on its axle, the cross-section will turn into an egg-like shape. In the papermills, the giant reels function as some kind of a buffer-stock. To prevent the reel from bulging out, every half hour they are slightly turned.

For the inland transport in Finland, use has to be made of rails and road. For road-transport, maximum width of the vehicle is 2.6 m. So, adjustments must be made to make it possible to move the giant-reels by lorry, as the diameter of the giant reel is now 3 m. While the forest products industry in Finland is of major importance, possibly dispensation can be obtained to move reels with a larger diameter.
Generation of potential solutions

If it is not possible to adjust the rules to the reels, the reels have to be adjusted to the rules. The diameter of the reels must be cut back to slightly less than 2.6 m. The length of the reels, produced by the papermill, cannot be adjusted easily, for that would mean a total revision of the paper-plant. However, the diameter is easily adjustable by just putting less metres of paper on a reel. The weight of the reel will decrease by 30% to 21 tons, which might have a negative influence to the logistic efficiency.

ANALOGY: STEEL-COILS

The analogy with the transport of coils of steel is obvious. Weight and shape are quite similar. Width and diameter differ, though. Of importance is, that coils also are very vulnerable and sensitive to weather influences (especially rust-hazard).

A way to transport steel-coils is using special cradles.

Possibly, the cradles with coils are placed into containers. The coil is secured by adjustable, wedge-like sides of the cradle. On the backhaul, the sides are put in a horizontal position and the cradles are stuffed into a container.

GIANT-REEL CRADLE

Based on this example, a special cradle for the transport of the giant-reels can be developed. The reel-cradle can be quite similar to the cradle for coils. However, the weight-volume ratio is much lower, so the construction can be kept less rigid.

Figure 4.5 Steel-coil cradle

Figure 4.6 Cradle for giant reels
The upper part of the cradle has to be made of a paper-friendly material to reduce damage. Thought is of a cradle made out of multiplex. The sub-structure is a cassette, fitting in the Rolux system. If possible, ordinary Rolux cassettes are converted into giant-reel cassettes. Otherwise purpose-built cassettes will have to be produced.

The aim of using the Rolux-system is to make the concept fit into an existing logistical system. Besides, RoRo operations from Finland to W-Europe tend to switch over from the traditional Mafi-trailers to Rolux-cassettes.

CRADLE CONTAINER

It might be possible to fit the cradle into a standard 40 ft container. In that case, the intermodal unit would be obtained.

When using standard-containers, the bottleneck is the height of the door opening. This height is 2.28 m, so the maximum height of reel plus cradle is restricted to that value. If high cube containers are used, the diameter of the reel can be increased.

The width of the reel can give some problems. If this remains 8 m, the volume in the container cannot be optimally utilized, for the present standards are the TEU ($L_{\text{internal}} = 5.89$ m) and the FEU ($L_{\text{internal}} = 12.01$ m). However, also differing sizes are used at the moment, so also a 30 ft container could be used.

Another possibility is the development of a dedicated reel-carrying container, where cradle and container make one construction. In that case, the maximum diameter of the reel can be kept somewhat larger.

The container is loaded over the side. The side-wall functions as a ramp, over which the reel can roll into its cradle aboard the container.

Figure 4.7 Giant-reel container with integrated cradle
The cradle consists of a flat middle surface and movable inclined sides. When the reel enters the container, one side is horizontal. If the reel is in the correct position, it is secured by giving an inclination to this side. This can be done by a mechanical, hydraulic or possibly even a pneumatic system. Then the ramp is closed and the container is ready to be transported, as figure 4.8 illustrates. A container in which a giant reel hangs on its axle is a possibility. In the papermill, the giant-reels are moved by Gantry-crane systems. The most logical way of loading the container, would be vertical, through the top. The reel hangs on points of suspension in the sides. A small electric motor turns the reel with a very small velocity, in order to prevent deformations of the reel.

**IDEA 5 TRANSSHIPMENT UNIT**

The next step beyond the intermodal unit is the transshipment unit.

**BARGE CARRIER**

The barge-carrier system makes the transshipment independent of harbour facilities. It was developed especially for use in developing countries, where one could not count on any harbour-equipment, because of the lack of financial resources. So, this system provides a transshipment unit without the need for an expensive quay-side logistic harbour-function.

The barges can be used to cover a larger part of the logistical chain than just the transshipment, when using the inland waterways. This is done by a tug, pushing a combination of barges.
Advantages:

- Short harbourtimes of the sea-going vessel because of fast transshipment.
- Possible use of inland waterways.
- Independence of harbour installations.
- Loading and discharging of the barges does not have any influence on the harbour-time of the carrier.

Disadvantages:

- Expensive equipment onboard the ship and the need for various sets of barges imply large investments.
- Maintenance and quality control of the barges give difficulties.
- The payload is very low, in relation to the total deadweight, because of the excessive ‘packaging’.

Examples of barge-carrier systems are:

- LASH Lighter Aboard SHip
- Seabee –
- BACAT Barge Aboard CATamaran
- BACO BArge COnainerliner
The LASH system had the widest use of the above mentioned systems. The barges of this system are relatively small with a deadweight of about 380t. They are lifted out of the water and transported onboard by way of a Gantry-crane with a capacity of about 500t. The carrier can contain over 80 of these barges. This system is still used for the transport of forest products from the Mississippi delta to Europe.

**POSSIBILITIES IN PAPER-CHAIN**

The barge-carrier could bring the following benefits into the forest products chain:

- Stevedoring is made independent of the presence of the ship, which is especially important for the Nordic harbours. This could bring a large reduction in labour costs, as barges could be loaded during normal working hours.

- Inland transportation of the barges by use of inland waterways is much more economical than the use of trucks. In that case, distribution would have to take place from warehouses in the middle of the distribution area.

The LASH system is not directly applicable in the Finland-Germany chain, because:

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*Figure 4.9 LASH-carrier discharging in the port of Rotterdam*
The ship is much too big with a deadweight of over 30,000 dwt. A regular (weekly or less) service would not be feasible with a ship of this dimensions, as the transport capacity would be far too much.

The LASH-barges are not built very friendly to forest products. The walls are covered with transom framing. Double walls would be better. Lots of corners make stowage difficult and increase damage.

The way the inland transportation takes place is not ideal. A large number of these barges have to be connected to each other and then are pushed up the river by a tug. In this configuration the speed has to remain low, and there is a lot of ship-resistance, due to the cubical shape.

The barge-carrier system, suitable for the forest products chain will have to be a ship, carrying a small number of large barges. The size of these barges is based upon the maximum dimensions allowed for the inland waterways. The use of a dock-system for transshipment through the stern makes fast loading and discharging of these barges possible.
Generation of potential solutions

FLOATING WAREHOUSE

The floating warehouse concept is developed at Kvaerner Masa-Yards Technology. The initial idea was generated by use of a creativity-technique, in which the following question was asked:

"When looking at the logistical chain, what would happen if one part was kept out?"

The stevedoring was kept out of the forest products chain. Then the idea surfaced to use floating warehouses in the harbours. When the forest products arrive at the Finnish harbour, they are not put into storage in a warehouse on the quay, but directly loaded into a floating warehouse. This can be a warehouse on a pontoon, a barge or even a ship. At regular intervals, these warehouses are shipped to the European distribution-site, no matter if they are completely full or not. By maintaining a regular schedule a good degree of service can be accomplished. At the European harbour, the distribution takes place directly from the floating warehouse, without transshipment.

The floating warehouse concept could bring down the transshipment costs substantially, as the activities in the port are reduced to a minimum. The use of ships as warehouses would be highly ineffective, because of the extreme high port-times of the high-value ships. Therefore, in the original concept big lighters functioned as warehouses. These lighters are transported by heavy lift dock-ships. This would provide an ultimate kind of a barge-carrier.
Figure 4.11 Floating warehouse on heavy-lift ship

Figure 4.12 Floating warehouse: Logistical costs against covered distance.
The original idea of a heavy-lift ship transporting the floating warehouses has some major disadvantages:

- Operations of a heavy-lift ship are too expensive to be able to start a competitive service in the low freight rates forest products markets.
- The floating warehouse is carried by the heavy-lift ship, so it does not have to withstand the waves by itself. But the ship movements imply large inertia forces, so that the warehouses require a heavy construction after all.
- These first two considerations will have a large negative effect on the net payload.

Another way to introduce a floating warehouse system is possibly a tug-barge system.

**TUG-BARGE SYSTEM**

A tug-barge is a kind of barge-carrier system. The principal difference is that, during the sea-journey, the barge (analogy: the transshipment unit) is not protected and carried within the hull of the sea-ship: it floats by itself. The tug (analogy: the ship) is used as the propulsion unit only. A second difference with the regular barge-carrier is the number of barges that are taken. For a tug-barge system that number is limited to one.

The tug-barge system was developed to separate the propulsion and the cargo-unit of a vessel. The most expensive part of the ship, which is the propulsion installation, is kept in almost continuous operation. This service-principal is called a ‘drop and swap’ operation. The tug is constantly moving barges between the ports, while in each harbour a tug is being loaded or discharged.

If the barges are used for the inland transportation, the restrictions in dimensions, especially the draught-limitations, make the barge quite unfavorable for the sea-operation. A possibility is to discharge part of the cargo at the harbour, before going up the river. In this case, the system can only be economical for the transport of goods with a relatively low specific weight and a high value. Examples of tug-barge systems, suitable for a ‘drop and swap’ operation, are:

- **Artubar** Non-rigid system with one degree of freedom between barge and tug. This gives very good seagoing qualities, but a slightly higher resistance.
INNOVATION in forest products shipping

- Finnpusku: A system developed by Kvaerner-Masa, which uses a three point connection. The connection is made by use of the tapered hull-form of the tug, one fixed bow wedge and two wedges on each side of the tug. The barges are provided with a special bow, so that good ice-going abilities are obtained.

![Figure 4.13 Finnpusku tug-barge system](image)

**TUG-BARGE IN FLOATING WAREHOUSE OPERATION**

The use of floating warehouses cuts back the number of activities that need to take place in the logistical chain dramatically. However, maritime transport by heavy-lift vessels is quite an expensive alternative. Using a tug-barge system in a floating warehouse operation is much more feasible. Perhaps the barges can be transported up the river to the middle of the consumer area. This is the way the logistical system would look like:

The reels are transported from the papermill to the Finnish harbour by truck or train. At the port, they are directly stowed into the barge. The barge remains in the harbour for a fixed period of time. Weekly, or maybe two-weekly a tug arrives to deliver an empty barge and pick up the full one. Even if the barge is not totally filled up, the tug takes it to the W-European port.

The tug drops the full barge and picks up the empty one, which is then transported back to Finland. The warehouse-barge remains at the quay. Trucks take the paper directly from the barge and transport it to the consuming industries, printing houses, cardboard box factories, etc.

It might be possible to use inland waterways to let the distribution take place from the middle of the market area. Then, the tug disconnects from the barge in the port. A, more economical, inland pusher-tug takes it up the river.

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When using the Rhine as inland waterway, the barge has to fit into the following maximal dimensions:

- **Length.** Maximum length for a vessel is 110 m. For a barges-pusher tug combination the maximum length is 185 m overall. That is the length-limitation for the tug-barge combination.

- **Width.** According to the regulations the maximum is 22.80 m.

- **Height.** Minimum clearance of the Rhine is 10 m. So, the maximum height above the waterline is 9.80 m.

- **Draught.** In the past twenty years, a draught of 2.5 m has always been possible to operate, up to the major industrial centers. However, four exceptions are known in the past four years, with a minimum of 2.27 m in October 1989.

Especially the draught limitation is a bottle-neck. To have good sea-going capabilities, the draught must be increased. This can be done by taking in waterballast or by taking cargo for the port. On the back-haul a lot of waterballast capacity is needed to reach an acceptable draught.

*Figure 4.14  Tug-barge system for car transport, using North-sea and Rhine.*
TWO-STOREY BARGE CARRIER

The warehouse that is to be transported onboard of a heavy-lift ship should be very spacious. Therefore the height must be as large as possible, as the width and length are subject to restrictions of the heavy-lift vessel. If the warehouse is to be transported up the inland waterways, the height is limited by the minimum clearance, due to bridges, etc. The second limitation to the height is contributed by the draught constraint of the waterways. Therefore the displacement cannot provide sufficient buoyancy for the required pay-load on the sea-leg.

To master this problem, the cargo which during the sea-transport is stowed into the height has to be spreaded out, either over the length or the width. By increasing the waterline area, sufficient buoyancy can be obtained, while staying within draught limitations. Two potential alternatives are found:

- Divide the warehouse horizontally. The warehouse-barges are stacked two-high on the heavy-lift ship. The upper barge is put on top of the lower one. At the port in Europe first the upper barge is released. The two barges are pushed in a line to the distribution-side by an inland pusher-tug.

Figure 4.15 Loading of the two floating warehouses to the heavy-lift vessel
Flo-Flo two storey barge carrier.

The sea-going vessel, a barge-carrier, is loaded by means of the float-on float-off system. Access is obtained by watertight stern-doors, one for each hold. The barges are dimensioned for the inland waterways. Hence, each hold can only carry one barge.

First, the lower door is opened, so that the first barge can be pushed into the lower hold. Then the door is closed. Water is pumped into the upper hold and ballast tanks. The ship sinks in until the waterlevel in the upper hold is equal to the outside waterlevel. Then the upper door is opened and the second barge is pushed into the upper hold. The door is closed and the water is pumped out of the holds and ballast tanks.

Figure 4.16 Two-storey barge carrier: logistical costs against the covered distance

Compared to the previous graph for a floating warehouse, the distance covered by using waterways is longer. This gives a reduction in distribution costs, because of the more economic means of transportation.
IDEA 6  BULK LOGISTICS

The common future vision of the forest products chain is a system with some kind of cargo-carrying units. What would happen, when the chain is looked at from the point of view of the bulk-sector, which has an entirely different approach to logistics?

Bulk logistics are process oriented. Operations are based on continuous flow technology.

WAREHOUSING

The sea-transport of bulk is slow. A major part of the bulk-stocks are at sea. Consequently, maritime transport has an important warehousing function. It is used for the correction of fluctuations, in production or demand, by varying the speed of vessels. Warehousing at the receiving port can be made, more or less, redundant. Then a just-in-time system is accomplished.

At the moment, the forest products industry uses excessive warehousing. This can possibly be prevented by using the sea-leg for correction of discontinuities.

STEADY-STATE CONTRACTS

Long-term contracts are made on the basis of constant deliveries in constant time intervals. When needed, the size of these batches is adjusted during the contract-period. The buyer is paying a constant amount for every batch. At the end of the contract-period, an account is made of the deviations that have occurred. This way only one bill a year has to be made.

Presently, paperreels are ordered almost one reel at a time. The entire amount of paperwork has to be repeated for every order. Introducing the proposed type of contract in the paper-industry could save a lot of secondary costs, which are caused by the huge amount of paperwork that is needed.
LOADING AND DISCHARGING

The transshipment of bulk-cargo is often done by conveyors, again a very continuous process.

Figure 4.17 Internal transport in papermill, using conveyor-belts.

Instead of the current StoRo method for the transshipment of forest products, a system with conveyors could be used, as illustrated by figure 4.17. The potential benefits of this method are:

- Less harbour-workers needed
- The number of times the paperreels are lifted by clamp-trucks can be reduced.
- Relatively simple equipment, makes the system reliable and requires little investments, compared to other automatic cargo handling systems.
- Weather influences can easily be overcome by a simple shelter over the conveyor.
LIQUID BULK

When discussing continuous flows in transportation, moving liquids by use of pipe-lines cannot be neglected. The connection with the paperchain is made by looking for analogies to pipeline logistics.

- Bionics: Peristalsis.
- Analogy from another technology: Pneumatic mail.

PERISTALSIS

When looking for analogies in nature, peristalsis came into mind as a method for loading and discharging that is being used in nature.

One of the principal goals a plant has in life is securing the survival of the species. One way of doing that is to spread out as far as possible. When in a certain area a species is destroyed, in other areas it will survive. Therefore a distribution system for the seeds is needed. Some species use the wind to take care of this, by producing light-weight seeds and attaching flying-gear to them, like wings or parachutes (e.g. dandelion). Others use the water and let the currents spread the seeds (e.g. coconut).

A lot of plants use animals for the distribution of their seeds. One option is to produce seeds that stick to the pelt (e.g. burdocks). Another way is to have the animals actually eating the seeds. This is done by putting a tasty and nutritious cover around the seeds. The seeds themselves have shells that are indigestible. So, after a while, as part of the excrements, the seeds are released from the animal, hopefully far away from the mother-plant.

When the seeds are eaten, loaded, they are internally transported by the esophagus to the hold of the animal’s body, the stomach. As the animal is getting close to the destination of the seeds, these are internally transported to the hatch, by use of the intestines. Then, during the discharging, the rectum controls the amount of mass that is let free.

When applying this concept in the logistical chain of paper products, an idea is to put a number of flexible tubes in the hold of the ship. The paperreels are transported by some way of peristaltic movement of the tubes. The reels are protected from hitting each other, by the narrowings of the tube in between, that are due to the peristaltic movement. This system is shown in figure 4.18.
Figure 4.18 Peristaltic movement of reels, using a contracting tube

Bottlenecks for this concept:

- The friction between tube and reel will have to be very small, to prevent the reels from damage. Perhaps a very slippery inside surface would do.

- The peristaltic movement will have to be performed by a technical alternative for a circular muscle. No production-ready alternatives of these circular muscles are known at the moment. Therefore the motive power has to be introduced in another way.
PNEUMATIC MAIL

An analogy of peristalsis can be found in pneumatic mail. Here, cylindrical containers are distributed in offices through a network of tubes by use of air-pressure.

The only essential difference to peristaltic movement is the motive power, which is obtained by air-pressure, instead of a contracting tube.

Some problems arise when trying to apply this system in the paperchain:

- Because of the differences in reel-dimensions, in this case especially in cross-section, it is difficult to fit the reel sufficiently tight to the tube. This is needed to obtain differences in air-pressure, through which the reels can be moved.

- The weight of reels is much higher than the weight of the containers that are used for pneumatic post. Very high pressures have to be used to be able to move the reels.

One option to avoid this is to keep to a level system. Then, the reels do not have to be lifted, just pushed forward.
IDEA 7 SYNECTICS EXCURSION

In order to generate completely new insights, a creativity technique called 'synectics' was used (V. Nolan, The Innovator's Handbook). An excursion was performed at the Delft University of Technology. Items on the list of striking objects that were jotted down are:

- Chain transmission system of a lift for disabled.
- Toilet roll holder
- Bottling room in a brewery
- Barrels of beer
- Fire-hose
- Sewer-pipe

TOILET ROLL HOLDER

A toilet roll holder that keeps about five rolls was found in a toilet. A wooden disc is the basis of the object. On this disc a stick is fitted in vertical position. The rolls are put on top of each other with the stick through the inside tubes. On the upper-side of the stick a removable top is placed. This object is shown in figure 4.19.

A system like this can be used to solve the lashing problems of cassettes. When cassettes are made with small holes on the platform, rods can be used for the lashing. The reels are put, if needed, on top of each other on the cassette. Then, the rod is pierced through the inside tubes of the reels and secured in one of the holes in the cassette. This system is shown in figure 4.20.

Figure 4.19 Toilet roll holder
CONNECTION SYSTEM REELS AND UNIT

Now what direction can be chosen to come from the extended toilet roll holder to a more feasible system? Look at the rod that is needed to connect the reels to the cassette. Maybe it is possible to eliminate the need for this rod.

![Figure 4.20 Lashing of cassettes, using rods](image)

A possibility is to adjust the inside tube of the reels so that it takes over the function of the rod. One end of the tube sticks out for a couple of centimeters. This part has a tapering shape. The other end is made so that the tapering part fits in exactly. Maybe even somekind of a bayonet-catch, like a twist-lock, is possible. This system is shown in figure 4.21.

![Figure 4.21 Connection system of reels](image)
IDEA 8    THE SHAPE OF THE CURRENT PAPER UNIT

The paper-unit that is used most often is the paperreel. Using the creativity method of progressive abstraction, the following core-questions were defined:

- "What is the shape of a paperreel?"
- "What advantages and opportunities does this shape bring?"

![Cylinders](image)

**Figure 4.22 Cylinders**

A paperreel is a cylinder. Qualities of a cylindrical shape (figure 4.22):

A cylinder:
- fits into a tube.
- has a smooth surface.
- has the ability to roll or be rolled.
- is a robust structure.
- is compact
- has an identical cross-section over its length.
- fits through a circular hole.
- is a solid of revolution over the length-axis.
- has a small surface area.

The capacity to roll is elaborated further. How can this be introduced into the logistical chain?
ROLLING REELS

CURRENT USE OF ROLLING REELS

In the papermills as well as in the printing houses, the rolling of the reels is utilized in the internal logistical systems.

In the papermill, rolling is used to move reels transversely over small distances, for instance for the connection of two conveyor belts. The conveyors take care of the longitudinal movement. This way, the reels do not have to be lifted to an upright position until the factory warehousing (for the paper is stored in a vertical position). By giving a small slope to these rolling paths, gravity takes care of the motions!

However, at the moment rolling movements of the reels are over very small distances.

In the printing house, a similar system is used to get the reels to the printing machine. However, the transport volumes of paper are much smaller. Therefore, the longitudinal movements take place by rolling the reels, and the transverse movement by use of a little cradle on rails. Vertical movement is done by a small gantry-crane. This is only needed to lift the reels into place in the printing machine.

POSSIBILITIES FOR TRANSSHIPMENT

To construct a bulk-like transshipment system, instead of using conveyors, use can be made of the forces of gravity. Inclined paths to and from the warehouse are created. The reels roll over these tracks to the ship at the quay. It is possible to have the paths take care of the warehousing-function, in the form of short-term buffer-stocks. Instead of the reels rolling one by one, a whole shipload, or deckload, can be loaded onto the path in advance. When the ship arrives, the reels only have to be released to roll into the ship.
ANALOGY: CAN DISPENSER

Can dispensers are machines that distribute cooled cans of softdrinks as seen in cafeterias, gas-stations, etc. (figure 4.23). The cans in the refrigerator are stacked in rows, on inclined shelves. When someone wants a can of Coke, he puts in a coin and pulls the small hatch open. A cradle bearing a can comes out. When the hatch is shut, the cradle slides back and because of the inclination of the shelf, the next can rolls onto the cradle.

In a ship, if the transshipment can be done through the stern, the movements can be kept in a longitudinal line. The complex system with cradles can be avoided. The essence of the analogy is that, just like the can dispenser, emptied spaces are filled up by use of gravity and the rolling capabilities of cylinders.

The concept can be implemented in the warehouse. The reel-carrying paths are given a small slope. If the first reel is taken out of the path, when it is loaded into the ship, the entire line of reels will shift one place, so that the next reel comes into the position to be loaded, etc. (figure 4.24).
PROBLEMS ROLLING REELS

Problems that arise when thinking about a transportation system with rolling reels:

- If a line of cylinders is pushed forward, friction-problems arise. Succeeding reels will have the tendency to turn counterclockwise. High friction between reels, or between ground and reel, imply high wear of the outer surface of the reel (figure 4.25).

![Figure 4.25 Friction to the reels](image)

- Due to this friction, a relatively large inclination is needed to initiate the rolling of the reels. And when they start to roll, the angle is too big for the reels to keep to a continuous, controllable, velocity. Speed will proceed to increase. The impact when stopped will damage the paper and also huge forces on the construction. This problem is also valid for the reels on wheels concept.

- Paper reels with a lot of different cross-sections are transported. It will occur that a reel with a large diameter is next to a reel with a small diameter. Because of the uneven division of forces, the large reel will be pushed out of the line, on top of the smaller reel (figure 4.26).

![Figure 4.26 Large reel pushed over smaller reel](image)

- If not guided, the reels will probably not roll in an exactly straight line, due to inequalities of reels or track. The heeling of the ship can also be a cause for this. Without a solution for this problem, the rolling reels concept cannot be realized.
ANALOGIES FOR THE SEA-GOING VESSEL

The kind of vessel that will be used for the ‘rolling reels’-system will have to be voluminous. A large rectangular hold is required. Inside this hold, a structure with a lot of decks can be placed. This structure can be kept light-weight, a box structure with small spans, and decks that are made out of multiplex. What kind of vessels have similar requirements?

- Livestock carrier. These ships, and especially the sheep carriers, are typical for their large quantity of decks and the high volume in comparison to the pay-load. The speed is relatively high, to keep the sheep seaborne as short as possible (figure 4.27).

  One can learn from the framing, out of which the sheep-decks are constructed. The cargo-space for paperreels will probably have a similar light-weight construction. Possible problems and their solutions can be adapted to the ship for ‘rolling reels’.

![Figure 4.27 Sheepcarrier "Benwalid"](image)

- Also the car-carrier is a ship of high volume with a large number of decks, as shown in figure 4.28.

![Figure 4.28 Car carrier](image)
These ideas can be translated into a 'Rolling Reels'-carrier, as figure 4.29 shows.

**Figure 4.29 Rolling reels ship**

**ANALOGIES FOR TRANSSHIPMENT OF ROLLING REELS**

The next step is to look for possible systems to get the reels from the quay into the ship and vice versa.

The transshipment of bananas is done by a special type of conveyor. Boxes of bananas are moved from the quay to the hold by use of a wall-based spiral-type conveyor. This shape is used, because of the small area that is needed for the positioning of the conveyor. A conveyor like this could be fitted onboard the ship. The reels at the various decks roll to the conveyor, with which they are lifted (or lowered) to a small ramp, from where they roll onto the quay-side installation.
MARBLE GAME

During the transshipment the forces of gravity can be used even more. An analogy is a marble-game, still known from childhood days. It is a wooden construction, with inclined gutters. At the end of each gutter is a hole, so that when a marble is released on the upper gutter, it rolls down the gutter, falls through the hole on to the next gutter, etc. After the last gutter, it falls onto a stairway which then produces some kind of musical tones. The marble comes to rest in a hole in the base-board. A picture of this construction is shown in figure 4.30.

A system like this can be applied onboard of the ship. Release the reel on the top-deck and from there it will roll down, until it is stopped by the queue of paperreels. Perhaps, the discharging can be done by an uncomplicated conveyor, that takes the reels from the bottom-deck to the quay. This system is shown in figure 4.31.
COMMUNICATING BARRELS

Applying the marble game principal to the ship, the reels first roll down to the lowest deck and then have to be lifted up again by a conveyor. It appears a waste of potential energy, obtained by loading the reels on the upper deck. Therefore methods are looked for to keep as much potential energy as possible in the system.

Figure 4.32 Implementation of 'communicating barrels'

If the system would be without any friction, the first and the last reel in line would be on equal altitude. However, in the real system a lot of friction is present which means losses of energy. Therefore a difference in altitude between the first and the last reel will remain. Furthermore, a pressure of this proportions cannot be allowed, for it will cause deformations of the reels, the circular cross-section will be squeezed in.
MARBLE GAME SPRINGBOARD TO REELS ON WHEELS

In the marble game, the connection of the gutters is achieved by a hole. The marbles fall from one gutter onto another. With paperreels a similar system cannot be accepted, as the reels would have to fall for well over one metre, which would cause major damage. Another way of connecting the decks must be found.

Figure 4.33 Heavy impacts on reels and the solution: 'reels on wheels'.

When the cross-section of the rolling part is made smaller, the distance between the decks can be decreased. If a steel bar is placed in the inside tube of the reel, and the decks are replaced by rails, the jump between decks can be kept to a couple of centimeters. To reduce the accelerations even further, a guiding system can be constructed (figure 4.33).

A problem that arises here is the danger of askew sliding of the reels with axle. To cope with this problem, small, uncomplicated, wheels can be connected to the axle. From this moment on...

The 'reels on wheels'-system is born.

Decks are not needed anymore, the internal structure of the hold will only consist of a steel framing with rails over the whole length of the cargo space. The rails will also function as longitudinal stiffeners.
REELS ON WHEELS

The concept of the ship's interior that was derived from the marble game is not practicable. But the idea of the reels with wheels rolling on rails is elaborated. The reels on wheels concept remedies the problems of the rolling-reels idea.

The axles will probably be made out of steel, because of the high forces the small diameter will have to withstand. Wedges take care of the fixation of the reel to the axle. Bearings are situated in the wheels, so that the reel does not turn during forward movement. One, or possibly both, wheels are removable. This way, the axle can be shoved through the inside tube of the reel.

A disadvantage of steel axles is that they have to be taken back to the papermills again, which makes the logistical system more complicated. Also, investments have to be made to provide the system with sufficient axles. An attempt was made to overcome this problem by using disposable, wooden, axles and reels. However, the wooden axles would be too valuable for using them only once.
Lots of different reel-sizes have to be transported. To be economical, the axle will sometimes have to take more than one reel. The maximum allowable diameter for the system will be determined when more knowledge is obtained about the product-mix of the dimensions of paper reels.

EXISTING USE OF REELS ON AXLES

As mentioned earlier, the giant reels that are produced in the papermill have axles, on which the paper is rolled. These are high-value products, for the forces that work on them have high requirements to the material. The giant-reels are moved by use of a gantry crane. The axle is not used to move the reel on a system of rails.

In the printing house, axles are used to position the paper reel in the printing machine. Wedges on the axle take care of the fixation of the reel.

This is illustrated by the following figures:

Figure 4.37 Shows a reel on an axle in the printing machine.
Figure 4.38 Gives a close-up of the axle-machine connection system.
Figure 4.39 Shows the axle.
Figure 4.40 The reel is fixed to the axle by wedges that are integrated in the axle.
Generation of potential solutions

Figure 4.39 Axle

Figure 4.40 Wedges to fix reel on axle
IDEA 9   THE LOGISTICAL CHAIN OF REELS-ON-WHEELS.

An entire chain using the reels on reels system is created, from the papermill to the printinghouse. Including the use of barges on the inland waterways. This way, the distribution function can take place close to the centre of the market area.

PAPERMILL

The axles with wheels are put on the reels when they come out of the production process. Then they are directly, by use of the forces of gravity, rolled into trucks or trailer combinations, so that the warehousing function at the papermill is eliminated (figure 4.41).

The swap-bodies are equipped with two lines of rails on top of each other. Removable (manual or automatic) rail-parts connect the different trailers, so that the reels in one continuous movement fill up a certain number of truck-loads. This may be two or three trailers, the maximum for one truck. Or it may be a bigger number. Then, the truck takes with him the last couple of trailers in the line.

Figure 4.41 'Road-train' for the reels on wheels system

To be able to load the reels longitudinally in the trucks, the length of the axles cannot exceed the maximum width of the vehicle. In Finland this is 2.6 m. Therefore the width of the reels must be kept under 2.5 m. If this is not possible, the trucks will have to be loaded transversely. It cannot be decided yet which of the two possibilities is preferable.

The trucks perform a continuous service, driving to the harbour, discharging the contents of the trailers into the warehouse, and returning to drop the empty trailers and pick up full ones.
At the quay the truck discharges its load into the warehouse, which consists of a number of inclined rail-tracks. This warehouse is situated directly to the quay. The reels roll down the tracks, so that the warehouse is automatically filled up, as shown in figure 4.42.

The arrangement of the tracks in the warehouse can be done in two ways:

- The lines of rails only two high. Along the quay, spreaded over the area the rails are situated. The length of the tracks is equal to the length of the tracks onboard the ship. An uncomplicated rain-shelter protects the paper from weather influences.

**Advantages:**

- The construction can be kept very simple and cheap.
- At the harbour, no electrical systems are needed at all. Gravity takes care of the discharging of the trucks and filling up the warehouse-tracks.

**Disadvantages:**

- A large area close to the quay is needed.
- The ship has to be shifted a couple of times, during the loading. Then, the process has to be interrupted. Labour is required to handle the ship.
Figure 4.43 Loading system with large area warehouse
The tracks can also be positioned on top of each other, so that a system very similar to the, earlier mentioned, can-dispenser is derived. A chain-conveyor takes the reels from the truck and delivers them onto the tracks. Another conveyor, at the quay-side, brings the reels from the tracks to the ship. This system is illustrated by figure 4.45.

Advantages:

- Much less harbour-area is needed.
- Reels can be sorted internally in the warehouse by use of the conveyors and a track with inverse slope.
- No shifting of the ship required during the loading.

Disadvantages:

- The construction of the warehouse will be more expensive.
- The chain-conveyors are electrically driven, which brings the danger of system break-downs. If a conveyor does not work, one track of the entire chain is out of order.

TRIM FOR TRANSSHIPMENT

The first idea was to have inclined decks onboard the ship. This way, the reels could roll from stern to the front. But then discharging would be a problem.

The inclination of the decks onboard a ship can also be controlled by its trim. Then, slope of the decks is variable, so that the inclination can be used for loading and discharging (figure 4.44). Consequently big ballast tanks are needed in bow and stern. Space for these tanks is available below the cargo-hold. In the present configuration the hold cannot be continued under the engine-room, for the rails have to be connected to the stern.
Figure 4.45 Loading system with multi-storey warehouse
ANALOGIES FOR HARBOUR-SHIP CONNECTIONS

GARBAGE TRUCK

The system with which garbage containers are lifted onto the truck is a good analogy. This mechanism also turns the container, so that the garbage drops into the hold of the lorry. The container is put back on the ground afterwards. A hydraulical cylinder moves a steel arm, which is connected to the lorry by a hinge joint. The container has pins on the sides which fit into the arms. By retracting the cylinder, the arm moves up in a circular movement. This system is shown in figure 4.46.

![Loading system of garbage truck](image)

Figure 4.46  Loading system of garbage truck

The strength of the system is its simplicity. To move masses in two dimensions only one hydraulical cylinder and one hinge at each side is needed.

The mechanism could be fitted onboard the ship, either one big version, that covers all decks, or a couple of smaller ones.
CHAIN CONVEYOR

Chain conveyors could also be used. It makes a very simple, continuous system. A wall-based conveyor delivers the reels to a small ramp on the ship, which consists of a number of rails. The reels roll onboard the ship, from where a shipborne chain-conveyor brings the reels from the quay to the different decks.

Because of the advantages of working with a known technology and because of the continuous character of the process, chain conveyors will be used in this concept, whenever vertical movement is needed.

MARITIME TRANSPORT

Due to shipmovements caused by the waves at sea, the axles will have to withstand dynamic loads that cannot be neglected. These forces can exceed 1.5 G. Also ways have to be found to fix the reels. Possible tools are brakes on the wheels, wedges or air-bags. For safety purposes, it is preferable to use a method of 'lashin' which does not require workers in the hold. Figure 4.47 shows a possible cross-section of the sea-going vessel.

Figure 4.47 cross-section of the loaded vessel
TRANSSHIPMENT WEST-EUROPEAN PORT.

At the W-European port, the vessel discharges its load into an inland barge. This barge is dimensioned so, that the capacity is sufficient for the entire deadweight of the sea-vessel. To accomplish this, the cargo-hold has to be spreaded out over the length. Giving it a larger width is not possible, for the number of lanes of rails in sea-vessel and inland barge have to be equal. Due to the small maximum draught, the displacement has to be spreaded over the length and width. The system is shown in figure 4.48.

The use of inland barges requires an additional transshipment, compared to a barge-carrier system. However, the barge can be kept very simple and light in construction. It does not have to withstand acceleration forces due to the ship-movements at sea. When a fast, labour-extensive, way of transshipment is used, this method is to be preferred.

The activities do not require any space on the quay. The vessel is moored on a buoy. The inland barge is brought up to the vessel by a pusher-tug. They are connected stern to stern. Large fenders prevent collisions. The connection has to be able to allow a certain freedom of vertical movement.

Figure 4.48 Transshipment from vessel into inland barge
The inland barge, as well as the sea-vessel are given an inclination by use of waterballast. In the barge, the ballast tanks are situated in the sides.

The chain-conveyor takes the reels to the same ramp as used for the loading in Finland. From here they roll onto the barge, where they are picked up by, again, a chain-conveyor that takes them to the different decks.

**Figure 4.49** The system of discharging

**INLAND TRANSPORT**

The barge is pushed up the inland waterway to the distribution-harbour close to the centre of the market area. The barge is moored, the pusher-barge disconnects and takes the empty barge back to the sea-harbour. The full barge is used as a floating warehouse. From here, the trucks that take care of the short-distance distribution are loaded.
Two possibilities:

- The reels are taken from the axles before they are loaded on the trucks.
  - Closed system, no risk of axles getting lost. Therefore, the number of axles can be limited.
  - The axles stay within the system, so control of the flows of axles takes little effort.
  - By removing the axles, the logistical chain is interrupted. But, while only small quantities of paper are ordered by the printing houses, the Reels-on-Wheels system does not give a large advantage in this link anyway.

- The axles remain in the system until the paper is used in the printing house.
  - The internal logistics in the printing house can be covered by the reels on wheels system.
  - For the system to be of any use, the warehousing at the printing house will have to be a system with rails.
  - A large quantity of axles is needed.
  - The axles with reels have to be recovered from the customers.

THE BACK-HAUL: TRANSPORT OF WASTEPAPER

The axles have to be brought back to the papermill. Also the ships have to get back. Maybe it is possible to use the system on the back-haul as well, for the transport of cargo. One possibility is the transport of waste-paper, compressed into cylindrical units around the axle.

In fact even box-shaped cargo-units can be transported by use of the reels on wheels concept. This is due to the bearings in the wheels, so that the cargo itself does not revolve. For a stable system the axle has to be located above the centre of gravity of the cargo-unit.
The system brings a reduction in capital costs, as long-time warehousing can be eliminated. The warehousing in the Finnish harbour and in the distribution harbour is just to cover the discontinuities in the chain.

The Finnish transshipment requires no harbour-workers at all, which gives a reduction in stevedoring costs.

The same is true for transshipment in the W-European sea-harbour. In addition to that, no expensive quay-length is required.

Transportation by inland barge is very economical. However, it has to weigh up against the extra travel distance.

An extra transshipment is needed at the inland distribution harbour. But this dischargement of the barge only consists of the loading of the lorries. Therefore, costs remain very low.

Distribution by lorries only over a short distance.
5 DESIGN PARAMETERS OF THE CARGO HOLD

The initial idea was to develop a cellular cross-section of the hold. Every pair of rails is separated from the others by a horizontal construction member. To optimize this cross-section, other configurations had to be generated. In order to be able to do this, information had to be obtained of the mix in paperreel dimensions.

For the purpose of weighing the alternatives, a slice of the hold of one metre, with a continuous cross-section is considered.

SPECIFICATION OF DIMENSION DISTRIBUTION OF PAPERREELS

One of the most important aspects of the transport of paperreels is the large variation in dimensions of the reels. Because of this, a very flexible way of handling and stowage of the reels is required.

A request was made to the major papermill organizations in Finland, Finnpap and Kymmene, for data of the mix in diameter and width of the produced reels. Transfennica, the transport organization of the Finnpap group, provided a very limited distribution. The Kymmene organization sent in a more specified distribution of a larger part of their total production. Because the Kymmene distribution and the Transfennica distribution give similar dimensional characteristics of the reels, the distribution of Kymmene is used as a basic indication of the features of the total volume. Figure 5.1 shows a graph in which the yearly volumes of paper from Kymmene papermills are set out for various groups of diameters. Figure 5.2 gives a similar distribution for Transfennica.

![Figure 5.1 Kymmene distribution](image)
It is not the objective of this study to give a detailed profile of the product mix of paper, but a certain assumption of the specifications of the cargo that is to be transported is required to get a criterion for which the logistical chain can be designed. The distribution of the Kymmene group is taken to fulfill that purpose.

This Kymmene-distribution is transformed into a distribution in Reels-on-Wheels (RoW) units, because often more than one reel can be put onto the axle. The following distribution is obtained. Finally, a distribution is needed that directly fills in the one metre length of the rails and that gives direct information about weight and probability. Therefore the ROM-unit is created, Reels-on-wheels-One-Metre unit. The RoW-distribution is transformed into a ROM-distribution, as shown in figure 5.3.
Design parameters of the cargo hold

The group with reel-diameters of 990-1040 mm contains by far the largest volume. The 1190-1240 mm group is also significantly larger than the rest. Together they contain two third of the total volume. The cross-section of the hold will have to be optimal for these two groups, and also acceptable for the remainder.

CROSS-SECTION 1  ONE RAIL PER CELL

The first idea about the configuration of the hold is one rail per cell. The hold is divided by horizontal and vertical structural members, so that the cross-section is divided into cells. Each cell contains one rail on which RoWs can be loaded.

Figure 5.4  Cross-section of the one-rail-per-cell alternative
Advantages:

- The construction can be kept very light, using some kind of a 'honeycomb'-structure.
- Loading the hold is very simple, misunderstandings and errors are very unlikely.

Disadvantages:

- If the total supply of reels has to be accepted, the height of the cells (and therefore the spacing of the reels) will have to be kept very wide. This implies the following:
  - Utilization of the available cargo-space is very low.
  - The vertical location of the center of gravity will be very high. This could give stability problems.

By using different cell-heights, the hold can be made more efficient. In that case, cells are created for small and large reel-diameters. But then the flexibility of the hold will decrease.

Also, extreme reel-sizes can be rejected. Then, the efficiency of the hold can be increased. The extreme reel-sizes are quite rare. So, it can be profitable to transport the largest, say 5% by other means. On the other hand, this is not a real, innovative, solution. It is more like solving the pain, instead of providing a cure. There must be better ways.

**CROSS-SECTION 2   THREE RAILS PER CELL**

The required height for one reel will have to be reduced, without a decrease in flexibility. This can be done by increasing the height of the cells, which means reducing the number of transversal stiffeners, so that more rails can be put into one cell. This way, large ROWs can be placed in the cell. The cell is then filled up with smaller ROWs in the remaining rails. If no fitting ROWs are available the remainder of the rails stay empty.

For this system, a minimum of three rails in one cell are required. If it is preferred to use more rails per cell, an odd number of rails is needed, so that small and large ROWs can be alternated. As it is assumed that a height of more than three rails would give problems with the strength of the construction, the option of three rails per cell is selected. Figures 5.4 and 5.5 illustrates the three-rails-per-cell alternative.
To optimize the load-factor, the decision was made to create a simulation model, so that the best spacing of the rails can be determined. A randomized supply of cargo was generated based on the available distribution.

In the first instance the idea was to use Linear Programming for creating the model. The primary objective of LP models is to optimize a certain product-mix (basic materials, destinations, etc.). For the ROW-problem, just an optimal height of the rails has to be determined. Because of that, a dedicated, simple, simulation model is better.

The model was made by writing in a pseudo-language and afterwards creating the real program in a spreadsheet program (Excel). This is not an ideal program for this purpose, but no dedicated logistics simulation programs (e.g. Must) were available. At first a simple version was created in the pseudo-language, which was then enlarged by reducing the number of assumptions made.

The outcome is that a rail-spacing of 1300 mm would give the optimal loading-factor.
Figure 5.6 Artist’s impression of the three-rails-per-cell system
INNOVATION-PROCESS

When one person works on one alternative for a longer period of time, he becomes protective about this option. He closes his mind for the disadvantages or the possibility that other ideas might be better. This is the so-called tunnel-vision. The origin of this protective behavior is that a person does not want the effort put into the idea to be stamped as useless. That is felt as doubt on his creative qualities. So the designer will tend to camouflage the disadvantages of the idea and upgrading the benefits. This is of value when the idea needs to be sold, but it is not leading to an optimal solution and therefore disastrous for the innovation process.

The elaboration of the ‘three rails per cell’ idea is an excellent example of the tunnel-vision. After working on this idea for two weeks, the affection with it became so big that it left no space for other options. After a lot of effort the first results of the idea were presented to the supervising professor. He did not like the idea too much, because of the still limited flexibility and the complexity of the system of filling the cells. New alternatives had to be found.

At first the feeling was one of disappointment, being mistrusted. After that came the anger, ‘my idea is good, and whoever doubts that is a fool!’ The best way of convincing others that they are wrong is to try out an extreme alternative and showing that it is not feasible. But, as could be expected, this alternative appeared feasible and even better.

Ways to avoid the tunnel-vision is to suspend the point where the ideas are judged. But this requires an enormous amount of discipline from the designer. This can partly be overcome by strictly following a predetermined strategy, so that multiple ideas are elaborated until a certain point, where a selection is made. But, if this way of working is adopted for the whole design-process, a large amount of work has to be done, with no use for the final solution. It is very valuable to use ‘suspended judgement’ in the innovation process, but only at certain times. Otherwise the process would become too cumbersome.

Another way of preventing the designer from undesired tunnel-vision is to involve more persons into the process. Either with a controlling function, intervening when the process gets out of bounds, like the supervising professor in the ‘three rails per cell’-case. Or the problem that is to be solved can be tackled by a team (more than one person). The members of the team keep control on each other, so that the possibility of ‘tunnel-vision’ is reduced to a large extent. This option reduces the risk of the designer taking the criticisms personally. It is easier to accept comments, from people that are on a similar level, the people one works with, than comments from somebody with a supervising role, the people one works for.
CROSS-SECTION 3  MULTIPLE RAILS

In the previous paragraph the need for a more flexible option is explained. So, what started with the purpose of retaliation ended up as a good idea. This in itself is a creativity technique, which was experienced during the innovation process without intention. Making people angry, takes away the barricades that retain the narrow perspective, so that in that state of mind fresh ideas can be produced. It is very important that the provocation is completely settled during the process and afterwards. This makes the method dangerous, so that it should only be used with a lot of care and only in cases of complete deadlock. It is some kind of an emergency exit.

The idea that came from this was to produce a cross-section with exaggerated flexibility. An idea that was given by another person was to place movable rails in the hold. That way, the hold would become very flexible. However, movable reels imply a complex mechanic construction. And mechanic constructions aboard of a sea-going vessel imply high risk of malfunction and lots of maintenance. Therefore the idea did not appeal too much. However, if the rails cannot be moved, another possibility to get a similar result is to put more rails into the hold. For instance one set that is optimal for the 1040 mm ROWs and one optimal for the 1240 mm group.

This way the loader is free to choose which set of rails to take. The flexibility of the system is increased. But, in this case, some rails have to be placed so close to each other that no wheel would fit in between.

With a small amount of extra rails, a system with a standardized, very small, rails spacing can be derived. The hold would not be totally optimal for the two largest groups any more, but better for the overall results. And the flexibility is improved considerably.

Figure 5.7 Hold with various sets of rails
What would be the maximum amount of rails that can be put into the hold? This amount is determined by the minimal railspacing required. The utter minimum railspacing is the distance, needed for the wheels, the cross-section of the rails and the required safety margins. The determination of these properties is discussed more closely in the chapter 'Details'. Here, just the results are given.

A spacing of the rails of 200 mm is regarded as a minimum. To make the spacing optimal for the biggest group in the cargo supply distribution, the spacing should be a division of the diameter (1040 mm) plus the safety margin between the reels, which is assumed to be 50 mm.

\[
\text{Railspacing} = \frac{\text{Diameter} + \text{Safety margin}}{5} = \frac{1040 + 50}{5} = 218 \text{ mm}
\]

One transversal stiffener is considered to be the minimum amount to keep the vertical columns at realistic proportions.

The first assumption of the height of the cells is a capacity of four reels of 1040 mm.

\[
\text{Cellheight} = 4 \times \text{Diameter} + 5 \times \text{Safety margin} = 4 \times 1040 + 5 \times 50 = 4410 \text{ mm}
\]

By use of sketches, shown in figure 5.8, the stowage capacities of this configuration are examined, when ROWs of other dimensions have to be loaded.

*Figure 5.8 Sketches of cells, filled with various RoW-sizes*
The loading-factor of the cells appears to be acceptable. For the 1040 mm ROWs it is optimal. For the 1240 mm ROWs, the second largest group, the filling is quite acceptable as well. If even bigger diameters have to be loaded, enough space remains in the cell to place a smaller reel.

So, the loading factor of this alternative is quite good. However, the flexibility is not totally perfect yet and the loading might be possible to improve on.

Figure 5.9  Cross-section of multiple rail hold with one transversal stiffener
With a hold of 9 ROWs of 1040mm reels high and 5 lanes wide, it is expected that the cargo per metre hold-length is similar to that of existing StoRo vessels. In that case, the hold will have to be split-up in cells of 5 and 4 ROWs with a diameter of 1040 mm. This implies that the cross-section is not optimal for the 1040 mm ROWs, but it is improved for other diameters.

Especially for these options with a limited cell-height, a large number of rails will not be used at all, due to their vertical situation in the hold. Weight and costs can be saved by removing those rails. For the alternative, shown in figure 5.10, the number of rails can be reduced by 60%.

![Figure 5.10 Removing redundant rails](image)

**CROSS-SECTION 4 MULTIPLE RAILS, NO TRANSVERSAL STIFFENER.**

To go even more into extremes, also the last transversal stiffener is removed. This gives ultimate flexibility, at a cost of a heavier construction. And the required width for the constructive members will be quite high. But, by selecting the appropriate rails, every RoW can be loaded efficiently.

This alternative will be discussed in a further stage. Figure 5.11 shows an artist’s impression of the hold with multiple rails.
EVALUATION OF THE DIFFERENT ALTERNATIVES

The various alternatives are weighed by giving value judgements on the most important decision parameters. These are:

- **Flexibility**: The simplicity with which the hold is loaded
- **Weight**: The weight of the construction
- **Volume**: For the construction required space. This is split in vertical and transversal required space.
- **Opinion**: The personal opinion when overlooking the judgements of value.

<table>
<thead>
<tr>
<th></th>
<th>Flexibility</th>
<th>Weight</th>
<th>Transv. space</th>
<th>Vert. space</th>
<th>Opinion</th>
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<tbody>
<tr>
<td>Cells, one rail</td>
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<td>Cells, three rails</td>
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<td>Multi rails, one stiff.</td>
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<td>Multi rails, no stiff.</td>
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</table>
It looks like the multiple rail options provide the best opportunities. The alternative with no transversal stiffener is given the most characteristic marks. This might be a signal for large opportunities, provided that the negative issues are dealt with.

**COMPARISON WITH EXISTING STORO VESSEL**

The cargo capacity per metre length is assumed to be equal to that of a StoRo vessel of similar dimensions. In order to prove this, a ship for comparison has to be selected. Also, some initial dimensions of the configuration can be derived from this ship. In a succeeding step, those dimensions will be refined. The ROW-carrier will probably be a small ship. The volumes of the trade are not very large. Thus, to be able to provide a regular service, it will have to be a relatively small ship.

The ‘Forte’ of the Dutch shipping company ‘Rederij Moerman’ is selected. This is a 4000 DWT ship of the StoRo type. Main Characteristics of the ‘Forte’:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length o.a.</td>
<td>90.84 m</td>
</tr>
<tr>
<td>Length b.p.</td>
<td>83.25 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>15.85 m</td>
</tr>
<tr>
<td>Depth to maindeck</td>
<td>10.00 m</td>
</tr>
<tr>
<td>Draught</td>
<td>6.42 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>4000 t</td>
</tr>
<tr>
<td>Depth top of hold</td>
<td>11.50 m</td>
</tr>
<tr>
<td>Width of hold</td>
<td>13.00 m</td>
</tr>
<tr>
<td>Length of hold (average)</td>
<td>60 m</td>
</tr>
</tbody>
</table>

![General arrangement 'Forte'](image)

*Figure 5.12 General arrangement ‘Forte’*
Cargo capacity per metre length of 'Forte'

The cargo capacity per metre length of the hold is taken as the decision parameter, with which the needed dimensions of the ROW-hold are determined.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deadweight</td>
<td>4000 t</td>
<td></td>
</tr>
<tr>
<td>Fresh water</td>
<td>53 t</td>
<td></td>
</tr>
<tr>
<td>Drinking water</td>
<td>34 t</td>
<td></td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>252 t</td>
<td></td>
</tr>
<tr>
<td>Diesel oil</td>
<td>47 t</td>
<td></td>
</tr>
<tr>
<td>Stores 1%</td>
<td>36 t</td>
<td></td>
</tr>
<tr>
<td>Cargo Capacity</td>
<td>3580 t</td>
<td></td>
</tr>
</tbody>
</table>

Then, the cargo capacity per metre length of the hold is:

\[
\text{Specific Cargo Capacity Forte} = \frac{3580}{60} = 60 \text{ t/m}
\]

Cargo capacity per metre for ROW-ship

The average weight of the paper in a ROM (Reels on wheels One Metre unit) of the group with diameters of 990-1040 mm:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average volume per metre raillength</td>
<td>1,6 m³/m</td>
</tr>
<tr>
<td>Specific weight paper</td>
<td>0,95 t/m³</td>
</tr>
<tr>
<td>Weight per metre raillength</td>
<td>1,52 t/m</td>
</tr>
</tbody>
</table>

For a cargo hold of 5 lanes wide, with per lane 9 of these ROWs, the cargo capacity of the hold is:

\[
\text{Specific Cargo Capacity ROW-carrier} = 5 \times 9 \times 1,52 = 68,4 \text{ t/m}^3
\]

So, some slack remains for ROWs that have a higher specific volume, or the height of the hold can be decreased. Another possibility is that the hold is kept shorter.
**Figure 5.13** Cross-section RoW-carrier, hold 5 lanes wide, 9 standardreels high.

**DETAILS OF THE CARGO HOLD**

Now that a good picture is obtained of the structure of the hold, it is important to go somewhat deeper into detail. At first a view must be obtained of the orders of dimensions of the various structural members. And the dimensions of some other parts have to be decided on: The cross-section of the rails, the wheels and axles.

A ship is seldom in a static condition and in order to be able to avoid calculations of dynamics, the dynamic forces are assumed to be 150% of the static forces. As the purpose of the calculations is just to obtain insight in the order of magnitude of the construction, it is of no use to get into a higher level of detail.
DIMENSIONS OF THE CONSTRUCTION

VERTICAL STRUCTURAL MEMBERS

The aim is to find out roughly what properties the structural members should have. The maximum allowable stresses in the members are determined by using the requirements of the Structural Stability Research Council (SSRC) as found in Gere and Timoshenko’s book: ‘Mechanics of Materials’.

Calculations are made for the optimal ROWs, the group of ROWs with the largest annual volume. Because the calculations involve a test of strength of the construction, a relatively heavy test-ROW is selected:

| Diameter | 1040 mm |
| Width    | 1100 mm (Width paper on ROW = 2*1100 = 2200 mm) |
| Mass     | 1775 kg |

The typical hold that is used in the calculation is 9 ROWs of 1040 mm high and 5 lanes wide, as shown in figure 5.13.

The vertical members have a large span, so the buckling strength is quite low. Maximum allowable tensile stress will only be a small part of the yield-stress. It is likely that this buckling-strength will determine the dimensions of the vertical members.

The vertical members will also have to withstand bending forces, that are due to the heeling of the ship. Those forces are the transversal components of the weights of the reels. Calculations are made at a maximum heeling angle of 25 degrees. In this case the deflections are the critical factor. An elementary model is made, based upon simple-supported beam, so that a first approximation of the deflections is obtained.

A maximum deflection of 0.01 m is accepted. Then, the required moment of inertia is:

\[ I = 61534 \, \text{cm}^4 \]

An I-section (I 305*305, 240 kg/m, Longitudinal spacing 1 m) can perform this function.
However, disadvantages of such a beam-construction are:

- **Large weight.** One metre of the hold would weigh:

\[
4 \times (9 \times \text{Diameter} + 10 \times \text{Safety margin}) \times \text{Specific weight} = 4 \times (9 \times 1,04 + 10 \times 0,05) \times 240 = 9,5 \text{ t}
\]

This consists only the vertical members; rails and other structural members are not considered yet.

- **Needed transversal space.** To get to the required moment of inertia, the constructive members require quite a large space between the rails.

- **Complexity of the construction.** Every metre of the length of the hold a column has to be placed, and every 218 mm of the height a rail. In this configuration, they will have to be connected with brackets, etc. It is not a truly fancy solution.

**CORRUGATED STEELPLATE AS VERTICAL STRUCTURAL MEMBER**

If a construction looks this complicated, it is quite probable that there is a more logical, more elegant solution. So then the next objective became looking for the most elegant solution. Instead of looking for the lightest, smallest, etc. solution.

This was found in the use of corrugated steelplate as vertical structural member. It takes away the discontinuous nature of the vertical members. Brackets are needed no more and the needed number of welds is reduced to a large extent.

In relation to the earlier mentioned alternative of the I-sections, the Corrugated steelplate is very light and the needed space in transversal direction is quite little. The selected configuration consists of corrugated steel-plates with the following dimensions:

- **Width of corrugations:** 110 mm
- **Thickness plate:** 6 mm
- **Weight one bulkhead per metre length of hold (h = 9,86 m):** 596 kg/m

The weight of the bulkheads per metre for the selected configuration of 5 lanes:

\[
\text{Weight one metre of hold} = 596 \times 4 = 2384 \text{ kg} = 2,4 \text{ t}
\]

So, compared with the I-section option, the weight and needed transversal space are both reduced by about 60%. Figure 5.14 shows the construction of the hold interior with corrugated steelplate.
Figure 5.14 Construction of the hold interior with corrugated steelplate.
UPPER DECK TRANSVERSAL STIFFENER

The primary objective of this member is to take over the transversal forces of the vertical members that are due to the heeling of the ship.

The usual spacing of these members is around 2.5 m. Each member has to take over the forces of 2.5 m length of the hold.

By assuming the member to be a simple supported beam, the construction is simplified.

As a result, a T-section is selected with the following dimensions:

<table>
<thead>
<tr>
<th>Web</th>
<th>220 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>-height</td>
<td></td>
</tr>
<tr>
<td>-thickness</td>
<td>9 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flange</th>
<th>160 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>-width</td>
<td></td>
</tr>
<tr>
<td>-thickness</td>
<td>16 mm</td>
</tr>
</tbody>
</table>

DESIGN PARAMETERS OF THE REELS-ON-WHEELS SYSTEM

WHEELS

The smallest rail-spacing possible has to be found. The major piece in this is the diameter of the wheels. Quite obvious, as the wheels will have to fit in between the rails. The remainder of the required space is the slack that is given to the wheel, so that it can move freely. The maximum space for the reels on the ROW is determined by the width of the wheels. So it is important to give shape to the wheels, before the rest of the process is to be continued with.

The shape of the wheel will be conical, just like wheels of trains. This way, the ROW will 'find its own way'. It will oscillate around its equilibrium, which is its state of lowest potential energy. Conical wheels have the lowest potential energy if the axle is horizontal. So, when the ROW is excited by a discontinuity in the rails, it will always tend to get back to its equilibrium.

Before this option of conical wheels was thought of, the idea was to connect the wheels to each other, so that some kind of a wagon is obtained. That seemed to be the most logical way to keep the ROWs in a line. But it happens to be just the other way round. If wheels on rails have a fixed position in relation to the other wheels on the wagon, the friction will be much higher. The axles do not have the opportunity of finding their own way of minimal resistance any more. In trains the axles are given a certain degree of freedom of movement as well, so that the equilibrium seeking behavior of the conical wheels is fully exploited. The ROWs are one-axled vehicles by nature. Then it makes no sense to combine them into more-axled wagons with a higher complexity implied.
By directly adopting the rail-configuration of the trains, it might be that some better ideas are neglected. Because of that, some other ideas are generated.

- The idea of conical wheels seems to be good. But would it be more practical to turn around the functions, using conical rails and simple wheels?

No direct benefits are found, but maybe the construction of the rails can be kept more uncomplicated.

![Figure 5.15 Simple wheels on conical rails](image)

- What about keeping the flange out of the configuration of the wheel? Its purpose might be adopted by the sides of the vertical stiffener, provided that it is flat. It would be like taking the flange from the reels, and spreading it over the length of the stiffener. The side of this member will have to be a continuous plate.

The benefit of the idea would be, that more length of the axle is made free for paperreels, the system would become more efficient. Objections could be the heavier construction needed, because the sides have to withstand collisions of the ROWs.

![Figure 5.16 Wheel without flange](image)
Because corrugated steelplate is used for the vertical construction, the sides of the vertical members are not continuous. So, the wheels without flange cannot be applied here. Therefore the initially derived configuration, the wheels with flange, is continued with.

Next, the dimensions of the wheel are determined, by dividing the wheel into its components, and giving them concrete forms. Figure 5.17 illustrates the selected wheel-rail configuration.

<table>
<thead>
<tr>
<th>Contact surface</th>
<th>The ROWs will need a certain transversal space for this wavering behavior. For this purpose, 25 mm should be sufficient to each side, which makes the width of the contact-part of the wheel 50mm. As a safety-margin, this part is enlarged by 5mm, so that the width of the actual wheel is 55mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange</td>
<td>To take away the hazard of ROWs falling out of the rails, a flange is attached to the innermost side of the wheel. It is merely a safety precaution, it is not supposed to be common practice that the flange hits the rail. Only because of extreme situations, like big discontinuities of the rails or excessive ship-movements, the flange is attached. Thickness of the flange is assumed to be 15 mm.</td>
</tr>
<tr>
<td>Axle</td>
<td>The diameter of the axle is 80 mm, determined by the inner diameter of the inside tube of the paperreels.</td>
</tr>
<tr>
<td>Bayonet catch</td>
<td>To make a fast wheel-axle connection, a bayonet-catch is used. The system is supposed to have a thickness of 10 mm, from which 5mm within the diameter of the axle, and 5mm outside.</td>
</tr>
<tr>
<td>Bearing</td>
<td>The bearing is placed inside of the wheel, with an assumed thickness of 10 mm.</td>
</tr>
<tr>
<td>Wheel</td>
<td>The outside side of the wheel has the smallest diameter. Sufficient material has to be put here to prevent the wheel from deforming. A thickness of 10mm is supposed to be sufficient. Then, because of the conical shape, the maximum thickness of the wheel (flange excluded) is 25 mm.</td>
</tr>
</tbody>
</table>
Adding the components:

**Width wheel:**
- Contact surface: 55 mm
- Flange: 15 mm + 70 mm

**Diameter wheel:**
- Axle: 80 mm
- Bayonet catch: 2*5 10 mm
- Bearing: 2*10 20 mm
- Wheel-material: 2*25 50 mm + 160 mm

**Diameter flange:**
160 + 2*15 190 mm

The wheel needs some vertical space to secure liberty of movement. The wheel should not have collisions with the rail above. With this margin included, the minimum required spacing of the rails becomes:

\[ \text{Spacing}_{\text{min}} = 200 \text{ mm} \]

*Figure 5.17 Selected configuration of wheel and rails*
AXLE

The outside diameter of the axle is 80 mm. Because of the large amount of axles used, the weight must be kept as low as possible. It would be a large benefit if these axles can be handled by hand by one man. For these reasons, an aluminum alloy would be best. An additional benefit of aluminum is that it does not rust, so there is no danger of contamination of the cargo.

Because it is not entirely certain yet if use of aluminum gives the best results, calculations are also made for alternatives with steel as basic material.

The assumptions that are made in the calculations:

- Reels are rigid bodies
- Wheels are supposed to be simple supports at half the width of the wheel
- Dynamic forces, due to ship movements are at maximum 1.5 times static forces.

The strength calculations are based upon two extreme reel-types:

**Maximum weight**

A ROW that is totally filled up with paper reels with a large diameter.

\[
\begin{align*}
\text{Diameter} & = 1370 \text{ mm} \\
\text{Width of paper} & = 2360 \text{ mm} \\
\text{Volume} & = 3.49 \text{ m}^3 \\
\text{Mass} & = 3305 \text{ kg} \\
\text{Free span of axle} & = 30 \text{ mm}
\end{align*}
\]

**Figure 5.18**

**Maximum free span**

A ROW bearing a reel with a large diameter. The space that is left on the axle is just too small to put a second reel onto the axle.

\[
\begin{align*}
\text{Diameter} & = 1370 \text{ mm} \\
\text{Width} & = 1180 \text{ mm} \\
\text{Volume} & = 1.74 \text{ m}^3 \\
\text{Mass} & = 1652 \text{ kg} \\
\text{Free span} & = 620 \text{ mm}
\end{align*}
\]

**Figure 5.19**
The calculations are also made for an average ROW, as a reference. This way the outcomes for the first two ROWs can be put into perspective:

\[
\begin{align*}
\text{Diameter} & = 1040 \text{ mm} \\
\text{Width of paper} \times 1000 & = 2000 \text{ mm} \\
\text{Volume} & = 1.70 \text{ m}^3 \\
\text{Mass} & = 1614 \text{ kg} \\
\text{Free span} (\frac{2420-2000}{2}) & = 210 \text{ mm}
\end{align*}
\]

Because the construction is symmetrical, only one half has to be considered. The axle-deflection appears to be equal to the deflection of a cantilever beam.

The tensile stresses that occur for the ROW with the maximum free span determine the needed strength of the axle.

To come to the best alternative, variations are made, using several materials (2 steel and 3 aluminum alloys). By 'trial and error' the optimal wall-thickness (t in figure 5.21) of the axle is derived for the various materials.

The subsequent configuration is selected:

- **Material**: Aluminum alloy 7075-T6 (Yield-stress 480 MPa)
- **Cross-section**: Hollow tube, wall-thickness 10 mm
- **Weight axle**: 15.86 kg

With this formation, the tensile stresses remain well under the maximum allowable stress. The maximum deflection occurs, as was to be expected, for the ROW with maximum span. This deflection is 15 mm. Because this ROW-type is very exceptional, this deflection is accepted. It is well within the safety-margin of 50 mm.
RAILS

The first idea about the rails was to use ordinary rail-sections, similar to those used by trains. These would have to be fitted on top of 'shelves', connected to the vertical member. Brackets under the shelves would be needed to deal with the bending moments. Except from the heavy construction and the large amount of welds needed, this configuration requires a lot of transversal space as well. It was thought to use ‘flat-bulb scantlings’ as a combination of shelf and rail.

Then, functional analysis was made of normal rails. What parts have a function, when used for the RoW-system. Actually, the only part with an explicit function is the contact-surface. The function of the rest of the rail-section is to make the rail suitable for placing it on a horizontal base. Because the RoW-rails need to be connected to a vertical base, this part of the rail is totally redundant. The rail-section for the ROW-system does not need the traditional rail-shape, provided that the contact surface is similar.

Factors that determine the shape of the cross-section of the rail:

- A large number of rails have to be installed in the hold. Because of that it is worthwhile to put some effort in decreasing the weight of the rails. In other words: The area of the cross-section has to be minimized.

- The rail-spacing is 218mm. In this interval the rail and the wheel will have to fit, in such a way that collisions are impossible.

- The transversal space required has to be as small as possible, to improve the efficiency of the hold. Also, the further the distance of the contact surface from the vertical stiffener, the larger the bending moments that have to be coped with.

One idea was using corrugated steelplate, with the corrugations in a horizontal direction. This way the vertical stiffener is also the rail. The needed space in transversal direction is very small, for the rails of two lanes are placed on top of each other. It would also give a very simple solution, just a corrugated plate filling in all the functions. Figure 5.23 illustrates this idea.
However, an obstacle that in the present view on the matter cannot possibly be conquered is related to the qualities of corrugated plate itself. This plate only gives strength in the direction of the corrugations. So the plate can either be used as stiffener, or as rails. No ways are found to use it for both functions at the same time.

**CROSS-SECTION OF THE RAILS**

A triangle-like rail section would give the best results (Figure 5.24). Some preliminary calculations are made, based upon the following assumptions:

- The needed strength of the rail is determined by the most extreme situation possible, a ROW of maximum weight (about 3t) in the middle of the free span. This is the length of the corrugations of the longitudinal bulkheads (1000mm).

- The shape of the cross-section is approximated by using a hollow triangle.

- A maximum deflection of 2.5 mm is accepted.

- The maximal height of the rails is 70 mm. Otherwise the space, available for the wheels would become too small.

The following cross-section is selected:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>70</td>
<td>mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>8</td>
<td>mm</td>
</tr>
<tr>
<td>Weight</td>
<td>12.9</td>
<td>kg/m</td>
</tr>
</tbody>
</table>
CROSS-SECTION OF THE VESSEL

Now that the most important details are quantified, a first view is made on the cross-section of the hold. For this approximation, the main dimensions from the 'Forte' are selected, and translated to the cross-section of the ROW-carrier.

Figure 5.25 Cross-section RoW cargo hold
INNOVATION in forest products shipping

The hold is capable of carrying RoWs with a diameter of 1040 mm and 10 high. Then, the depth to the top of the hold is similar to that of the 'Forte'.

\[ \text{Cargo capacity} \times 5 \times 10 \times 1.52 = 76 \text{ t/m} \]

\[ \text{Cargo capacity 'Forte'} = 60 \text{ t/m} \]

So, if this configuration is maintained, the length of the hold of the ROW-carrier can be kept 80% shorter.

The dimensions of double bottom and double sides are similar to those of the 'Forte'.

WEIGHT ESTIMATION OF THE HOLD

The weight of the interior of the hold is calculated. This weight determines the extra costs of the ROW-carrier.

\[ \text{Figure 5.26 Division shipweight in weight of hull and weight of hold interior} \]

The given figures are the weights of the construction per metre length of the entire hold.

- Longitudinal bulkheads of corrugated steel plate: 2384 kg/m
- Rails: 5934 kg/m
- Transversal stiffener upperdeck: 187 kg/m
- Total: 8505 kg/m

So, the extra weight of the ROW-construction in the hold is 8.5 t/m. Possibly, this weight can be reduced by taking away those rails, that are very unlikely to be used.
OTHER IDEAS/REMARKS

- The damage stability is very poor if the longitudinal bulkheads are watertight, due to unsymmetrical flooding in case of damage to the hull. The conventional way of taking care of this is to make holes in the bulkheads, so that the water can spread freely over the entire hold. This way, symmetrical flooding is obtained.

It seems to be a shame to first install nice watertight bulkheads into the ship, and then making holes in them, so that their capability to keep the entire hold from flooding is taken away.

Perhaps it is possible to connect the lanes symmetrically, by use of corridors under the tanktop. The tanktop does not have to carry anything, so it would not inflict on the operational abilities of the vessel. When the ship is damaged, and a lane gets flooded, the corridor makes sure that the lane at the opposite side is flooded as well. So, symmetrical flooding is derived while maintaining the buoying capacity of the remaining lanes.

*Figure 5.27 Corridors for symmetrical flooding in tanktop*
It might not be needed to make the vessel entirely double-hulled. Perhaps either a double bottom or double sides would do.

The tanktop does not have an actual function, no cargo is put on top of it and no lift trucks need to drive on it. So it seems to be most logical to remove the tanktop. Then, the tanks will situated in the double sides, stern and forward part of the vessel.

Maybe even both tanktop and double skin can be removed. Then, all tanks will have to be installed in stern and front.

**Figure 5.28 Various configurations of the cross-section of the hull**

- The volume of the hold will be determined by ROWs with a large volume, in relation to their weight. The hold has to be of sufficient volume for the vessel to reach its maximum cargo capacity for the ‘volume ROWs’. So, when the vessel is loaded with optimal ROWs, the volume of the hold will only partly be used.

- To take the dynamic forces into account, calculations are based on a dynamic load of the cargo which is 150% of the static load. However, these severe dynamic loads only occur in the front of the vessel. Possibly the rest of the interior of the hold can be can be dimensioned somewhat lighter, with dynamic forces of about 130% that have to be coped with.
6 DESIGN PARAMETERS OF THE VESSEL

After defining the design parameters of the cargohold, the next step is to define the parameters for the vessel. This starts out with a hypothetical service.

THE SERVICE

In order to be able to base the design of the vessel on a real service, a rough assumption is made of what this service could look like.

The ROW-system is planned to be introduced into a service from Rauma to Rotterdam.

- **Rauma**: Biggest Forest Products port in Finland. The Transfennica exports from Rauma consist of an annual volume of 1,780,000t.

- **Rotterdam**: The Reels-on-Wheels system is meant to take care of a large part of the forest products logistical chain. Inland transport to Western Germany is taken care of by inland barges on the Rhine. In this study just the sea-leg is discussed, due to time restrictions. To give a view of the maritime transport part of the same chain, Rotterdam is selected as port of discharge.

![Map of the route](image)

**Figure 6.1 Map of the route**
INNOVATION in forest products shipping

The market share will consist of all the Transfennica exports from Rauma to the Netherlands, which is around 10% of the total exports from Rauma:

\[
\text{Annual volume }_{\text{Netherlands}} = 1.780.000 \times 10\% = 178.000 \text{ t}
\]

The paper volume, destined for Western Germany is added. The market area is the Ruhrgebiet. Here about 50% of the German paper consuming industry is situated. About 40% of the Transfennica transports from Rauma is going to Germany.

\[
\text{Annual volume }_{\text{Germany}} = 50\% \times 1.780.000 \times 40\% = 356.000 \text{ t}
\]

Both are going through Rotterdam, so:

\[
\text{Annual Vol. }_{\text{ROW, Rotterdam}} = 178.000 + 356.000 = 534.000 \text{ t}
\]

Sailing distance Rauma ⇔ Rotterdam:

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rauma ⇒ Kiel canal</td>
<td>600 nM</td>
</tr>
<tr>
<td>Kiel canal ⇒ Rotterdam</td>
<td>287 nM +</td>
</tr>
<tr>
<td>Kiel canal</td>
<td>940 nM</td>
</tr>
</tbody>
</table>

PORT TIME ROW-CARRIER

At this stage the port time has to be approximated, in order to be able to determine the roundtrip time of the vessel. Then, the cargo capacity and the service speed of the vessel can be decided upon.

The port turnaround time consists of the following components:

- **Arrival in the harbour.** When approaching, and in, the harbour, the ship cannot sail at full speed. Also, the pilot will have to board. Time needed for entering the harbour:
  \[t_{\text{entering}} = 25 \text{ min.}\]

- **Mooring.** The ship-wall connection and connecting the internal transport system of the ROWs to that of the warehouse by means of a small ramp, consisting of rails.
  \[t_{\text{mooring}} = 5 \text{ min.}\]
Trim for transshipment. Before the ROWs can be loaded or discharged, the vessel must be given a certain trim angle. The filling of the ballast tanks will take some time, as around 1000t of water has to be loaded. However, if the stability of the vessel is not in danger, the ballast water can be taken in while entering the harbour.

Quite extreme trim-conditions have to be used for loading and discharging. Sailing in these conditions might not be possible; e.g. the propeller will break through the water surface. So, while entering the harbour, the vessel will be ballasted to its maximum allowable sailing condition. Then, probably, the 5 minutes needed for mooring will be sufficient to bring the ship to its loading/discharging trim.

If this time is not enough, some extra time will have to be reserved for the trim of the vessel. For now the time available is assumed to be sufficient.

Loading/Discharging. The critical factor for the transshipment speed will not be the conveyor, as was expected. The maximum speed of this kind of a conveyor is about 2-3 m/s. The required speed will be much lower, assume 0,5 m/s.

Maximum speed for ROWs rolling down the rails is taken 1 m/s. Distance between ROWs is taken minimal 10 m. This is a safety margin, to avoid unwanted collisions taking place due to possible variations in speed. The distance also gives the controller time to react, if something might go wrong. Figure 6.2 gives an overview of the assumptions made for the dynamics of transshipment.

Transshipment speed:

\[
\begin{align*}
\text{For one lane:} & \quad 1/10 \quad [\text{m/s}] / [\text{m}] \\
& = 0.1 \quad \text{ROW/s} \\
& = 650 \quad t/h \quad \{W_{\text{ave.}} = 1.8 \ t/m\}
\end{align*}
\]

\[
\begin{align*}
\text{For five lanes:} & \quad 5*0.1 \\
& = 0.5 \quad m/s \\
& = 3250 \quad t/h
\end{align*}
\]

If the vessel carries the same amount of cargo as the ‘Forte’ (3580 t), total transshipment time would be:

\[
\begin{align*}
t_{\text{transsh.}} & = 3580/3250 \quad = 1.1 \text{ hour} \\
& = 66 \text{ min}
\end{align*}
\]
Trim for sailing. The ballastwater will have to be pumped out of the ship, to regain a sailing-condition. For the time needed the same arguments are valid as for the trim for transshipment. For now no extra time is counted for this purpose.

Casting off. Consists of taking in the ramp, closing the cargo entrance door, and removing the ship-quay connection.

\[ t_{\text{casting off}} = 5 \text{ min} \]

Departure. Time needed for leaving the harbour, because of the reduced speed and the pilot that has to be disembarked.

\[ t_{\text{departure}} = 25 \text{ min} \]

Thus, provided that the cargo capacity is equal to that of the 'Forte', total harbour time is:

\[
\begin{align*}
\frac{t_{\text{entering}}}{t_{\text{mooring}}} &= 25 \text{ min} \\
\frac{t_{\text{transsh.}}}{t_{\text{casting off}}} &= 5 \text{ min} \\
\frac{t_{\text{departure}}}{t_{\text{HARBOUR, TOTAL}}} &= 25 \text{ min} + 126 \text{ min} = 2 \text{ h}.
\end{align*}
\]
At present, for ships of the StoRo type, like the 'Forte', the transshipment time by itself consists of 2 shifts, 16 hours. So, transshipment time will theoretically be reduced to some 7% of the StoRo transshipment time. Total harbour time is reduced to around 15%.

Because the cargo capacity of the ROW-carrier is not determined yet, the harbour time is calculated as a variable, depending on the cargo capacity.

**NOTE:** The determined harbour time is extremely short, it is reduced to an almost unrealistic value. The calculations that lead to this value are based upon rough estimates.

**DETERMINATION OF THE SERVICE, (SERVICE SPEED AND PAYLOAD)**

By variations in departure intervals from Rauma, and the number of ships that are used in the liner service, various alternatives are generated. Regular departures make sure that the delivery time is reduced, a factor of increasing importance in paper logistics, and therefore an important decision parameter for the ROW-system. Regular departures are derived by using a relatively large number of relatively small ships. A large vessel needs less departures to take in the annual volume, but is economically more attractive. So, some kind of an equilibrium must be found between the 'regularity of service' and the 'economy of scale'. A vessel of about 4000 dwt is among the smaller vessels in the Nordic trade. The ROW-carrier will probably have about this deadweight.

From the various alternatives (Number of departures, number of ships) the service speed and payload are calculated. The extreme values are eliminated:

\[
\begin{align*}
10 \text{ Kn} & > & V_s & > & 40 \text{ Kn} \\
2500 \text{ t} & > & \text{Cargo cap} & > & 5000 \text{ t}
\end{align*}
\]

For the remainder, the Froude Number is estimated, based upon selected ships for comparison. Then, the alternative with residual resistance in a 'trough' is selected. If this is the case, and the alternative looks good by all other means as well, this configuration is selected. Figure 6.3 illustrates this by a residual resistance diagram.
The following alternative meets the requirements best:

- **Interval of departure**: 60 hours
- **Number of vessels**: 2
- **Service speed**: 16.2 Kn
- **Payload vessel**: 3630 t
- **Port time**: 127 min
- **Froude Number**: 0.27

![Diagram](image)

**Figure 6.3 Residual resistance diagram**

**INITIAL DIMENSIONS OF THE SHIP**

**SHIPS FOR COMPARISON**

A number of ships for comparison is selected. These are all relatively small Storo ships, except for the 'Bore Sea' and the 'Bore XI', which are RoRo vessels. The selected ships are (in increasing order of deadweight):

<table>
<thead>
<tr>
<th>Shipname</th>
<th>Deadweight (t)</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breant</td>
<td>3340</td>
<td>110.50 oa</td>
</tr>
<tr>
<td>Forte (tf)</td>
<td>4001</td>
<td>90.84 oa 83.25 bp</td>
</tr>
<tr>
<td>Link Star (tf)</td>
<td>4017</td>
<td>107.45 oa</td>
</tr>
<tr>
<td>Bore Sea</td>
<td>4232</td>
<td>107.35 oa 98.00 bp</td>
</tr>
<tr>
<td>Baltic Press</td>
<td>4600</td>
<td>135.85 oa</td>
</tr>
<tr>
<td>AnnMari (tf)</td>
<td>4600</td>
<td>114.40 oa</td>
</tr>
<tr>
<td>Bore XI</td>
<td>4760</td>
<td>113.47 oa</td>
</tr>
<tr>
<td>Hämno (tf)</td>
<td>5387</td>
<td>122.00 oa 112.00 bp</td>
</tr>
</tbody>
</table>

(tf) = Ships under Transfennica charter
Also, a statistic selection of 500 RoRo (and StoRo) carriers is obtained, through the Information System of the NAPA program, a data service of Fairplay International. These data are used in combination with publications of self-selected ships for comparison, which offer more specific information. The ships for comparison also perform a check-up function.

**ROW-CARRIER**

The selected main-dimensions for the RoW-carrier are, if possible directly determined. Then, the ships for comparison have only a controlling function. If this is not possible, important ratios are used to obtain an initial value for the required main dimension. If the NAPA data suggest a clear dependency, also these data can be used. In the following, the considerations that lead to the various main-dimensions are discussed. Only the final values are given, for a number of variations took place before the final configuration was decided upon.

**Length between perpendiculare**

Determined by the Froude Number of 0.27. Then, the residual resistance is in a trough, so that the hull of the vessel is relatively efficient.

\[ F_n = \frac{v}{\sqrt{gL}} \]

\[ L_{pp} = \frac{(v/F_n)^2}{g} = \frac{(16.5 \cdot 1852/3600)/0.27)^2}{9.8} = 97.4 \text{ m} \]

**Breadth**

The ratio length/breadth will be kept quite normal, for the hold is of ordinary proportions as well. It is expected, that by using an average breadth, stability will be sufficient.

\[ \frac{L_{bp}}{B} = 5.80 \]

\[ B = 16.80 \text{ m} \]

**Depth**

For the time being the depth is determined by the, in the previous chapter, produced cross-section of the ROW-carrier.

\[ D_{upperdeck} = 12.5 \text{ m} \]
Deadweight

A first assumption about the deadweight is derived by selecting a residual deadweight (DWT-cargocap.), similar to that of the 'Forte'.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deadweight ‘Forte’</td>
<td>4001 t</td>
</tr>
<tr>
<td>Cargo capacity ‘Forte’</td>
<td>3580 t</td>
</tr>
<tr>
<td>Residue</td>
<td>421 t</td>
</tr>
<tr>
<td>Cargo capacity ROW-carrier</td>
<td>3630 t</td>
</tr>
<tr>
<td>Deadweight ROW-carrier</td>
<td>4100 t</td>
</tr>
</tbody>
</table>

Draught

The ratio Deadweight/L*B*T is an important indicator for the required draught. This ratio is derived by looking at the NAPA-data. The ratio can be supposed to be on the low side, because of the relatively high light ship weight, due to the interior of the hold.

\[
\frac{\text{Deadweight}}{\text{L} \times \text{B} \times \text{T}} = 0.42
\]

\[
\frac{\text{T}}{\text{m}} = 6.10
\]

Displacement

Displacement volume is, as a starting point, obtained by using the deadweight/displacement ratio of the selected ships for comparison.

\[
\frac{\text{DWT}}{\text{Displacement}} = 0.67
\]

\[
\text{Displacement} = 6100 \text{ m}^3
\]

Now, the block coefficient can be determined.

\[
C_b = \frac{\text{Displacement volume}}{\text{L} \times \text{B} \times \text{T}} = \frac{6100}{97.4 \times 16.6 \times 6.2} = 0.61
\]

Braked power

A first idea of the needed propulsion installation is derived from the NAPA-data. Variations in speed of the RoRo vessels are very large, so no clear view can be obtained from the deadweight versus braked power graph. Braked Power has a dependency to the third degree to the speed, so the graph can be made without dimensions by dividing the braked power by the service speed to the third. From this graph, the following estimation can be deduced:

\[
\frac{\text{Total Braked Power}}{\text{Speed}^3} = 1.1
\]

\[
\text{Braked Power ROW-ship} = 4700 \text{ kW}
\]
DESIGN-PROCESS

The main dimensions are all interdependent. Therefore, a number of iterations are made to come to sufficient accuracy. This remains the best way to come to a solution, for it is too complex a problem to head straightforward for an accurate solution.

Concluding, the dimensions that are used as input data for the NAPA hydrodynamics program, which provides a hull-form, are:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{bp}$</td>
<td>97.40 m</td>
</tr>
<tr>
<td>$B$</td>
<td>16.60 m</td>
</tr>
<tr>
<td>$T$</td>
<td>6.10 m</td>
</tr>
<tr>
<td>$C_b$</td>
<td>0.62</td>
</tr>
<tr>
<td>$V$</td>
<td>6108 $m^3$</td>
</tr>
<tr>
<td>$v_s$</td>
<td>16.5 kn</td>
</tr>
</tbody>
</table>

HULL-FORM

The hull-form is generated by use of the NAPA hydrodynamics software package. The shape of the hull is based upon a RoRo vessel, because of the similar requirements of the hold to the shape of the hull. These requirements are:

- The internal transport of cargo is in a horizontal direction. This is similar for a RoRo as well as for a ROW-vessel. In a way, the ROW-system is a Roll on, Roll off system.

- The hold needs to have a continuous cross-section, especially in the aft-body of the ship. The use of lanes implies, that the cargo will have to pass every part of the ship at the same transversal position, until the cargo arrives at its stowage position. A narrowing of the hold will make the use of a lane in the front of the ship impossible.

In order to begin the hold as far to the stern as possible, a ‘pram-type’ afterbody will be used. This way, the width of the hull is continuous to the largest extent. However, continuous draught is restricted because the angle of entrance of the flows of water into the propeller should be no larger than 15°.

The selected hull-form is illustrated by figure 6.4, a lines drawing, and figure 6.5, a perspective view of the hull.
Figure 6.4 Lines drawing
Kværner Masa-Yards
Technology

Figure 6.5 Perspective view of the hull-form
IDEAS OBTAINED BEFORE HULL-SHAPE

A number of ‘loose’ ideas are obtained during the process of finding a hull-form. In the following, these are recorded, because they might be of use in a later stage. The availability of a hull-form will limit the field of vision. Before that is the case, it is important to make note of these ideas. Because if one gets stuck in the process, they might be of use to break open the design process again.

Ideas:

□ The need for a continuous cross-section of the hold in the stern can be avoided by using a second chain-conveyor, that is situated in front of the engineroom. The reels for the lower part of the hold are firstly loaded and the last that are to be discharged. To feed this second chain conveyor, the lowest rail in the stern-part of the hold is used. After the lower part of the hold is loaded, the rest of the hold can be filled.

Benefits:  
- The volume of the hold is more efficiently used.
- A conventional engineroom can be installed in the part of the hull that cannot be used because of the needed angle of entrance

Constraints:  
- The loading of the hold is more complex, which increases the probability for mistakes.
- More mechanic installations onboard the ship, make it more expensive, and increase the danger of malfunction.

Figure 6.6 Cargo hold with second chain conveyor in front of engine room
Design parameters of the vessel

- The rails, that are designed in the previous chapter, can also be made out of ordinary steel plate at the shipyard. In that case, the plate is folded into a triangular shape, and the ends are welded to each other.

Benefits
- Cheaper, no special section needs to be ordered.

Constraints
- The strength of the profile might be less than the strength of the extruded version.
- The smoothness of the surface is less predictable.

![Figure 6.7 Folded rails versus extruded rails](image)

- The harbourtime of the ROW-vessel is extremely short. This quality of the ROW-system can be exploited best, by using relatively fast ships in the service. Would a Euro-Express ROW-carrier be feasible? The Euro-Express is a fast-ship feeder concept of Kvaerner Masa-Yards Technology from Finland. The vessel is a super-slender monohull, designed for a service speed of about 30 knots. For a ship with such a large speed, short harbourtimes are extremely important. The ROW-system could provide that to the Euro-Express.

Benefits:
- The superslender monohull has a long continuous cross-section. It seems very suitable to place a ROW-hold inside.
- The fast ship reduces the delivery time of the logistical chain. An important parameter, for the paper consuming industry will require 'Just In Time' delivery more and more.
INNOVATION in forest products shipping

Constraints:

○ A fast ship is expensive to build and expensive in exploitation, primarily because of the large fuel-consumption.

○ The cargo capacity is a relatively small part of the total weight. It is best suitable for volume-cargo of high value, which paperreels is not.

Possibly another kind of cargo, with higher specific value, can be transported using the superslender monohull, and a ROW-like way of cargo-handling.

![Figure 6.8 Slender monohull container carrier](image)

![Figure 6.9 General arrangement Euro Express RoW-carrier](image)
Design parameters of the vessel

- To ensure a long, continuous hold, possibly use can be made of a diesel-electric installation. Here, propulsion and energy generating unit are separated. The propulsion can be taken care of by an Azipod unit. This is a gondola under the hull, which consists of the electric engine and the propeller. A rudder is redundant, because the steering is done by turning the Azipod unit.

![Azipod unit](image)

**Figure 6.10 Azipod unit**

**Benefits:**
- The engine room can be placed anywhere in the ship.
  - Thought is of the forward of the ship, for the cargohold cannot extend till there and it might bring a more favourable longitudinal center of gravity of the light ship.

**Constraints:**
- The efficiency of the propulsion is some 75% of that of a conventional configuration.
- Initial investment of the Azipod is about 6% higher.

- If the tanktop is removed, it might be possible to put the engineroom in the double sides of the ship. Then, two enginerooms are placed on each side of the ship. These engines might drive either propellers on each side of the ship, or an Azipod unit in the middle. Figure 6.11 shows this alternative.
An other configuration, known to expand the space available for the hold, is to place the engine above the shaft. The connection between engine and shaft is made by means of a special gear-box.

Figure 6.11 Enginerooms in the sides

Figure 6.12 Engine above shaft
Would it be of use to create a service with multiple ports?

Benefits:  The various paper ports have just small annual volumes. By multiple ports of call, a larger, more efficient, service can be created.

Constraints:  Multiple ports require more quay-side installations, which makes the system more expensive, if the cargo-volumes per port are small. Then, it might be possible to keep the entire conveyor system onboard the ship, so that at the quay, just a rack of rails is needed. If this rack can be kept only two high, no conveyor is needed to taking in rails from the trucks.

Figure 6.13  Small RoW-warehouse for multiple ports service.
7 DESIGN OF THE REELS-ON-WHEELS CARRIER

Up until this stage, the various parts of the ship are, more or less, independently determined. Main components are the internal structure of the hold, the details of the ROW-system and the hull-form. Now, these need to be combined into a real ROW-carrier.

To come to an optimal solution, a large number of variations are generated. Most important factors are the shape of the hold, location of the engineroom and the accommodation. Also, the location of the quayside-connection for the transshipment of the ROWs is an important factor.

VARIATIONS OF CONFIGURATION

ENGINE ROOM

The conventional location of the engine room is low in the aft-body of the ship, so that the distance between propeller and engine is as short as possible. Thus, the shaft is kept short, which implies little loss in power and low weight of the shaft.

By using different types of engine installation, efficiency decreases and invested capital is higher. However, more freedom of location is gained and therefore the hold can be placed more favourably into the ship. The benefits of this kind of an installation will have to outstrip the extra costs. When using a diesel-electric installation, the following alternatives are thought of:

- **Engineroom in front.** The forward part of the vessel is not suitable for placing the hold. Putting the engineroom here will not inflict on the optimal configuration of the hold. Also the trim is positively affected. When loaded, the center of gravity of the cargo will probably be behind the center of buoyancy, so that the trim will tend to be to the stern. Placing the engineroom in the front will bring compensation

- **Engineroom in double sides.** This option is discussed in the previous chapter. It is only possible if these double sides are sufficiently wide. The engineroom(s) bring no restrictions to the location of the hold.

- **Engineroom on top of main-deck.** The hull is kept free for cargo-space. The engineroom is easy of access for the crew. However, the vertical center of gravity is negatively affected.

The alternative with an engineroom in the forward part of a ship is most commonly used. If possible, it is favorable to use a conventional engine installation. That is, when it is not too disadvantageous for the cargo-hold.
SHAPE OF HOLD

The cargo hold has to fit in the shape of the hull. Variations in shape of the hold that are thought of:

- Long and flat versus short and deep
- Wide and flat versus narrow and deep
- Long and narrow versus short and wide

Figure 7.1 Variations in shape of the cargo hold

Benefits of a long and flat hold:

- Cargo evenly divided over the length of the ship, so a level distribution of forces.
- Little shifts of rails have to take place, so a small number of discontinuities in the process of loading and discharging.
- The vertical construction members can be kept light, because the unsupported span is relatively low.
- Perhaps a conventional engineroom can be placed below the tanktop.
Benefits of a short and deep hold:

- Large ballast capacity in the front and stern of the ship.
- Uncomplicated construction of the vessel by omitting the tanktop.
- Sufficient space in the stern for a conventional engineroom.
- Good stability, as the vertical center of gravity of the cargo is relatively low.
- Entirely box-shaped hold.
- The RoWs are situated in an area of the ship with relatively low accelerations that are due to shipmovements.

*Long and narrow versus short and wide:* By taking away one lane, the hold can be extended further over the length. On the other hand, by replacing the double sides for an extra lane, the hold will have to be shorter, but also containing more ROWs per metre length.

**ACCOMMODATION**

The accommodation can be placed in every location on the ship, with as extreme situations the deckhouse at the stern and deckhouse in the front of the vessel.

Benefits of accommodation on the stern:

- Higher comfort for the crew. The accelerations at the stern are low, compared to the bow.
- Better view over the ship from the wheelhouse, especially while manoeuvring.
- The accommodation is close to the engineroom. In case of emergencies, the engineer needs little time to get to the engine room.

Benefits of accommodation in front:

- The flow of the RoWs is not affected by the accommodation, nor does the accommodation have to be placed on top of the rails for transshipment with a complicated construction.
- The accommodation can be kept light, by integrating it with the hold.
- The longitudinal center of gravity is positively influenced.
CARGO ENTRANCE

Variations can be made of the location, where the ROWs enter the ship. Main groups are:

- Cargo entrance through the stern, by use of a small ramp, consisting of rails. This is the most obvious alternative, the way most RoRo-vessels operate.

- Cargo entrance over the bow. A larger, more complex, ramp is required. However, with the conveyor in the front, the voluminous stern can be optimally utilized.

- Cargo entrance over the side. Then, the ROW-carrier can moor alongside the quay. With a conveyor in the middle, the front and the stern of the ship can be utilized optimal as cargo space. However, the ROWs will have to be turned some 90 degrees. Or perhaps another configuration of the quay-side installation can be thought of. Another constraint is that the ship will need to be put in two different trim-situations, while loading. Loading the forward part of the hold requires trim to the front, and loading the after part trim to the stern. This means an undesirable time-consuming operation during the process of transshipment.

GENERATED VARIATIONS

A number of variations are obtained by fitting the hold into the lines drawing. Engine room and accommodation are placed in appropriate locations. The distance from base line to top of hold is kept the same for all the alternatives, so that the available capacity for ROWs, the most important decision parameter, can be weighed for each configuration. This capacity is measured in tons, by multiplying the available volume by the specific weight of high-volume ROWs. The maximum cargo capacity should be reached, when the hold is entirely filled with ROWs with a weight of 70% of the optimal ROWs, that have a diameter of 1040mm, while the required cargo-space per ROW remains the same.

\[
\begin{align*}
\text{Weight optimal ROW:} & \quad = 1,52 \ t \\
\text{Weight volume ROW:} & \quad 0,7 \times 1,52 = 1,07 \ t
\end{align*}
\]

Thus, when entirely loaded with ‘optimal’ ROWs, the hold will only be filled for 70%.

By producing a large number of different options, new ideas might come up. In the following, each alternative will briefly be discussed.
Alternative 1

Cargo capacity 3360 t

The initial configuration. A hold of five lanes wide, with a conventional engine room behind the cargo hold. Accommodation is in the after part of the ship. The ROWs are loaded over the stern. Rails on top of the maindeck feed the conveyor. The accommodation is situated above these rails.

The longitudinal shape of the hold differs from the box-shape that was the basic idea. The forward part is inclined, so that additional cargo-space is gained. The rails at every altitude are stretched to the maximum extend, so that the outside rails just fit into the hull. Needed space for framing is taken into account. Some 800 t of extra cargo capacity is gained this way.

The more complex shape of the hold does not make the planning of stowage substantially more difficult. Just the differences in length of the rails have to be taken into account.

Figure 7.2 General arrangement alternative 1
Alternative 2

Cargo capacity 3350 t

Objective of this idea is to make use of the voluminous stern. Therefore a high tanktop is required. This tanktop is taken as freeboard deck. The hold is placed on top of this deck, entirely above the waterline. It has a long and low shape.

The engineroom can be placed under the hold, so that the conventional engine configuration can be maintained. The deckhouse is placed in the front, so that the stern is made free for handling the ROWs.

With a center of gravity of the hold that is this high, problems with stability can be expected.

Figure 7.3 General arrangement alternative 2
Alternative 3

Cargo capacity

3500 t

Here, a diesel electric installation is installed. The hold can be made deeper. The engineroom is in the front of the ship. The hold is somewhat shorter than in the previous configuration. For propulsion unit, an 'Azipod' installation is used.

Figure 7.4 General arrangement alternative 3
Alternative 4

Cargo capacity 3550 t

An inclination of the hold in the stern makes it possible to use the volume in the stern to the maximum extent. This is possible by putting the conveyor in the front of the hold. The transshipment of the RoWs will have to take place over the bow. The forward of the ship cannot be used as cargo-hold for the front of the hold needs to be vertical, because of the conveyor. Distance between conveyor and ramp will be quite large. Because of the shape of the bow, a large ramp will be needed to be able to feed the outside lanes of the hold as well.

In the front is sufficient space to fit the engineroom in. The accommodation is situated on top of the transshipment rails.

Figure 7.5 General arrangement alternative 4
Alternative 5

Cargo capacity 4040 t

The hold can be enlarged even further by an inclined conveyor. Then, every rail can be extended to its maximum length within the hull. The following points of discussion are thought of:

- An inclined conveyor would have to take smaller forces when taking up, or putting down a RoW. The acceleration of a RoW will be more gradually.

- The construction of hold and conveyor will be more complicated and heavier, compared to the vertical conveyor.

Figure 7.6 General arrangement alternative 5
Alternative 6

Cargo capacity 4660 t

A second conveyor is placed in front of the engineroom. The hold can be made both deep and extended into the stern. The second conveyor makes transshipment more complex, but a very large cargo-hold is derived. A conventional engineroom fits into the remaining space in the afterbody. The accommodation is placed as far to the front as possible to compensate the trim.

Apparently, discontinuities in the hold give problems of stowage. Except for the front, where the length of each pair of rails can be changed independently.

Figure 7.7 General arrangement alternative 6
Alternative 7

Cargo Capacity

3010 t

The option of a very narrow hold is examined. The hold is only 4 lanes wide. The side-view of the hold in the vessel gives an attractive picture. The hold occupies a large part of the available area. However, leaving out an entire lane gives a too large reduction in cargo capacity. Therefore, total cargo capacity is very low.

The center of gravity of the hold is situated quite far to the front. For compensation, accommodation is at the stern.

Figure 7.8 General arrangement alternative 7
Alternative 8

Cargo capacity 3800 t

If the narrow hold gives such a bad cargo capacity, what opportunities would a very broad hold bring? Possibly, the opposite shape of the hold will also have a cargo capacity that is on the opposite side, in this case relatively large.

The hold is 6 lanes wide, so that it just fits in the hull. No space is left for double sides. The rails for transshipment wig cover the entire upper deck of the vessel. This will give some problems with the funnel. Exhaust gas pipes will require a minimum of about one metre space in the sides. It is a constraint that can probably be overcome. But the danger is to come to a makeshift solution.

The cargo capacity of this small, wide, hold is quite high indeed, especially compared to the previous idea.

Figure 7.9 General arrangement alternative 8
Alternative 9

Cargo Capacity 4400 t

The two previous alternatives are combined into one hull. The four lanes wide hold of alternative 7 is accompanied by two outer lanes, named 'wing-lanes', that have the same shape as the lanes of alternative 8.

Actually, each lane can be shaped independent from the others. So, the differences in length and height of the lanes does not make the stowage much more complex. This brings much more freedom to the shape of the hold.
Alternative 10

Cargo capacity 3800 t

The various lanes can be made different from each other even further. Up till now it was assumed that the conveyors are connected in parallel, all conveyors driven by the same shaft. If the conveyors are separated, there are no restrictions to vary the extension of the hold to the stern for each lane.

In this alternative, the bottom of the hold is kept at equal altitude. The hold consists of five lanes, each with a different shape. The engineroom under the hold and the accommodation in the front, for compensation of the trim, and to keep the stern free for the internal transport of the ROWs.

Figure 7.11 General arrangement alternative 10
Alternative 11

Cargo capacity 3620 t

The in parallel connected conveyors are preferred, because of the simplicity of the system. The hold is five lanes wide, and the wingtanks are less deep than the rest. The engineroom is placed half in a gondola under the stern, half under the hold. Accommodation is in the front.

Figure 7.12 General arrangement alternative 11
Alternative 12

Cargo capacity 3560 t

Similar principal idea as alternative 11, though some small changes are made.

- the bottom of the middle lanes is levelled with the wing-lanes. This gives a more simple construction, while the loss of cargo space is very small.
- A middle-speed engine can be placed entirely inside of the hull, under the cargo space. The location of the engine requires a longer shaft, but also difficulties with the trim are overcome by doing so.
- The following dimensions belong to this alternative:

\[
\begin{align*}
H_{\text{tank top}} & = 4.8 \text{ m} \\
H_{\text{freeboard deck}} & = 11 \text{ m} \\
H_{\text{top hold}} & = 14.2 \text{ m}
\end{align*}
\]

Figure 7.13 General arrangement alternative 12
THE INNOVATION PROCESS

By producing a lot of different concepts, the designer gets to know the problem better. The different concepts should be generated really fast. This way, the field of view is not restricted by judgements. New ideas or insights are obtained just by following a natural order of design. During the process of thinking out an alternative, new ideas come up, that form the foundation for the next idea, etc.

In this case, the 'suspended judgement' is kept, not excluding any alternative. But possible constraints and/or benefits are jotted down, because the next alternative is, at least partly, based upon these.

This 'creativity method' is experienced as very effective in an innovation process that is in a further stage of progress, where the field of view is deliberately narrowed by focusing on one idea. Within the workspace, the field of view, the borders are explored, which brings useful new ideas.

SELECTION OF THE SHIP CONFIGURATION

At first, alternative 11 was selected to continue with. But the unlogical location of the engine room and the small difference in height between the lanes triggered concept 12. This is the alternative that is continued with. The main dimensions of the RoW-carrier are:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{bp})</td>
<td>97.40 m</td>
</tr>
<tr>
<td>B</td>
<td>16.60 m</td>
</tr>
<tr>
<td>T</td>
<td>6.10 m</td>
</tr>
<tr>
<td>(C_b)</td>
<td>0.62</td>
</tr>
<tr>
<td>Cargo Cap(_{weight\ RoW})</td>
<td>3620 t</td>
</tr>
<tr>
<td>Cargo Cap(_{Vol.\ RoW})</td>
<td>3560 t</td>
</tr>
<tr>
<td>(V_s)</td>
<td>16.5 kn</td>
</tr>
</tbody>
</table>

Factors that played a part in the selection of the ship configuration:

- The benefits of the stowage of a long hold.
- The hold has sufficient volume, while the vertical center of gravity is acceptable.
- Spaces in the front and stern are large enough to maintain the large ballast tanks needed for transshipment.
- A conventional engine room with a medium speed engine is relatively cheap, and operation costs are low.
Additional features of the selected ROW-carrier:

- The free height above the engine is kept low, for a hatch can be placed in the tanktop, which is opened when cylinders need to be removed.
- The rails that take care of the ramp-conveyor connection are placed high, to provide a safety margin for the distance to the waterlevel, when the ship is being discharged. Then the vessel is trimmed to the stern. The mooring equipment in the stern is placed on top of the main-deck, below the rails for transshipment.

**WEIGHT CALCULATION OF THE SHIP**

The weight and the vertical center of gravity of the light ship are calculated, as they are needed for the calculation of the stability and required draught. The steelweight is an important parameter for the calculation of the building costs. In the following a rough estimate is made, sufficient as an initial value for the refinement of the design.

A sub-division is made:

\[
W_{\text{light ship}} = W_{\text{hull}} + W_{\text{engine room}} + W_{\text{constr. hold}} + W_{\text{accommodation}}
\]

\[W_{\text{hull}}\]

The steelweight is derived using the method of Schneekluth for the steelweight of containerships. The ROW-carrier is also a cellular ship, though the loading takes place horizontal, instead of vertical for the containers. But the results will be of a similar order of magnitude.

The steelweight is calculated by use of a standard formula, with a dependency of the steelweight to the displacement volume for the height to maindeck. The outcome is then corrected by coefficients that take care of the various aspects that influence the steelweight.

The maindeck is assumed to be at a height of 12.2 m.

\[W_{\text{hull}} = 1430 \ t\]

A formula for estimation of the position of the vertical center of gravity is also given.

\[K_{\text{hull}} = 5.93 \ m\]
Design of the RoW carrier

\[ W_{\text{engine room}} \]

The weight of main engine and gearbox are found by selecting suitable alternatives, and looking up the weight in catalogues. The remaining part is approximated by formulas of estimation.

- Main engine (Wärtsilä Vasa 12V32): 43 t
- Gearbox: 5 t
- Shaft: 36 t
- Propeller: 1 t
- Generator sets: 36 t
- Remainder (pipes, etc.): 250 t + 337 t

\[ KG_{\text{engine room}} = 2.5 \text{ m} \]

\[ W_{\text{hold interior}} \]

The determination of the weight of the hold interior, the structural members and rails, is based upon the initial configuration, alternative 1. The weight of different alternatives will be of the same order of magnitude.

- Average length of hold: 70 m
- Specific weight hold interior: 8.5 t/m
- \[ W_{\text{hold interior}} = 595 \text{ t} \]

The height of the center of gravity differs for each alternative. For the selected nr.12, this height is calculated:

\[ KG_{\text{hold interior}} = 9.5 \text{ m} \]

\[ W_{\text{equipment}} \]

This consists of the mooring equipment and the cargo handling material. An estimation formula is used, which assumes a dependency between weight of the equipment and length*breadth.

- \[ W_{\text{equipment}} = 320 \text{ t} \]

The height of the center of gravity is somewhat above the main-deck, for most of the machines are placed here. The height is reduced by the conveyor, which has a lower center of gravity, for it reaches down to the tanktop.

\[ KG_{\text{equipment}} = 11.4 \text{ m} \]
W_{accommodation}

The area of the accommodation is assumed to be equal to that of the ‘Forte’:

\[
\begin{align*}
A_{accommodation} &= 250 \, m^2 \\
A_{wheelhouse} &= 50 \, m^2
\end{align*}
\]

Specific weights:

\[
\begin{align*}
W_{accommodation} &= 55 \, kg/m^3 \\
W_{wheelhouse} &= 45 \, kg/m^3
\end{align*}
\]

Height of floors in deckhouse = 2.6 m

\[
W_{deckhouse} = (0.055 \times 250 + 0.045 \times 50) \times 2.6 = 40 \, t
\]

The height of the center of gravity of a deck is situated at about 80% of the height of the deck. So, if the height of the decks is 2.6 m, their center of gravity is at 2.1 m.

\[
K_G_{deckhouse} = 17.7 \, m
\]

W_{light\ ship}

So, the total weight of the ship, without cargo or stores, is:

\[
\begin{align*}
W_{light} &= 1430 \, t \\
W_{engineerroom} &= 337 \, t \\
W_{constr.\ hold} &= 595 \, t \\
W_{equipment} &= 320 \, t \\
W_{accommodation} &= 40 \, t + \\
W_{LIGHT\ SHIP} &= 2722 \, t
\end{align*}
\]

The metacenter height and other hydrostatic values are calculated for this configuration.

- Draught appears to be 6.4 m.
- Transverse metacenter height is 0.36 m. This is just enough, for a minimum of 0.35 m is required.
- Trim is 0°, when fully loaded. By small variations in the longitudinal position of the engineroom, this level trim is obtained.

In the next chapter, a closer look will be given to the ship’s stability.
TANK CAPACITY AND TRIM

TRIM-CAPACITY

For the loading and discharging of the ROWs, quite a large trim has to be given to the ship. For this, large ballast-tanks are required in front and stern. The required trim-angle of the rails is assumed to be 2,5°.

The ballast tanks for trim to the front are placed in front of the wing-lanes. In the stern, behind the chain conveyor, sufficient space is available for the ballast tanks that provide the trim to the stern, when discharging.

TANKS AND HOLD

The hull is filled by the hold, the various tanks, and other needed spaces, by using the chart of the frame area of the vessel. Only the end situations are given. The tanks are decided upon by an interactive process of correcting and re-calculating. In an iterative way the final solutions are found, taking into account the needed volume, trim and stability.

Figure 7.14 shows a longitudinal cross-section of the RoW-carrier. The 'negative' bow of the vessel has merely a cosmetic purpose. Kvaerner Masa Yards Technology has developed a fast ship with a pronounced negative bow, as is shown in figure 6.9 and 6.10. To make the connection with this Euro-Express vessel, the RoW-carrier was also given a negative bow. However, the RoW-carrier is not a high speed ship. Therefore the bow was given only a small negative inclination.

Figure 7.15 shows the chart of frame area.

WATERBALLAST

For trim to stern

Ballast tank 5 is intended for this purpose.

\[
\begin{align*}
\text{Volume} & = 1133 + 114 & = 1360 \quad m^3 \\
\text{Permeability} & = 0.85 \\
\text{Specific weight seawater} & = 1.024 \\
\text{Ballast capacity} & = 1360 \times 0.85 \times 1.024 & = 1085 \quad t
\end{align*}
\]
Figure 7.15 Longitudinal cross-section of the RoW carrier
For trim to front

This volume is split into 3 tanks:

Ballasttank 1 In front of the collision bulkhead

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>175 m³</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.80</td>
</tr>
<tr>
<td>Specific weight seawater</td>
<td>1.024 t/m³</td>
</tr>
<tr>
<td>Ballast capacity</td>
<td>100 t</td>
</tr>
</tbody>
</table>

Ballasttank 2 Below tanktop

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>550 m³</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.80</td>
</tr>
<tr>
<td>Specific weight seawater</td>
<td>1.024 t/m³</td>
</tr>
<tr>
<td>Ballast capacity</td>
<td>450 t</td>
</tr>
</tbody>
</table>

Ballasttank 3 In front of the wing lanes under the maindeck.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>1010 m³</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.80</td>
</tr>
<tr>
<td>Specific weight seawater</td>
<td>1.024 t/m³</td>
</tr>
<tr>
<td>Ballast capacity</td>
<td>830 t</td>
</tr>
</tbody>
</table>

Total ballast capacity for trim for loading:

\[ 100 + 450 + 830 = 1380 \text{ t} \]

For volume ROWs

If the hold is entirely filled with volume ROWs, waterballast is needed in the tanktop to come to an acceptable GM. For this tank a tank is placed in the remaining void space, ballasttank 4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballast capacity tank 4</td>
<td>320 t</td>
</tr>
</tbody>
</table>
STORES

Stores are dimensioned so, that once every two roundtrips new supplies have to be taken in.

Fuel

Tanks for fuel and diesel oil are situated as close as possible to the consuming machines, so close to the engine room.

\[
\begin{array}{ll}
\text{Needed fuel per roundtrip} & 82 \ t \\
\text{Needed fuel capacity} & 165 \ t \\
\text{Volume of tank} & 240 \ m^3 \\
\text{Permeability} & 0,95 \\
\text{Specific weight fuel oil} & 0,95 \ t/m^3 \\
\text{Fuel capacity} & 190 \ t \\
\end{array}
\]

Diesel oil

For the generators required diesel oil per roundtrip: 25 \ t

\[
\begin{array}{ll}
\text{Needed diesel capacity} & 50 \ t \\
\text{Volume of tank} & 70 \ m^3 \\
\text{Permeability} & 0,75 \\
\text{Specific weight diesel oil} & 0,95 \ t/m^3 \\
\text{Diesel capacity} & 50 \ t \\
\end{array}
\]

Fresh water

The fresh water tanks are placed close to the accommodation. Required amount per roundtrip of fresh water and drinking water is 43 \ t.

\[
\begin{array}{ll}
\text{Needed fresh water capacity} & 85 \ t \\
\text{Volume of tank} & 140 \ m^3 \\
\text{Permeability} & 0,85 \\
\text{Specific weight fresh water} & 1,00 \ t/m^3 \\
\text{Fresh water capacity} & 110 \ t \\
\end{array}
\]

The required volumes and the volumes of the tanks do not match totally. If the volume of the tank is slightly too large, this is accepted. A too small volume is corrected.
INNOVATION  in forest products shipping

STABILITY AND TRIM FOR VARIOUS SITUATIONS.

Now, with the material about the weights of ship and its contents, a stability and trim calculation can be made. Use is made of the hydrostatic curves of the vessel.

Minimal requirements:

- GM in seagoing situation > 0.35 m
- GM in harbour > 0.00 m
- Needed trim-angle for transshipment > 2.5°

Figure 7.16 Hydrostatic curves of RoW carrier
HOLD LOADED WITH VOLUME ROWS, SEAGOING CONDITION

If the cargo consists of volume ROWs, the vessel does not reach its maximum deadweight, while the hold is fully loaded. The height of the center of gravity of the cargo is maximal. The stability of the vessel is just too little to meet the requirements (GM > 0.35m). To compensate this, waterballast is placed in the tank in the double bottom that is intended for that purpose.

| Draught | 6.4 m |
| GM      | 0.36 m |
| Trim angle | 0.0° (Trim to stern is pos.) |
| Waterballast | 225 t |

LOADED WITH VOLUME ROWS, BALLAST FOR DISCHARGING

The situation when the ROW-carrier just started discharging.

| Draught | 7.0 m |
| CG cargo | 9.6 m |
| GM      | 0.04 m |
| Trim angle | -2.5 (Trim to stern is pos.) |
| Waterballast | 1085 t |

The margin of the metacentre height is very little, it meets the requirements, but it is probably not sufficient to cope with extreme situations. In a next stage of design, this should be looked at more closely.
EMPTY HOLD, SEAGOING CONDITION

This is the situation the ship is in for the return-voyage. The draught at the stern must be sufficient to keep the propeller submerged. A small trim angle to the stern is accepted.

<table>
<thead>
<tr>
<th>Draught</th>
<th>4.2 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>4.12 m</td>
</tr>
<tr>
<td>Trim angle</td>
<td>0.4°</td>
</tr>
<tr>
<td>Waterballast</td>
<td>600 t</td>
</tr>
</tbody>
</table>

EMPTY HOLD, TRIM FOR LOADING

A large amount of water is needed to get to the required trim-angle, for the levers of tank 2,3 and 4 are relatively small.

<table>
<thead>
<tr>
<th>Draught</th>
<th>4.9 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>2.74 m</td>
</tr>
<tr>
<td>Trim angle</td>
<td>-2.7°</td>
</tr>
<tr>
<td>Waterballast</td>
<td>1605 t</td>
</tr>
</tbody>
</table>
EMPTY HOLD, TRIM FOR DISCHARGING.

At the end of the process of discharging, no ballast is needed to give a sufficient trim angle, because of the backward location of the center of gravity of the light shipweight.

| Draught | 3.8 m |
| GM      | 2.27 m |
| Trim angle | 2.6° (Trim to stern is pos.) |
| Waterballast | 0 t (Ballast tanks empty) |

LOADED WITH WEIGHT ROWS, SEAGOING CONDITION.

In this situation, the hold is filled for 70% to reach the maximum cargo capacity. The center of gravity of the hold is decreased, for the uppermost rails remain empty. No ballast is needed, for the trim angle is very small and the Gm is of a sufficient magnitude.

| Draught | 6.3 m |
| GM      | 0.86 m |
| Trim angle | 0.2° (Trim to stern is pos.) |
| Waterballast | 0 t (Ballast tanks empty) |
GENERAL ARRANGEMENT

Figures 7.23 and 7.24 show the general arrangement of the RoW carrier.
Figure 7.23 Side- and topview
Figure 7.24 Frontview and cross-section
8 EVALUATION OF THE ROW-CONCEPT AND THE INNOVATION PROCESS

REELS ON WHEELS COMPARED TO CONTEMPORARY SYSTEM

An evaluation of the RoW-system is made, by relating its costs and benefits to those of a StoRo-system, the most common system in Forest Products logistics of today. It is not the intention to come to a specific determination of the costs. By estimating percentages of reduction or increase of costs of the various components of the service, a first indication is derived. The comparison is made for an ongoing RoW-system, so the start-up costs of the service are not taken into account.

The RoW-idea brings benefits over the entire logistical chain. Capital costs are cut back because the time the paper is in the logistical chain is reduced. The costs of the inland transport in Western Europe are reduced by use of cheap river barges. Distribution by lorries takes place from the centre of the consuming industry. And transshipment costs are reduced by, among others, the elimination of stevedore-labour. An overall reduction in costs of about 50% is expected.

![Figure 8.1 Est. reduction of logistical costs of the entire chain](image)

Just the parts of the chain in which this ROW-carrier is involved are worked out into more detail. Therefore only transshipment costs and the cost of sea transport are evaluated. The other components of the logistical chain are too little specified to base an evaluation on.
INNOVATION in forest products shipping

The sub-divisions that are influenced by the new system are listed:

Transshipment:
- Labour
- Equipment
- Warehousing
- Quay-charges

Service:
- Needed deadweight capacity
- Special features of vessel

LABOUR

Transshipment time of a StoRo ship of comparable size is usually about two shifts, 16 hours. A gang consists of 8 persons, 6 drivers of clamp-trucks and tug-masters and 2 supervisors, one in the hold and one in the warehouse. Apart from that, the administrative part of transshipment also takes labour, assume in total one tallyman is needed for this. So, the needed labour for the transshipment of one vessel is:

Total labour hours: \((8 + 1) \times 16 = 144\) h/shipload

The loading/discharging of the lorries takes a full daytime job for two clamptruck drivers and one supervisor.

Total labour hours: \(3 \times 40 = 120\) h/week

With \(7/2.5 = 2.8\) shipments a week, the needed labour is:

Labour per week: \(2.8 \times 144 + 120 = 520\) h/week

If the transshipment cannot be completed in the two shifts, expensive overtime has to be paid for, or the ship has to stay overnight, which upsets the schedule.

The RoW-system is a lot less labour-intensive. One man is needed for the control of the flow of RoWs leaving or entering the warehouse. Because it is just a control function, this person can take care of transshipment of the lorries and the vessel. Similar to the contemporary system, one tallyman is needed. One additional labourer is required for the control of the flow of RoWs during night-time.

Labour per week: \(3 \times 40 = 120\) h/week
If the crew of the RoW-carrier takes care of the control of transshipment, this process becomes independent from land-side activities. This way there is no need for overtime work. By one push on a button, the process of transshipment, which sequence is previously determined, is activated. Then, just one watch is needed to see if everything goes right. By optimizing the shifts, more reductions in labour might be possible.

The needed labour for stevedoring is only 23% (120/520 *100) of the current demand.

EQUIPMENT

For transshipment two clamp-trucks in the hold and two in the warehouse are needed. Two tug-masters move some six trailers from warehouse to ship and vice versa. If a side-loader is used, two extra clamp-trucks are needed to feed the side lift. The loading/discharging of the lorries is also taken care of by two clamp-trucks.

The RoW-system just uses two chain-conveyors. Their mechanic aspects are very uncomplicated, so the maintenance costs will be very low, compared to the maintenance of the current fleet of clamp-trucks and tugmasters. Assumed is that the costs for equipment will be reduced by 70%.

WAREHOUSE

The warehouse of the RoW-system will be more expensive, due to the more complicated construction. However, the special requirements for the floor-surface of the current warehouse reduce the difference. The floor of the conventional warehouse needs to be absolutely flat and clean to prevent the reels from being damaged. An educated guess is that the RoW-warehouse will be some 30% more expensive.

QUAY-CHARGES

Because the RoW-carrier stays in the harbour for a significantly smaller period of time, the costs of occupying the quay will be lower. In a previous chapter a quay-time of one hour is determined. For this might be somewhat too optimistic, a quay-time of 2 hours is taken into account.

Minimum quay-time for the Storo ship is 16 hours, two shifts.

The quay-time is reduced by 87%. The quay-charges will be reduced by an amount according to that.
NEEDED DEADWEIGHT CAPACITY

Because of the short harbour-times, more time is left for sailing. So, the RoW-carrier can be smaller than a Storo ship in the same service. Or, a RoW-carrier with a cargo capacity that is equal to the Storo vessel can have a smaller service speed to meet the demand of annual transport capacity.

For the Rauma-Rotterdam line, the service speed of the Storo would have to be 21 knots, while the RoW-carrier could perform the same service with a speed of just 16 knots. This would give large savings in fuel costs.

SPECIAL FEATURES OF THE VESSEL

The RoW-vessel will be more expensive because of the ship’s interior. Some insight in the amount can be gained by comparing the differences in steelweight. The extra steelweight that is needed gives a good indication of the extra costs of the ship.

ROW-carrier:

\[
\begin{align*}
W_{\text{hold interior}} & = 595 \text{ t} \\
W_{\text{shell}} & = 1430 \text{ t} \\
W_{\text{steel}} & = 2025 \text{ t}
\end{align*}
\]

Storo-vessel

instead of the rails and longitudinal bulkheads, the Storo vessel needs to have two RoRo decks, which have a specific weight of about 0,3 t/m². Select the hold dimensions of the ‘Forte:

\[
\begin{align*}
A_{\text{roon deck}} & = 525 \text{ m}^2 \\
A_{\text{tanktop}} & = 450 \text{ m}^2 \\
W_{\text{decks}} & = 290 \text{ t} \\
W_{\text{shell}} & = 1430 \text{ t} \\
W_{\text{steel}} & = 1720 \text{ t}
\end{align*}
\]

The steelweight of the RoW-carrier is 120% of the steelweight of the Storo vessel. About half the costs of the vessel are determined by the steelweight, which implicates a ship with 10% higher building costs.
ESTIMATED COST-REDUCTION

It is very hard to give a calculated overall cost-estimation. A rough estimate is given for the transshipment. For the sea-leg, no estimation is made, for it is too uncertain what the costs will turn out to be.

For the transporter, transshipment costs in Rotterdam at the moment are on a level of about fl 35,- per ton. By introducing the RoW-system, this can be reduced to about fl 12,50 per ton. In Finland, the transshipment costs will be decreased by an even larger percentage, for there labour costs are a more dominating factor.
EVALUATION OF INNOVATION PROCESS

At the end of the first phase of the study, a view was made on how the innovation process should look like. This schedule was not followed very closely, for in a creative process it is not wise to follow a predetermined path too closely. Then, the possibility of looking for better ways is taken away. It will be of interest to notice the differences in the planned and the actual second part of the innovation process.

At the begin of the second phase, a more detailed strategy was made for the elaboration. The bottleneck analysis and the part of solving the bottlenecks were postponed. The bottleneck analysis was transformed from a specified block-function in the process into a 'notebook'-function. When a bottleneck appeared it was noted and then put aside, if not essential for the design process.

This way, the negative input that comes from the bottlenecks can be moved to a later part of the process, so that the innovation process is not affected in a negative way. However, if the bottleneck that is encountered blocks the continuation of the design-process, the bottleneck is directly taken care of. Such bottlenecks can trigger new ideas.

The smaller bottlenecks are noted. If an idea to overcome such a bottleneck arises, this is also recorded. Neither these minor bottlenecks, nor the generation of solutions are allowed to obstruct the main innovation process.

Figure 8.3 Initial view on the structure of an innovation process
PLANNED STRUCTURE OF THE PROCESS OF ELABORATION

The idea of the 'Reels on Wheels' is worked out further. At first a 2-dimensional view of the hold is optimized by producing a simulation program, to determine the optimal vertical spacing between the rails. Decision parameters of the simulation are the load-factor, vertical center of gravity and the number of reels that cannot be loaded. The dimensions of the supplied paper are generated by a randomized distribution of paperreels.

After the optimal 2-dimensional configuration is decided upon, the hold is given a third dimension. The 3-dimensional construction is looked at.

Then, the box-shaped hold needs to be put into a vessel. Thus, a hull is shaped so that the hold fits best. This vessel is elaborated further to meet the special demands, e.g. trim-ballast capacity, etc.

When the development of the ROW-carrier is completed the vessel is put into a service. The liner service is determined. This provides the basis for economic evaluation. Then, after the essential service is given sufficient shape, some important details are looked at, as well as the noted bottlenecks.

The project is concluded by an economic evaluation to weigh the benefits and disadvantages of the new system.
THE ACTUAL PROCESS

As mentioned earlier, the planned process is not followed. In fact, the real process turned out to be quite different. Instead of a process with divergent and convergent phases, it turned out to be more like succeeding creative and engineering phases feeding each other. The creative part is not the only phase from which new ideas are generated. The engineering part, in which calculations are made, brings deeper insight in the actual requirements. This way preconceived opinions are eliminated and the field of view is widened.

E.g. transversal stiffeners in the hold were expected to be needed to give the construction of the hold sufficient strength. Ideas were generated with this in mind. And these ideas did not turn out to be optimal. Rough calculations were made of the requirements in strength of the construction. A hold of the ROW-carrier without any transversal strengthening appeared to be feasible, which lead to a satisfactory solution. This time the calculating, engineering part was the originator of a new idea, followed up by a creative part to give the idea more shape.

This way of thinking is used a number of times, generating the idea and then diving into the calculations that apart from backing up the idea brings up new ideas as well.

Similar to the creative/engineering contradiction that is worked with to stimulate the process, also the perspective is changed all the time. Sometimes the perspective is wide, globally handling things. As the process gets stuck at this level, the perspective is lowered to let the process go more into detail. If the problem is solved, the level is raised again.

A couple of times, searching an expert opinion opened up new ways of thinking. If the process is in a deadlock, another person may have a different angle of perspective, which might bring new opportunities. And, the expert opinion gives a view on what is possible, so that the constraints can be adjusted.

In the first phase the process had a parallel (divergent/ convergent) character, firstly generating a number of independent solutions and then weighing those against each other. In the second phase most ideas were generated in a serial sequence, the constraints and benefits of the previous idea triggering the following idea.
Evaluation of the RoW concept and the innovation process

It appears that, if the direction is not decided upon yet, if the field of view is wide open, the divergent/convergent way is most applicable. This way the opportunity of the wide perspective is fully used, giving room to all possible ways to grasp the problem. In the second phase however, the perspective is deliberately narrowed, so that a small range of solutions can be elaborated to a sufficient extent. A serial approach, one idea following up on another, gives the best coverage of the small area.

As an example, an analogy illustrates this point:

A watch is lost and a group of people volunteers to go looking for it. If the watch was lost at a grassfield, e.g. during a game of soccer, the volunteers can give the best coverage over the field by drawing up in a line side by side. With relatively little walking metres per volunteer the whole field is embodied. But if the watch was lost in a narrow area, e.g. during an excursion in a mine or cave, and the watch can easily be overlooked because of the rough or muddy surface, a serial approach is more effective. For this way every piece of ground is looked at several times. If a piece of ground is neglected by the first person in the row, a number of people come behind him and will most probably cover this part as well. So the chances to find this watch are largest.

While looking for a solution to a problem is like looking for a lost gadget, the same methods are applicable, wide and superficial versus narrow and deep.

Especially the generation of the different vessel-alternatives is a good example, with each alternative introducing new ways of thinking, which is then used to create a new concept, and so on, until no new concepts can be thought of.

This serial method should only be used if the elaboration of the concept is in a far enough stage, for it brings a deliberately introduced ‘tunnel-vision’.

Figure 8.5 shows a flow-diagram of the actual innovation process, as it was experienced. The various parts of the diagram are briefly amplified.
Figure 8.5 The actual innovation process, as it was experienced.
Cross-section

The second phase was commenced with by the search for an optimal cross-section for the hold interior. Soon the idea came into mind of using the 'three rails per cell' option to come to more flexibility. With this idea in mind a lot of effort was put in building the simulation program. The supervising professor intervened, noticing the flaws of the alternative. More flexibility was required. When looking for this, the multiple rails idea was developed.

Details

A break was made in the cross-section part. First some details were worked out further, to gain more information about the various aspects that determine the cross-section.

Cross-section (continuation)

With this information in mind, it became possible to construct a hold with multiple rails, without the need for a transversal stiffener, splitting the hold in two horizontally.

Service

An estimation was made of a possible service the ROW-system could fill. It was born in mind that the investigated part of the logistical chain, the sea-transport and transshipment, is only a part of the total ROW-chain, as was described in the ROW-idea at the end of the intermediary report.

Hull

The main dimensions of the hull were found by weighing the contributions of ships for comparison, the NAPA-data set and the special demands the ROW-carrier requires.

Vessel

By putting the various components together alternatives for the configuration were generated with the, earlier mentioned, serial approach. So, the first configuration that passes the evaluation was accepted as the ROW-carrier.

Evaluation

The pro’s and cons of the ROW-system were briefly evaluated, with an emphasis on the economic aspects.

Loose ideas

During the entire process, loose ideas that were met with were noted. This list of ideas was used when the various vessel-alternatives were generated and for the final evaluation. Every idea bears some kind of value, if only that somebody else does not have to put effort in developing it all over again. It would be a waste of creative energy to neglect the ‘loose ideas’, if these are not directly applicable.
INNOVATION  in forest products shipping


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Innovation in forest products shipping

Shipping is one of the most innovative sectors in the economy, witnessing the multitude of new transportation- and ship concepts which have been developed over the last four decades. Supertankers, bulk carriers, containerships, chemical tankers, gas ships, roll-on/roll-off ships are just a few examples of the creative energy which is generated within the sector.

Some impulses for innovation are derived from technological innovations, but the majority comes from market forces. The shipowner or operator seeks new ways to provide a better quality service at a lower cost. This search for continuous improvements will never come to an end and can be stimulated by looking for opportunities to innovate in the transport chain, for example the forest products chain.

By looking at the total chain, in a holistic way, we have developed a possibly revolutionary new way of transporting paper reels: the Reels-on-Wheels system.

The innovation itself, as well as the process which led to its development are described in this book. Its purpose is therefore twofold:

* to demonstrate the potential of the ROW-innovation to reduce costs and improve the quality in the total logistical chain of paper reels;
* to provide an innovation guideline for those involved in developing new transport concepts, in the private sector as well as in university education.

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