WEGEMT ANNUAL CONFERENCE & FOURTH WORKSHOP

SHIPS FOR RIVER-SEA AND SHORTSEA SHIPING-
HINTERLAND TRANSPORTS WITH SHALLOWWATER EFFECTS

26. IX. 1997

INSTITUTE OF SHIP TECHNOLOGY
GERHARD-MERCATOR-UNIVERSITY
DUISBURG
WEGEMT
FOURTH WORKSHOP
Friday 26 September 1997

SHIPS FOR
RIVER-SEA AND
SHORTSEA SHIPPING
Hinterland Transports
with Shallow Water Effects

Proceedings

Hosted by
INSTITUTE OF SHIP TECHNOLOGY
DUISBURG (ISD)

Gerhard-Mercator-Universität
Gesamthochschule Duisburg
MANY THANKS TO THE SPONSORS
SHIPS FOR RIVER-SEA
AND
SHORT-SEA SHIPPING

Hinterland Transport with Shallow Water
Effects

Duisburg, Germany
26th September 1997

This workshop is jointly sponsored by:

- GERMANISCHER LLOYD
- Haeger & Schmidt
- HANIEL
- LEHNKERING
- LUX-Werft
- MAN Nutzfahrzeuge
- RS Partnership
- SCHOTTEL
PROGRAMME (update)

08:00 - 09:00 Registration
09:00 - 09:10 Welcome
Lady Mayor B Zieling, Prorector Professor H Luck
09:10 - 09:30 Simulation of Nonlinear Waves Generated by Fast Ships in Shallow Water
Dr-Ing T Jiang, Professor Dr-Ing S D Sharma (ISD - Institute of Ship Technology, Duisburg/D)
09:30 - 09:50 Ships for Extremely Shallow Water (VEBIS Project)
Dr-Ing H-G Zibell, Professor Dr-Ing E Müller (VBD - Duisburg Shipmodel Towing Tank, Duisburg/D)
09:50 - 10:10 From Road to River - Innovative Short Sea Shipping Concepts
PD Dr-Ing V Bertram, Dipl-Ing J Isensee (IfS - Institute of Ship Building, Hamburg/D)
10:10 - 10:34 Coffee
10:40 - 11:05 Investigation of the Hydrodynamics of a Manoeuvring Ship in Deep and Shallow Water
Professor A Inceck (Univ of Newcastle upon Tyne/UK)
11:05 - 11:30 Manoeuvring in Shallow Water - Criteria, Test Methods and Prediction
Dipl-Ing Th Guesnet, Dipl.-Ing. A Gronarz (VBD - Duisburg Shipmodel Towing Tank, Duisburg/D),
Manoeuvring in Shallow Water - Manoeuvring with Steerable Propulsion Systems
Dipl-Ing R Reuter (Schottel, Spay / D)
11:30 - 12:30 Lunch
12:30 - 13:00 Logistics and Telematics Promoting River-Sea and Shortsea Shipping
Dipl-Math F Arendt (ISL - Institute of Shipping Economics and Logistics Bremen / D)
13:00 - 13:30 River-Sea Shipping Between Duisburg and the Iberian Peninsula
Professor Dr P Engelkamp (EBD - European Development Centre for Inland Navigation Duisburg / D)
13:30 - 14:00 Tea
14:00 - 14:20 Improved Port-Ship Interface (The IPSI Project)
Professor J T Pedersen (Kværner, Lysaker / N)
14:20 - 14:40 DITrans: A Program for the Development of an Integrated System for Robotized Large Scale Container Transport
Professor dr ir J J M Evers (TU Delft / NL)
14:40 - 15:00 High Speed River-Sea Transport System
Dipl-Ing G Andersson (Blohm + Voss, Hamburg/D)
15:00 - 15:30 Open Forum
15:30 - 15:45 Tea
15:45 - 17:30 Excursion
Automatic Fast Handling Terminal, Duisburg
Dipl.-Ing. D Schrix (Krupp Fördertechnik / D)
17:30 - 19:00 Formal Reception in the Mercator Room, Town Hall
(Rathaus, Burgplatz 19) Lady Mayor B Zieling

The workshop has been scheduled to coincide with two international fairs that are being held in Duisburg between 24 – 27 September 1997.

BKB '97 - The Shipping Fair for Inland and Coastal Shipping.
The former events in 1993 and 1995 were regarded as a success by the participating companies and organisations because every area of the shipping world was represented.

LOGISTRA '97, An International Trade Fair for Logistics, Traffic and (Intermodal) Transportation
This fair will take place in parallel with BKB '97. A large number of companies from the transportation industry, including shipping companies and ports, will be represented.

OPEN HOUSE Saturday 27 September 1997
Workshop participants are also invited to visit the Institute of Ship Technology (ISD), the Duisburg Shipmodel Towing Tank (VBD) and the European Development Centre for Inland Navigation (EBD) on Saturday, 27 September 1997.
Purpose of the workshop

This workshop will take a broad view of technical possibilities in transport chains of short-sea shipping and river-sea through traffic. Special attention will be given to the effects of restricted water. Aimed particularly at those concerned with manoeuvring, loading and unloading ships, the workshop will include recent knowledge from effective operations in these areas.

Participants

The workshop has been designed for engineers, naval architects, ship operators and forwards employed in shipbuilding, shipping, shipping agencies, river and port authorities, classification societies, ship-model tanks and ship research establishments. It will also be of interest to maritime students at graduate and postgraduate levels.

Lecturers

Members of the teaching staff are experts from European marine industries, research organisations and universities, who are actively engaged in the field of river-sea and short-sea shipping. The lectures and workshop notes will be in English.

Venue

This fourth WEGEMT workshop will be hosted by the Gerhard Mercator University, Institute of Ship Technology, Duisburg (ISD). All lectures will take place in the following lecture hall:

Hörsaal MC 122
Gerhard-Mercator-Universität - GH Duisburg
Lotharstraße 1
Duisburg-Neudorf

Accommodation

You are advised to make your hotel arrangements early because of other events in Duisburg. To book a hotel through the workshop secretary please indicate your requirements on the registration form. Hotel charges are to be paid directly to the hotel.

Participants who register late should note that it may be difficult to obtain conveniently located hotels.

Single and double rooms are available at the following rates per night including breakfast:

<table>
<thead>
<tr>
<th>Letter</th>
<th>Hotel</th>
<th>Rate</th>
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<tbody>
<tr>
<td>A</td>
<td>Wolfsburg</td>
<td>50 - 90 DM</td>
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<tr>
<td>B</td>
<td>Rheinischer Hof</td>
<td>70 - 110 DM</td>
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<td>C</td>
<td>NOVOTEL</td>
<td>140 - 180 DM</td>
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<tr>
<td>D</td>
<td>Duisburger Hof</td>
<td>160 - 200 DM</td>
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</tbody>
</table>

(Prices are given as a guide only)
Fourth WEGEMT Workshop  
26 September 1997  
Duisburg, Germany

SHIPS FOR RIVER-SEA AND SHORT-SEA SHIPPING  
Hinterland Transport  
with Shallow Water Effects

Registration Form  
(Capital letters please)

Name:  
Title:  
Address:  
Company or Institution |
Phone:  
Fax:  
Email:  
Hotel Category:  
A □ B □ C □ D □  
Single Room □ Double Room □  
No. of Persons:  
Arrival Date:  
Departure Date:  

☐ Workshop fees: £80 (£60*)  
☐ 50% reduction for students

All course fees include course material, refreshments, lunch and excursion.

Cancellations received up to 5/9/97: 50% refund  
Cancellations received after 5/9/97: No refund

*Registration before 16 August 1997

☐ I have enclosed a cheque (in sterling) payable to WEGEMT.  
☐ I have arranged for payment to be made to: Royal Bank of Scotland,  
Drummonds Branch, 49 Charing Cross,  
London SW1X 2DX UK.  
Account name: WEGEMT.  
Account no. 00299127.  
Sort code: 16-00-38.

☐ My company is interested in a poster show

I accept the conditions concerning registration and cancellation

Date and Signature:

Out and About in Duisburg

Located in one of Europe's most important industrial regions, Duisburg has the largest inland harbour in the world and the Free Port of Duisburg offers facilities for duty-free import of goods. The complex of harbours and cargo terminals extends for 23 miles on either side of the river Rhine, and is referred to nowadays as "Rhein-Ruhr Hafen Duisburg".

The town also has a number of interesting museums. The Museum of German Inland Navigation is located in Duisburg-Ruhrort, and exhibits include "Oscar", a paddle-wheel steam tug built in 1922. The new Museum of Cultural and City History has taken up residence in a restored former grain factory. Here, visitors can see some of the original terrestrial and celestial globes as well as maps of the famous Gerhard Mercator. Born in 1512 in Rupelmonde near Antwerp of German parents, he moved in 1552 to Duisburg where he lived and worked until he died in 1594. He developed a new method of projecting the spherical surface of the earth on to a flat plane to produce a conventional two-dimensional map, especially suited for navigation. This so-called Mercator Projection is still used today by seafarers and aviators.

Other interesting places are the Lehmbruck Museum, a European centre of modern sculpture, and the 500-acre Wedau sports and leisure complex. The annual Duisburg Regatta is held at Wedau and attracts international canoeists and rowers. Duisburg also has a beautiful zoo, noted for dolphins, whales and Europe's largest collection of primates.

Founded in 1655, refounded in 1972 and renamed in 1994, the Mercator University Duisburg with its wide range of integrated degree courses has earned national and international acclaim. Last but not least, the Duisburg Shipmodel Towing Tank (VBD) specializing in shallow water hydrodynamics is well known in the marine field.

Registration

Please complete the registration form and send it to the workshop secretary at the address below. General enquiries should also be addressed to the workshop secretary:

Prof. Klaus W Wietasch  
Mercator University  
Institute of Ship Technology (ISD)  
D-47048 Duisburg  
Germany

Phone: +49 203 379 2779  
Fax: +49 203 379 2779  
e-mail: wietasch@nav.uni-duisburg.de
THE WEGEMT SCHOOLS, COLLOQUIA AND WORKSHOPS

24 Schools, 3 colloquia and 3 workshops have been organised since 1978 on a wide range of subjects. These were:

- Advanced Ship Design Techniques, 1978 (Newcastle upon Tyne)
- Advanced Aspects of Offshore Engineering, 1979 (Trondheim, Aachen, Wageningen)
- Managing Ship Production, 1980 (Strathclyde and Glasgow)
- Advanced Ship Power Plant Design and Operation, 1981 (Berlin and Trieste)
- Fishing Vessel Technology, 1982 (Madrid)
- Teaching Marine Technology in Europe, 1982, (Southampton)
- Winter Navigation, 1983 (Helsinki)
- Ship Design for Fuel Economy, 1983 (Gothenburg)
- Computers in Education in Marine Technology, 1984 (Hamburg)
- High Speed and Pleasure Craft 1985, (Genoa)
- Education and Training in Offshore Engineering, 1986 (Newcastle upon Tyne)
- Propulsion Systems, 1989 (London)
- Design Techniques for Advanced Marine Vehicles and High Speed Displacement Ships, 1989 (Delft)
- Design and Analysis of Slender Marine Structures - Risers and Pipelines, 1991 (Trondheim)
- Underwater Technology, 1991 (Helsinki)
- Noise, Vibration and Shock on Board Ships, 1992 (Genoa)
- Risk and Reliability in Marine Technology, 1993 (Lisbon)
- FRP Composite Materials and their Marine Applications, 1993 (Southampton)
- Numerical Simulation of Hydrodynamics: Ships and Offshore Structures, 1993 (Nantes)
- Fishing Vessel Technology, 1994 (Madrid)
- Ships for Coastal and Inland Waters - Design, Building, Operation, 1994 (Duisburg)
- Accidental Loadings on Marine Structures: Risk and Response, 1995 (Lyngby)
- Damage Stability of Ships, 1995 (Lyngby)
- Waves and Modelling the Marine Environment, 1996 (Edinburgh)
- Conceptual Designs of Fast Sea Transportation, 1996 (Glasgow)
- Surface Support for Subsea Task, 1997 (Glasgow)
- Full Scale Surveys of the Performances of Ships and Platforms, 1997 (Genoa)

WEGEMT publishes comprehensive notes from its Schools and Workshops as well as a Directory of European Teaching Staff in the marine sector; a regular Newsletter concerned with training matters is also published in London, Fax +44 171 838 9147
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<td>Conference Dinner:</td>
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<td>HANIEL Specher</td>
<td>RATHAUS, Burgplatz 19</td>
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<td>Franz Haniel Platz 1, Duisburg Ruhrt</td>
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Please watch venue codes with those on map

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Venue codes I - VIII
Participants

Ambs, Raymond, Dipl-Ing  Institute of Ship Technology Duisburg - ISD
Andersson, G, Dipl-Ing  Blohm + Voss, Hamburg
Andrews, D, Prof  University College London
Arendt, F, Dipl-Math  Institute of Shipping Economics and Logistics - ISL - Bremen
Benedek, Z, Dr  Technical University of Budapest
Billingham, J, Prof  Cranfield University
Boote, Dario, Prof  Universita di Genova
Boudry, Francis  RISS Transport, Dunkerque
Bruggen, van, P, Director  Marine Heavy Lift Partners, Rotterdam
Cordonnier, J-P, Dr  Ecole Centrale de Nantes
Demir, Ekrem, Student  Institute of Ship Technology Duisburg - ISD
Engelkamp, P, Prof Dr  European Development Centre for Inland Navigation - EBD - Duisburg
Engja, H, Prof  Norges Tekniske Hogskole, Trondheim
Evers, J J, Prof  TU Delft
Gassien, Dominique  Sollac Groupe USINOR, La Defense
Gerigk, M, Dr Eng  Technical University of Gdansk
Goldammer, E-H  Neuss
Goppelsröder, Martin, Prof  Zentrum für Musik und Kunst, Gerhard-Mercator-University Duisburg
Grant, Jim  Secretary General WEGEMT, London
Guedes-Soares, C, Prof  Universidade Técnica de Lisboa
Guesnet, Th, Dipl-Ing  Duisburg Shipmodel Towing Tank - VBD - Duisburg
Günter Corell  Duisburg
Haas, Alexander, Student  Institute of Ship Technology Duisburg - ISD
<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>Heimes, Steffen</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<tr>
<td>Henn, Rupert</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<tr>
<td>Hove, van, J</td>
<td>MLB Manfred Lauterjung, Emden</td>
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<td>Incecek, A, Prof</td>
<td>Univ of Newcastle upon Tyne</td>
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<td>Isensee, J, Dipl-Ing</td>
<td>Institute of Ship Building - IfS - Hamburg</td>
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<td>Jascanu, M, Prof Dr Ing</td>
<td>Rector Universitatea &quot;Dunarea De Jos&quot; Galati</td>
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<td>Jensen, J, Dr</td>
<td>Technical Uni of Denmark, Lyngby</td>
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<td>Jiang, T, Dr-Ing</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<td>Keil, H, Prof Dr-Ing</td>
<td>Institut für Schiffbau Hamburg</td>
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<td>King, J, Prof</td>
<td>University of Wales, Cardiff</td>
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<td>Kock, Boris, Student</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<td>Krauss, G R, Prof</td>
<td>Università degli Studi di Napoli</td>
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<td>Kruppa, C, Prof</td>
<td>Technische Universität Berlin</td>
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<td>Larsson, L, Prof</td>
<td>Chalmers University of Technology, Göteborg</td>
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<td>Lauterjung, M</td>
<td>Reederei M Lauterjung, Emden</td>
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<td>Lucas, K, Prof Dr-Ing</td>
<td>Gerhard-Mercator-University Duisburg</td>
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<td>Luck, H, Prof, Prorector</td>
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<td>Maestro, M, Prof Ing</td>
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<td>Meyer-König, T, Student</td>
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<td>Miyashita, Keiti</td>
<td>Kawasaki Heavy Ind., London</td>
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<td>Monerris, A M, Prof</td>
<td>Universidad Politécnica de Madrid</td>
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<td>Nguyen Duc, Hung Viet</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<td>Nikiforov, V, Prof</td>
<td>State University for Water Communications, St Petersburg</td>
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<td>Papanikolaou, A, Prof</td>
<td>Technical University of Athens, Zografos</td>
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<td>Pedersen, J T, Prof</td>
<td>Kvaerner, Oslo</td>
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<td>Pfeifer, Peter, Dipl-Ing</td>
<td>Institute of Ship Technology Duisburg - ISD</td>
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<td>Pinkster, Jo, Prof</td>
<td>Technische Universiteit Delft</td>
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Plunke, Bernd, Dipl-Ing
Psaltis, N
Reuter, R, Dipl-Ing
Rutgersson, O, Prof
Ruxton, T
Schädel, Ditmar, Dipl-Kulturpäd
Schädel, Josefine
Schauland, Jörg, Naval Architect
Schrix, D, Dipl-Ing
Shala, Daniela, Student
Sharma, S D, Prof Dr-Ing
Skogman, A, Naval Architect
Stokke, Tor, Naval Architect
Stuntz, Norbert, Dipl-Ing
Sutton, R, Dr
Thomzik, Ralf
Thorpe, Ian
Thorpe, Mrs.
Toxopeus, Serge, Consultant
Truijens, P, Prof
Valkhof, Henk, Senior Consultant
Varsta, P, Prof
Vassalos, D, Dr
Velthoven, van, J
Velthoven, van, junior
Wellicome, J, Dr

Institute of Ship Technology Duisburg - ISD
Athens
Schottel, Spay
Kungl Tekniska Högskolan, Stockholm
Liverpool John Moores University
Zentrum für Musik und Kunst, Gerhard-Mercator-University Duisburg
Duisburg
KSW Systems, Hamburg
Krupp Fördertechnik Essen
Institute of Ship Technology Duisburg - ISD
Institute of Ship Technology Duisburg - ISD
Aquamaster Rauma Ltd, Rauma
Kristiansand
Institute of Ship Technology Duisburg - ISD
University of Plymouth
Institute of Ship Technology Duisburg - ISD
University of Newcastle upon Tyne
Newcastle upon Tyne
MARIN, Wageningen
Universiteit Gent, Zwijnaarde
MARIN, Wageningen
Helsinki University of Technology, Espoo
University of Strathclyde, Glasgow
VECOMAR International, Rotterdam
VECOMAR International, Rotterdam
University of Southampton
Wendorff, J V, Dipl-Ing  Preussag AG, Hannover
Wiedemann, Renate  Zentrum für Musik und Kunst, Gerhard-Mercator-University Duisburg
Wietasch, K W, Prof Dipl-Ing  Institute of Ship Technology Duisburg - ISD
Wolfram, J, Prof  Heriot-Watt University, Edinburgh
Zibell, H-G, Dr-Ing  Duisburg Shipmodel Towing Tank - VBD - Duisburg
Zieling, B, Lady Major  City of Duisburg
Welcome

- Lady Major
- Prorector
- Dean
Welcome

Address by the Mayor of the City of Duisburg
Barbel Zieling on the occasion of the opening of the WEGEMT Workshop in Duisburg on 26 September 1997

Ladies and Gentlemen,

for several days you are experiencing our city entirely in the vein of traffic and logistics:

On our trade fair grounds at the Wedau Stadium both the European Fair for Inland Shipping, Coastal Shipping and Freight Traffic and the 'Logistra', the international Fair for Logistics, Transport and Traffic are taking place up to tomorrow, Saturday.

I hope you have already had the opportunity to visit them and possibly even time for one or two talks among experts.

At the same time the 4th WEGEMT Workshop, to which it is my pleasure to welcome you here in Duisburg, is dealing with the technical aspects and the new opportunities provided by transport chains in the area of shipping. This is definitely a particularly specialized topic, which at first glance is likely only to be interesting to specialists in shipping.

Yet, when one looks again, the potential and significance for Duisburg attached to events such as these become evident. However, let me return to this point later.

Ladies and gentlemen,

as a rule the appointments entered in the diary of a mayor bear testimony to and exemplify what is happening in a city, what is having an impact on the city in a particular month or year and the topics that are crucial to the city.

Even approaching the issue from this perspective the importance of traffic and logistics and the variety of related disciplines can hardly be rated highly enough in Duisburg. Indeed, these are the future topics for Duisburg.

Therefore, I am particularly delighted that our city is not only establishing itself as a location of economic activity in the traffic and logistics field but also as a centre of theoretical and scientific debate on issues relevant to logistics and related disciplines.

In a few weeks time, for instance, a further high-quality congress of the University of Duisburg will take place bearing the title 'Logistics and regional structural change'.

My special thanks are thus extended to the Gerhard Mercator University of Duisburg for its involvement in these disciplines which are so important for our city. In particular, however, I would like to thank WEGEMT which, as a European-wide association in the field of ship-building and marine technology, has opted for Duisburg to hold its first annual meeting in Germany, thus bringing specialists from all around Europe to our city.
It was from Duisburg that our city's great son, after whom our university has been named, Gerhard Mercator, rendered outstanding services to shipping and navigation as a cartographer and inventor of the 'Mercator Projection' four centuries ago.

Thus, in figurative terms it is 'historic territory' on which you find yourselves here in Duisburg, dealing with shipping issues from your respective scientific angles.

Let me just say one or two things about the history of our city. Especially due to its location at the point where the rivers Rhine and Ruhr meet, but also thanks to outstanding entrepreneurs such as Franz Haniel and Carl Lehnkering, Duisburg has a tradition as a centre of goods traffic and transshipment which goes back centuries. Both these personalities mentioned come from a time when entrepreneurs of their kind were still called 'Kaufleute' - merchants - or 'Kommerziensrat' - a title conferred on distinguished business people. The development of the city into one of the most important locations of the steel industry in Europe is based on its geographical situation. This situation also enabled the development of Duisburg's Rhine-Ruhr harbour into the largest inland port in the world.

We take up this tradition again when we embark on the ambitious task of developing Duisburg further into a traffic and logistics centre on the European scale. The further development of the location of Duisburg in this way is crucial, ladies and gentlemen, to ensure the successful management of the ongoing structural change in our city. Yet, that is not all.

Beside the importance in terms of the economy and locational policy of this economic sector to the city the opportunity arises not only to enhance the profile of the city as a centre for goods traffic flows of all kinds but also to provide the city with a new overall image.

Indeed Duisburg faces considerable image problems. Whilst its inhabitants rate the quality of life in the city highly, elsewhere Duisburg is still almost exclusively associated with heavy industry and its corresponding side effects such as considerable environmental problems.

Nowadays, however, it is evident that the importance of heavy industry has to be seen in relative terms. Therefore, to provide the city in the eyes of the outside world with a new image we hope for a new orientation from logistics.

In this vein Duisburg wishes to distinguish itself as a port city, as a city at the water's edge, as a cosmopolitan city. I cordially invite you to visit the harbour neighbourhood of Duisburg-Ruhrort or Duisburg's Inner Harbour, where the city's new face can already be experienced.

Against this background, I am sure that you, ladies and gentlemen, will understand how much I am delighted that you are here. The workshop will focus on issues concerned with the construction of ships that can operate both in coastal traffic and on inland waterways.

Since Duisburg is not only the largest inland port in the world but also the most western sea port in Germany, you are constructing - and please excuse this somewhat unscientific short-cut - the ships which are the harbingers of hope for this city and its economic development.

Thus, it is in the interests of Duisburg for you to go 'full steam ahead' and embark on your work as soon as possible. Consequently, I shall hurry to finish my welcome to you - as the mayor I have to keep an eye on the well-being of the city!

Ladies and gentlemen,

I extend a warm welcome to you in our city and wish you every success with the fourth WEGEMT workshop.

Thank you.
Preface

The Institute of Ship Technology Duisburg (ISD) has organised the 1997 WEGEMT Workshop entitled "SHIPS FOR RIVER-SEA AND SHORT-SEA SHIPPING - Hinterland Transport with Shallow-Water Effects", which is the fourth event of its kind. The workshop is being hosted by the Gerhard Mercator University of Duisburg and will be held on the university campus in lecture hall MC 122 on 26 September 1997.

The fourth WEGEMT Workshop is in response to:

- the rising global significance of river-sea and short-sea shipping within an integrated navigational network,

- the pan-frontier development of inland waterways to meet the needs of maritime vessels and

- the 25th anniversary of re-establishing the Gerhard Mercator University of Duisburg in 1972.

The WEGEMT Foundation Annual Conference is also being held as part of the workshop. This will make Duisburg the first German city to have hosted the conference since the foundation was set up in 1975.

Fourth WEGEMT Workshop

In 1994, the 21st WEGEMT School, which dealt with the topic of inland and coastal navigation, was held in Duisburg, the centre of German inland navigation. In contrast, this workshop will take a broader look at the technical options open to short-sea-shipping transport chains and river-sea traffic, under special consideration of restricted-water effects. As the workshop will chiefly address the topics of vessel manoeuvrability and loading/unloading, recent knowledge gained in these areas by successful vessel operation will be given particular attention.

The workshop is being sponsored by, among others, the City of Duisburg, the Gerhard Mercator University of Duisburg and various marine technology companies.
The teaching staff comprises European experts from the fields of marine industry and research as well as from universities, all of whom are actively involved with short-sea and river-sea shipping. While the majority of the teaching staff are German speakers, lectures and workshop notes will be in English.

Out and About in Duisburg

Duisburg's port can even boast an "Oscar", namely the 1922 paddle-wheel steam tug that now forms part of Duisburg's Museum of German Inland Navigation. Duisburg's harbour and cargo-terminal complex - whose official title is "Rhein-Ruhr Hafen Duisburg" - covers a stretch of 23 miles on either side of the Rhine. The Free Port of Duisburg, as the world's largest inland harbour, is situated in one of Europe's key industrial regions and provides complete facilities for the duty-free import of goods.

The originals of some of Mercator's famous terrestrial and celestial globes and maps are kept in Duisburg's Museum of Municipal and Cultural History, which recently moved to a fully restored former grain factory. Gerardus Mercator was born in Rupelmonde near Antwerp in 1512. His parents were German and moved to Duisburg in 1552. Mercator then went on to live and work in Duisburg until his death in 1594. He developed a new method of projecting the spherical surface of the earth onto a flat plane to produce a conventional two-dimensional map, especially suited for navigation. This so-called Mercator Projection is still used by seafarers and aviators today.

Other places of interest include the Lehnbruck Museum as a European centre of modern sculpture and the 500-acre Wedau sports-cum-leisure complex. The regatta course adjoining the athletics and football stadium deserves particular mention with regard to the latter, since the international canoeing and rowing competitions regularly attract large numbers of athletes from all over the world. Duisburg is also known for its flourishing and attractively landscaped zoo, whose special attractions include a marine mammal show with dolphins and whales as well as Europe's largest collection of primates.

Duisburg looks back on a chequered history from an academic point of view. The city's first university was founded in 1655 and later closed again in 1818. It was finally re-established in 1972 and was then re-named "Gerhard Mercator University of Duisburg" in 1994. The university has earned international acclaim on account of its high academic standard and its wide range of degree-course subjects. On a more specific note, it should also be mentioned that the VBD (Duisburg Ship-Model Testing Tank), a special institute for shallow-water hydrodynamics, has made a particular name for itself in the field of maritime research.

The supporting programme of the workshop will include the following highlights: a night-time boat ride along the Rhine and parts of the harbour, visits to the city of Duisburg, a formal reception in the Mercator room of the Civic Hall and a trip to the Haniel Museum on the history of industrialisation in the Ruhr District with regard to the shipping, mining, foundry and steel industries. Tours of the VBD and the EDB (European Development Centre of Inland Navigation) are also planned.
Participants

The ISD will take pleasure in welcoming over 60 participants from 18 nations to the workshop. This multi-national group will comprise representatives from the fields of engineering, naval architecture, ship operation, forwarding agencies involved with shipping, shipping agencies, river and port authorities, classification societies, ship-model tanks and ship research institutes. In addition, a number of both under- and postgraduate students of maritime technology will also be taking part.

WEGEMT Foundation

The WEGEMT Foundation is a European association of 37 universities spread across 17 countries. It was founded in 1975 with an original complement of 15 member universities from 10 European states. The aim of the foundation has always been to broaden the knowledge as well as update and enhance the skill and competence of engineers and postgraduate students performing advanced work in the areas of marine technology and related sciences. The field of marine technology is becoming an increasingly interdisciplinary science as it draws on a steadily growing number of different industrial sectors.

In pursuit of this aim, the Foundation encourages associated universities to

- operate as a network and actively collaborate in all related activities,

- participate in sophisticated joint research, education and training measures and

- exchange and disseminate relevant information.

Since 1978, 22 WEGEMT schools, three symposia and three workshops have been held on a wide range of subjects. The WEGEMT Office in London can provide information on the prices and availability of the written reports of the above events. Please send fax enquiries to: 0044 171 *** ****

Acknowledgements

The ISD wishes to thank:

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- the sponsors for their financial support,

- the lecturers for presenting their papers in Duisburg and

- the participants for their interest in Duisburg.
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Manoeuvring in Shallow Water - Criteria, Test Methods and Prediction
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Paper 1

Dr-Ing T Jiang
Prof Dr-Ing S D Sharma
Simulation of Nonlinear Waves Generated by Fast Ships in Shallow Water

Tao Jiang and Som Deo Sharma
Institute of Ship Technology
Mercator University, D-47048 Duisburg, Germany

Abstract

Based on nonlinear shallow-water wave-theory the wave generation by fast ships in shallow water was numerically investigated. In the transcritical speed range the Boussinesq type of shallow-water wave equations were applied using an implicit scheme; in the supercritical speed range, the Airy type of shallow-water wave equations using an explicit upwind and high-resolution scheme. An improved slender-body theory was used to approximate the influence of the hull form on the flow in the far field. Preliminary calculations for a ship and a pressure distribution showed that the waves at supercritical speeds are characterized by a steady shock-wave-like pattern; at transcritical speeds, by a Havelock-like wave pattern. A ship moving in a shallow-water channel may shed solitons at transcritical speed, implying an unsteady wave pattern relative to the ship. It was also shown that the wave resistance is much larger in the transcritical speed range than in the supercritical range.

1 Introduction

One significant aspect of the waves generated by fast ships in shallow water is their nonlinearity. A ship moving in a shallow water channel can even shed so-called solitary waves when the ship speed is near the critical speed, defined by water-depth Froude number \( F_{nh} = 1 \). These solitary waves travel a bit faster in front of the ship and cause oscillations of the ship. The wave pattern relative to the ship is then no more steady in spite of constant ship speed and uniform rectangular channel. These essentially nonlinear and unsteady phenomena were repeatedly observed in the towing tank long ago, e.g., by Thews and Landweber (1935), Helm (1940) and Graff et al. (1960). They have been also confirmed by recent experimental studies on ship wave generation in the Duisburg Shallow Water Towing Tank (VBD). Observing the photograph in Fig. 1 we can see that three solitary waves (perfectly transversal to the channel) have been generated by a series 60 hull moving at critical speed in the shallow-water tank within the available steady towing length of 150 m, demonstrating the unsteady nature of the wave pattern relative to the ship. Looking now at the photograph in Fig. 2, taken at a transcritical speed of \( F_{nh} = 1.2 \), we notice that these solitary waves can even break, indicating the essentially nonlinear nature of shallow-water waves.
Figure 1: Solitary waves generated by a Series 60 Hull at the critical speed $F_{\text{cr}} = 1$ in the VBD Towing Tank

Figure 2: Breaking solitary wave generated by a Series 60 Hull at a transcritical speed $F_{\text{rh}} = 1.2$ in the VBD Towing Tank
In the theoretical investigation of these nonlinear and unsteady phenomena in shallow-water channels, considerable success has been recently achieved, e.g., by Mei and Choi (1987), Choi and Mei (1989), and Chen and Sharma (1992). The basic tool of these theoretical analyses is the technique of matched asymptotic expansions, where the potential flow in the far field is approximated by a Kadomtsev-Petviashvili (KP) type of equation from the shallow-water wave-theory and the potential flow in the near field by the slender-body theory. In recent papers by Chen and Sharma (1992) and Jiang et al. (1995) it was shown that a modified Kadomtsev-Petviashvili (KP) equation based on the shallow-water-wave theory is even more effective in predicting the wave resistance and squat of a ship moving in a shallow-water channel, not only in the transcritical but also in the subcritical and supercritical speed range.

The present study concentrates on the new development of an efficient algorithm using more general shallow-water-wave equations, namely, the well-known Boussinesq equations. Unlike the KP equation, the Boussinesq equations are also valid for truly unsteady cases caused, for example, by hydrodynamic interactions between passing ships, by geographical changes of the water bottom, by ambient waves near a coast, and so on. Due to a higher order term of the time derivative, however, their numerical approximation is not an easy task. Different numerical methods will be implemented to solve the initial-boundary value problem governed by the Boussinesq equations.

2 General Formulation

Consider a ship or a pressure distribution undergoing rectilinear motion with forward speed \( V \) in inviscid shallow water of depth \( h \). Let \( Oxyz \) be a ship-bound Cartesian coordinate system centered at the midship with the plane \( Oxy \) lying on the undisturbed free surface, the \( x \)-axis pointing toward the bow, and the \( z \)-axis being positive upward. The irrotational flow generated by the moving ship can be thus described by a velocity potential \( \Phi \) governed by the Laplace equation,

\[
\phi_{xx} + \phi_{yy} + \phi_{zz} = 0, \quad (1)
\]

in the whole fluid domain and by the following boundary conditions:

first, kinematic and dynamic conditions,

\[
\zeta_t - V \zeta_x + \phi_x \zeta_x + \phi_y \zeta_y = \phi_z, \quad (2)
\]

second, no-flux condition,

\[
\phi_t - V \phi_x + \frac{1}{2} \frac{\nabla \phi^2}{\rho} + g z + p = 0, \quad (3)
\]

respectively, on the free surface \( \zeta = \zeta(x,y,t) \), where \( g \) is the acceleration due to gravity, \( \rho \) the water density and \( p \) the pressure distribution on the free surface; second, no-flux condition,

\[
F_t - VF_x + \nabla \Phi \cdot VF = 0, \quad (4)
\]

on the hull-surface \( F(x,y,z,t) = 0 \); third, no-flux condition,

\[
\phi_z = 0, \quad (5)
\]

on the water bottom \( z = -h \); and fourth, radiation condition,

\[
\nabla \Phi \rightarrow 0, \quad (6)
\]

at infinity \( \sqrt{x^2 + y^2} \rightarrow \infty \).

3 Basic Solution Technique

If the flow problem considered here is further restricted by the relatively small water depth as well as by the slender-ness of hull form, then the well-established technique of matched asymptotic expansions, first introduced by Tuck
(1966), can be used. According to this approach the fluid-field is divided into an outer region (far field) and an inner region (near field) relative to the ship. In each flow region a scale analysis is then performed by selecting suitable scales for all variables, and the resulting simplified forms of the original governing equations are matched by means of asymptotic multiple-scale expansions in both regions.

The basic assumptions in the far field are that the waves generated by the ship are weakly nonlinear and long in comparison to water depth. These two features lead to a reasonable approximation of the 3-D potential $\Phi$ in terms of a depth-averaged 2-D potential $\varphi$ in the horizontal plane as defined by

$$\varphi = \frac{1}{h+\zeta} \int_{-h}^{h} \Phi(x,y,z,t) dz,$$

where $\zeta$ denotes the local wave elevation.

Following standard shallow-water wave approximation (Taylor expansion in vertical direction) and using the 3-D Laplace equation as well as the no-flux condition at water bottom with constant water depth, the kinematic and dynamic conditions for the free surface can be approximated by the well-known Boussinesq theory as follows:

$$\zeta_x - \nu \zeta_{xx} + \nabla \cdot [(h+\zeta)\mathbf{u}] = 0,$$

$$\mathbf{u}_x - \nu \mathbf{u}_{xx} + (\mathbf{u} \cdot \nabla)\mathbf{u} + g \nabla \zeta = \frac{1}{3} h^2 \nabla \cdot (\mathbf{u}_x - \nu \mathbf{u}_x) - \nabla \frac{P}{\rho},$$

where the $\nabla$-operator from now on takes its 2-D form, e.g., $\nabla \varphi = (\varphi_x, \varphi_y)$, and $\mathbf{u} = (u, v) = \nabla \varphi$.

Now, by further assuming that the pressure is hydrostatic, i.e., the pressure is proportional to the local dip from the free surface, the so-called shallow-water wave equations of Airy theory are obtained:

$$\zeta_x - \nu \zeta_{xx} + \nabla \cdot [(h+\zeta)\mathbf{u}] = 0,$$

$$\mathbf{u}_x - \nu \mathbf{u}_{xx} + (\mathbf{u} \cdot \nabla)\mathbf{u} + g \nabla \zeta = -\nabla \frac{P}{\rho}.$$ (11)

The basic assumption in the near field is that the hull form is considered as a slender body, which means that beam and draft of the hull are small compared with its length. Based on this assumption, the 3-D potential $\Phi$ in the near field can be approximated by means of a 2-D potential in the vertical plane at each hull cross-section. After a lengthy derivation of asymptotic outer expansions the no-flux boundary condition on the hull surface for the far-field flow is reduced to

$$\varphi \big|_{y \to a} = \frac{1}{2} \int_{-h}^{h} [S(x,t)(V-u_0)^2].$$

In comparison with the classical slender-body theory this formulation takes account also of the effects of the longitudinal perturbation velocity $u_0 = \frac{1}{2} [u(x,0^+)+u(x,0^-)]$ as well as of the varying instantaneous cross-section area $S(x,t)$, which depends on sinkage, trim and local wave elevation $\zeta_0 = \frac{1}{2} [\zeta(x,0^+)+\zeta(x,0^-)].$

### 4 Numerical Approximation of the Airy Equations

Due to the dynamic analogy of the Airy shallow-water-wave equations (10-11) to the well-solved Euler equations of 2-D gas dynamics, the highly developed numerical methods of aerodynamics can be used. In the previous work by Jiang (1996) the upwind and high-resolution explicit schemes were implemented to solve the initial-boundary value problem.
governed by the Airy equations. The main efforts required were:

- Flux formulation of the Airy equations
- Flux-difference-splitting based on the eigenvalue splitting
- Advective upstream splitting
- High-order interpolation using MUSCL approach
- Conservative space discretization of the flux vectors
- Runge-Kutta time-stepping

We now apply the computer program based on the numerical method introduced above to simulate a ship moving at a supercritical speed of \( F_{\text{sh}} = 1.5 \) in the VBD shallow water tank. Fig. 3 shows the body plan of the subject ship. Fig. 4 shows three steady shock-wave-like wave patterns, graph (a) resulting from the flux-difference-splitting method, graph (b) from the advective upstream splitting method, and graph (c) from an implicit scheme for the modified KP equation of Chen and Sharma (1992). All three wave patterns comprise only divergent waves within an angle analogous to the Mach angle at hypersonic flow in gas dynamics. However, these shock-wave angles are different from the mathematical Mach angle defined by depth Froude number \( \alpha = \pm \arcsin \frac{1}{F_{\text{sh}}} \), which lies between the bow-wave and the stern-wave angles. Furthermore, we can observe: (i) Airy equations generally yield steeper waves than those from the KP equation; (ii) In comparison to the flux-difference-splitting method the advective upstream splitting method reveals more details of the wave pattern, see the secondary divergent waves in graph (b).

Figure 3: Body plan of the subject hull (VBD Model No. M601)

5 Numerical Approximation of the Boussinesq Equations

In principle, we can also apply the upwind and high-resolution explicit schemes to solve the initial-boundary value problem governed by the Boussinesq equations. Unfortunately, the high order term on the right-hand side of the
Figure 4: Wave patterns of a ship moving in a shallow-water channel at supercritical speed $F_{\text{sh}} = 1.5$, at water-depth $h = 2.27T$, channel-width $W = 2.87L$, visualized as density plots.
Boussinesq equations (8-9) leads almost always to numerical instability of these explicit schemes, as far as different discretization schemes for the high order term have been tried. Therefore, we temporarily leave these rapid explicit schemes and turn to the slow, but numerically more stable, implicit schemes. This involves:

- Crank-Nicolson scheme for the time and space discretizations
- Approximation of the values $\zeta$, $u$, $v$ for the nonlinear terms at the required time step by means of Taylor expansion to same order as the right-hand side of (8-9)
- Iterative solution of the linear algebraic equation system
- Overrelaxation to accelerate the convergence process
- Local and global filtering to overcome the numerical oscillations

To test the new computer program based on this implicit method, we study first shallow-water waves generated by a pressure distribution moving in a rectangular channel, aiming at the simulation of a surface-effect-ship (SES) moving in shallow water. The pressure distribution is analytically given as follows:

$$p(x, y) = p_0 \, e(x) \, f(y)$$  \hspace{1cm} (13)

$$e(x) = \begin{cases} 1 & 0 < |x| < \frac{1}{2} \alpha L \\ \cos^2 \left( \frac{n \pi (|x| - \alpha L)}{(1-\alpha)L} \right) & \frac{1}{2} \alpha L < |x| < \frac{1}{2} L \end{cases}$$  \hspace{1cm} (14)

$$f(y) = \begin{cases} 1 & 0 < |y| < \frac{1}{2} \beta B \\ \cos^2 \left( \frac{n \pi (|y| - \beta B)}{(1-\beta)B} \right) & \frac{1}{2} \beta B < |y| < \frac{1}{2} B \end{cases}$$  \hspace{1cm} (15)

With the specific values of $L = 8m$, $B = 4m$, $\alpha = 0.7$, $\beta = 0.4$ and $p_0 = 0.1gh$, the parameters for the pressure distribution as well as the channel configuration are the same as used by Ertekin et al. (1986), enabling some numerical comparisons. Fig. 5 shows the temporal evolution of the wave pattern at the

![Figure 5: Temporal evolution of the wave pattern of a pressure distribution moving at the critical speed $F_{nb} = 1.0$ in a shallow-water channel at water-depth $h = 1m$ and channel-width $W = 8m$, visualized as density plots](image)
critical speed, visualized as density plots. As expected, solitary waves are generated one after another, the wave pattern relative to the uniformly moving pressure patch is no more steady. Consequently, the resulting wave resistance is oscillating about its mean value, see Fig. 7a.

Fig. 6 shows a perspective view of the wave pattern at a high speed of $F_{\text{nh}} = 2.0$. The wave pattern is now steady and comprises only divergent waves. The steady wave resistance at this supercritical speed in Fig. 7b is much smaller than the mean value at the critical speed in Fig. 7a, pointing up the advantage of traveling at supercritical speed.

Turning now to the ship moving in shallow water without the side-wall restriction, Fig. 8 shows a perspective view of the wave pattern generated by the pressure distribution moving at the critical speed. Obviously, no solitary waves are generated and the wave pattern relative to the uniformly moving pressure is steady. Fig. 9 displays the wave pattern at a supercritical speed of $F_{\text{nh}} = 2.0$. It is a steady wave pattern comprising not only divergent waves but, surprisingly, also transverse waves far downstream, which require further scrutiny. Fig. 10 compares the wave resistance at the critical speed (graph a) and a supercritical speed (graph b). Again, there is a clear advantage at the supercritical speed, at least from the wave-resistance point of view.

6 Acknowledgments

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Figure 7: Time histories of wave resistance of a pressure distribution moving in a shallow-water channel at water-depth $h = 1$ m and channel-width $W = 8$ m.
Figure 8: Perspective view of the wave pattern of a pressure distribution moving at the critical speed $F_{nh} = 1.0$ in shallow water at water-depth $h = 1m$

Figure 9: Perspective view of the wave pattern of a pressure distribution moving at a supercritical speed $F_{nh} = 2.0$ in shallow water, at water-depth $h = 1m$
Figure 10: Time histories of the wave resistance of a pressure distribution moving in shallow water at water-depth $h = 1\text{m}$, channel-width $W = 8\text{m}$
Paper 2

Dr-Ing H-G Zibell
Prof Dr-Ing E Müller
Inland Ships for Extremely Shallow Water

Abstract

Concerning the R+D-project VEBIS (improvement of the efficiency of inland water transportation) innovative types of ships and propulsion systems were developed and investigated for operation on extremely shallow water. The investigations may result in an obviously better utilisation of the inland waterways of the new federal countries in Germany. Different types of ships and propulsion systems are estimated and evaluated considering the operation conditions. Optimal units for variable transport tasks and regions of operation are presented with their transport capacities and power demand. Hints and recommendations for the design of inland ships for extremely shallow water can be taken from the results of the R+D-project.

An R+D-program was carried out for the development of new inland vessels,
- which will help to increase transport capacities on existing waterways and
- which will also operate effectively with larger drafts under better conditions after rebuilding waterways [7].

Partners of the R+D-program were:
Engineering Centre Shipbuilding, Rostock (IS)
Potsdam Model Basin (SVA)
Schottel-Yard, Spay (SCHOTTEL)
Duisburg Model Basin (VBD)
Hamburg Model Basin (HSVA)
Techno Trans, Rostock (TTR)
Propeller- and Engine Factory, Wismar (WPM)
Dr. W. Pagel - Scientific Software (WPSoft)

1. INTRODUCTION

In the near and farer future the improvement of the efficiency of inland waterway transport can not only be achieved with investments in waterways. Innovative types of ships and propulsion systems will result in a better utilisation of the existing waterways. Over longer periods the rivers Elbe and Odra allow only ships drafts between 1.0 m and 1.4 m. Therefore the new vessels to be designed must be qualified for extremely shallow waters.

2. CONCEPTS

It was stated, that existing concepts of vessels on inland waterways
- self propelled inland ships
- pushing inland ships
- and pusher trains
are needed also in farer future as transport technology.

Recommendations for new types of vessels on the rivers Elbe and Odra and the canal system between the rivers resulted from the
analysis of the special conditions on these waterways:

For new vessels the main dimensions were recommended in agreement with the federal ministry of traffic:

- total length: \( L = 82 \text{ m} \)
- breadth: \( B = 9.5 \text{ m} \)
- depth: \( H = 2.65 \text{ m} \)
- maximum draft: \( T_{max} = 2.5 \text{ m} \)

Inland ships and pusher trains with these dimensions can sail on the larger waterways east of the river Elbe from and to Berlin since 1992 (partly with reduced draft). These vessels must have active bow thrusters.

In their smallest configuration pusher trains (push-boat plus one barge) shall be able to pass the main existing locks on the waterways.

The new transport systems must have better container-capacities. Low heights of the bridges over the rivers Elbe and Odra reduce container storage to 3 containers in height. On the canals there are only 2 loaded containers in height possible.

Different loading conditions resulted in requirements of future bridge heights of 5.25 m and 7 m for the transport of 2 container layers in height resp. 3 layers [6].

### 3. Pusher Trains

#### 3.1 Barges

The new barges designed are similar to those types "Europe I" and "II b", sailing on the western European inland waterways. Both types "Canal, E I c" and "Elbe, E II c" have lower depths, to reduce the steel weight [8].

The barge type "E II c" (Fig. 1) was especially developed for the rivers Elbe and Odra. Stowing 4 rows containers in breadth is possible. After the renewing of the canal connection between rivers Rhine and Elbe this barge can operate also in the transit traffic and can be integrated in pusher trains travelling on the river Rhine without difficulties.

![Fig. 1 Pushed Barge ELBE. E II C (L = 76.50 m; B = 11.40 m; T_{max} = 2.50 m)](image)

The dead-weight reaches 1830 t (maximum draft, \( T_{max} = 2.5 \text{ m} \)) with a steel weight of approximately 255 t, the depth is \( H = 2.65 \text{ m} \).

The barge type "Canal, E I c" (length, \( L = 70 \text{ m} \); breadth, \( B = 9.5 \text{ m} \)) was designed for operation mainly on the canals between the rivers Elbe and Odra and also on these rivers themselves.

A pusher train (one barge "E I c" and one push boat of 12 m length) reaches the total allowed length on the main waterways east of the river Elbe. Sailing on waterways class IV with a push boat of 15 m length is possible.
With a steel weight of about 210 t the barge has a maximum deadweight of 1380 t \((T = 2.5 \text{ m})\). At a minimum draft of 0.8 m the loading capacity is still 275 t.

3.2 Push Boats

Concerning the regions of operation four different types of push boats were designed.

Systematic resistance- and propulsion tests with different train configurations and loading conditions have been carried out on waterdepths from 1.5 m to 3.5 m. From the results an economical speed as a function of the water-depth and loading condition can be determined. The maximum allowable speed and the squat without touching the ground on extremely shallow water is given.

![Fig. 2 Push Boat UPPER-ELBE \((L \times B \times T = 27.0 \times 10.5 \times 0.8 \text{ [m]}\)](image)

The breadth of the push boat UPPER-ELBE (Fig. 2) is limited to pass the tchechan locks. The length of 27 m is necessary to reach a sufficient displacement of 195 t with the very low draft of 0.8 m. Operating during about 330 days a year on the Elbe routes E1 to E5 is possible. Two pump-jets are chosen as propulsion system.

![Fig. 3 Push Boat MIDDLE-ELBE \((L \times B \times T = 23.5 \times 25 \times 11.4 \times 1.1 \text{ [m]}\)](image)

The push boat MIDDLE-ELBE (Fig. 3) has two propellers in nozzles with a diameter of 1.2 m. The boat will operate with a draft of 1.1 m on the river Elbe between Gesthacht and the Saale mouth. A bow thruster replaces the flanking rudders and gives the boat good manoeuvrability. A total power of 2 x 400 kW will be installed. Installation of higher power needs alternation of the tunnel design and using larger propeller diameters. In Tab. 1 delivered power at the propellers and speed for different formations and waterdepths are listed. Load capacities for the different conditions are shown. Problems may arise with 4 barges on extremely shallow water and stream velocities with more than 2 m/s. For those condition manoeuvrability will be insufficient.
The small push boat CANAL (Fig. 4) can operate on waterways of class IV and V with a waterdepth of 3.5 m. The push boat has a draft of 1.7 m. The two rudder propellers in nozzles have diameters of 1.38 m. In Tab. 2 for different loading conditions the speed achieved with the delivered power of 2 x 350 kW is given.
Table 2  Speed  (Delivered Power at Propellers. \( P_D = 2 \times 350 \text{ kW} \))

<table>
<thead>
<tr>
<th>Formation Push Boat CANAL</th>
<th>Barge Type</th>
<th>Water-depth [m]</th>
<th>Draft (Barge) [m]</th>
<th>Deadweight, about. [t]</th>
<th>Speed [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELBE E IIc</td>
<td>3.5</td>
<td>2.5</td>
<td>1830</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td>ELBE E IIc</td>
<td>3.5</td>
<td>2.5</td>
<td>3660</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>ELBE E IIc</td>
<td>3.5</td>
<td>2.5</td>
<td>3660</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>CANAL E Ic</td>
<td>3.5</td>
<td>2.5</td>
<td>1380</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>CANAL E Ic</td>
<td>3.5</td>
<td>2.5</td>
<td>2760</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>CANAL E Ic</td>
<td>3.5</td>
<td>2.5</td>
<td>2760</td>
<td>9.1</td>
<td></td>
</tr>
</tbody>
</table>

The lines of push boat CANAL / ELBE \((L \times B \times T = 15.0 \times 9.5 \times 1.0 \text{ [m]})\) are similar to those of Fig. 2. The boat will operate on the river Elbe and in the transit traffic coming from the river Rhine. Because of the low draft two pump-jets as propulsion system are chosen. Sailing on the river Elbe on 200 days a year shall be possible. Though the displacement of 110 t is low the draft could not be reduced below 1.0 m.

### 4. PUMP-JETS AS PROPULSION AND STEERING DEVICES

For extreme shallow water conditions pump-jets (PJ) can work with a better efficiency than propellers with very small diameters [5].

Fig. 5  Schottel-Pump-Jet  (SPJ 132 T. \( P = 650 \text{ kW} \))
- Installing PJs the form of the aftship can be very simple.
- the PJ is a compact propulsion system with low noise level.
- a minimum draft of 0.5 m is possible.
- the PJ will not be damaged by grounding or driftage.

The model test series with the push boats showed in some cases extreme loss of efficiency. With a wake equalising plate behind the pump-jet an increase of the efficiency could be achieved. In the meantime the producer of the pump-jet recommends the installation of wake equalising plates and some ships have been equipped with such plates.

Fig. 5 shows a Schottel-Pump-Jet Type SPJ 132 T with a maximum power input of 650 kW. The weight is 5 t.

Two pump-jets of this type can be installed on the push boats Upper-Elbe and Canal-Elbe. Travelling on extreme shallow water the installed power of these pump-jets is only partly needed. The customer has to decide whether a smaller type is satisfactory for operation.

5. SELF PROPELLED INLAND VESSELS FOR WATERWAYS CLASS IV AND V

For the different operating conditions on the eastern waterways several types of ships were designed. The form of the aftship is mainly influenced by the waterdepth of the operating region and from type and arrangement of the propulsion system to be installed. Basis of the ship lines of the propeller driven units were lines from the R+D-program "Inland Cargo Ship of the Future" [4].

A good manoeuvrability of the new ships is achieved by installation of an active bow thruster. The bow thruster, for example a pump-jet, should be usable also for propulsion and in stopping manoeuvres.

The one-screw ship \( (L = 82 \text{ m}, B = 9.5 \text{ m}, T_{\text{max}} = 2.5 \text{ m}, dw = 1330 \text{ t}) \) was designed for operation without pushing a barge. For the ship a simple form nozzle type "Schuschkin" and a wake adapted nozzle was designed and tested.

![Section A](image)

![Section B](image)

Fig. 6  Unconventional Wake-Adapted Nozzle  (VBD-Model-Nozzle D 323)
The form of the unconventional nozzle (Fig. 6) was designed by systematically theoretical investigations and model tests in the cavitation tank [2, 3].

**Vessels with two propulsors**

On inland ships mainly operating on the rivers Elbe and Odra different types of propulsion and steering systems can be installed [1]:

- propellers in fixed partly integrated nozzles with conventional rudders (in the following called type I and IV)
- rudder propellers (azimuth propellers) in integrated nozzles (type III)
- jet-propulsion systems

The pump-jet was chosen as a bow thruster for all units. For the different propulsion systems three types of aft ships were designed. Concerning shallow water conditions the propeller diameter was fixed with 1.2 m for the propeller driven types.

**Fig. 7** Twin Screw Ship Type IV ($L = 82.00\, \text{m}; B = 9.50\, \text{m}; T_{CW} = 2.50\, \text{m}$)

Fig. 7 shows the design of type IV to be equipped with propellers in fixed nozzles. The nozzles are partly integrated in the ships hull in the top of the tunnel. A larger propeller diameter with a better efficiency can be installed. Type IV was developed with alternations from a former type I. The front ship now has a V-shaped bow. The distance between the propellers became larger, they were positioned nearer to the stern.

The front ship of type IV was also used for the following types (III and II).

**Fig. 8** Model of a Rudder Propeller in an Integrated Nozzle
Type III (not shown here) is quite similar to that of type IV. Slight alternations had to be made in the top of the tunnel for installing the rudder propellers. Fig. 8 shows a model of a rudder propeller. The nozzle is partly integrated in a turntable.

For installing pump-jets as propulsion systems a totally different form of the aftship is necessary. Fig. 9 shows the type II to be driven by jets. Minimum values for the distance between the two jets and the water pressure at the inlet of the jets are given by the producer (Schottel). With a minimum draft of 0.7 m the ship can operate on the river Elbe all over the year. Travelling with a draft lower than 1.0 m is only possible with this type but with very low load capacity.

<table>
<thead>
<tr>
<th>Self Propelled Inland Vessels with two Propulsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>type I</td>
</tr>
<tr>
<td>$h$ (m)</td>
</tr>
<tr>
<td>1.32</td>
</tr>
<tr>
<td>0.9</td>
</tr>
<tr>
<td>1.80</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>3.00</td>
</tr>
<tr>
<td>2.5</td>
</tr>
</tbody>
</table>

Tab. 3 Speed Achieved and Delivered Power at Propellers

On extremely shallow water speed and delivered power at the propellers are small. Results of the propulsion tests with the 4 types, speed to be achieved and delivered power as function of waterdepth, are listed in Tab. 3. Raising shaft power will cause only little increase in speed. The risk of grounding will be evident at low tip clearance. The differences of speed, that can be reached with the different types of ships, are small. Greater differences in speed are to be seen at a waterdepth to draft ratio of $h/T = 1.2$. 

---

8
Only the propeller driven types (I, III, IV) can be compared with respect to the delivered power at the propellers. Values of the used power input of the pump-jets driving type II can be specified by the producer only. The power input of the jet given in the VBD-report [Baumgarten] was estimated from measurements of rate of revolution and volume flow of the axial pump, which was used to model the jet system.

It can be stated, that under sufficient water conditions the jet systems of type II will need higher power input than the propeller driven units. Type II has advantages under extremely shallow water conditions, when travelling with the other units is not efficient or impossible. The propulsion investigations were carried out on shallow water with waterdepths up to 3.0 m. On higher waterdepths more delivered power can be applied. For the power to be installed the stopping behaviour and the power demand pushing a barge is relevant.

Results of the propulsion tests with the vessel type IV and nozzles of different forms (Wageningen 19a, Schuschkin) showed no significant differences on waterdepth to draft ratios \( h/T \leq 2 \). Unconventional nozzles (type Schuschkin) with one side widened showed the best results in propulsion-, tow-rope pull- and bollard pull tests. This results differ from that with the one-screw ship and can be explained with the unbalanced wake distribution in the inner tunnel region of the twin-screw ship.

6. SUMMARY

To improve the efficiency of inland waterway transport especially on the waterways in the new federal countries of Germany new types of ships were developed. Four new push boats were designed regarding different regions of operation and the conditions there. Pusher trains can operate on the rivers Elbe and Odra. For different loading conditions and waterdepths speed achieved and delivered power are given.

Self propelled ships, which can operate on the greater canals in the traffic from and to Berlin and on the rivers Elbe and Odra were designed and tested with different propulsion systems. Pump-jets as new propulsion systems can be of advantage on extremely shallow water.

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Paper 3

PD Dr V Bertram
Dipl-Ing J Isensee
From Road to River – Innovative Short Sea Shipping Concepts

Summary

A general analysis yields design guidelines for ships to compete successfully with road and rail, pointing out the importance of an overall logistic concept. Various designs for special inland water vessels, mainly for the transport on the Elbe river, have been developed. Here ships have to cope with severe draft restrictions for all-year operation. The design examples include a containership, a liquid-gas carrier, and a passenger-boat. Surface-piercing propellers are identified as a promising shallow-draft propulsor featuring higher efficiencies than the usual fully-submerged small-diameter propellers.

1. INTRODUCTION

'Short sea shipping' poses challenges to logistics and engineering experts who have to develop innovative solutions to the cope with current and future demands for economically and ecologically superior alternatives to land-based transport.

Short sea shipping designs for sea transport developed at the Institut für Schiffbau in Hamburg have been internationally presented in the past, e.g. a Ro-Ro catamaran ferry with a side-loading concept, Kohnagel and Bertram (1995), and a futuristic hydrofoil passenger ferry, Bertram and Schmidt (1995), Bertram et al. (1995). The focus in this paper shall therefore lie on more recent and de facto unpublished design proposals for river transport.

2. GENERAL DESIGN ASPECTS FOR SHORT SEA SHIPPING

The issue of competitiveness in short sea shipping and its consequences for ship design has already been discussed extensively by Bertram (1994a). We will repeat in this chapter only the main points and add a few thoughts specific for river transport.

Transport by rail and road has greatly limited inland and coastal water transport over the last 100 years. But with the ever increasing congestion of rail and road routes and the high costs to upgrade them, interest is returning to waterborne transport. Inland and coastal shipping...
have the largest remaining transport capacity reserves. Reasonable alternatives to road and rail transport appear for passenger commuter and medium-distance travel and for low-density, high-value freight.

Already a very high percentage of low-value bulk goods is transported by ships, i.e. the potential for a shift in transport is low, unless new water routes are opened. Bulk goods are usually not transported on the road except for local distribution. The main potential in low-value bulk traffic would be a shift from rail to ship. This is to a large extent a political issue involving existing subsidies to railways and channels.

Passengers and light-weight, high-value cargo requiring fast transportation are transported by road or airplanes. This segment will not be considered further here, but Andersson (1997) presents one of the few proposals for high-speed inland waterways transportation.

The target of short sea shipping is a shift of transport from land (mainly road) to water. The value of the service 'transport' can be evaluated in terms of time, cost, and flexibility. Road transport is extremely flexible. No other transport service can beat cars or trucks in this sense. Local distribution will therefore almost always be roadbased. Short sea shipping will subsequently usually involve a combined transport with ships acting in concert with land-based transport. This introduces automatically at least two additional transfers of cargo (shore-to-ship, ship-to-shore) as a major challenge for competitive logistics. A combined service might get close enough in flexibility to pure road transport, although it will never quite match the flexibility and require a certain minimum of transport demand to make sense. This leaves the 'time' and 'cost' aspects. 'Time' should be understood as door-to-door transport time including average idle time spent waiting for the transport service. Many goods do not need to be transported quickly, but rather reliable and punctual. This suffices e.g. for most 'just-in-time' concepts in practice. Low 'cost' should be the big advantage of water-based transport unless inappropriate high speeds destroy the inherent transport efficiency advantage of ships.

In special cases, ships may have a natural advantage. This is the case when the water route is considerably shorter than the land route, e.g. across a bay as for the Osaka - Kansai airport route or across a river as for the Stade - Hamburg ferry service. A related aspect may be exploited for the transport of dangerous goods where waterways pose much lower risks for populated areas than roads or even railways.

Most probable areas of success in competing with land-based transport are then:

- transport for short distances in crowded areas (commuter traffic)
- passenger (and car) transport on medium distances along coastlines or on rivers
- medium-value cargo transport on medium distances
- dangerous goods

Short sea shipping is not just a question of sea or river transport. It is just as much a question of creating transport systems where all elements cooperate to achieve a short and thus competitive throughput time. On short routes the relative importance of cargo handling time increases. For ferry services, transfer between different transport services should be fast. Also, waiting time should be minimized by frequent services or coordinated schedules of various transport services.

3. HYDRODYNAMIC CHALLENGES OF RIVER TRANSPORT

3.1. Wash

Ships create typical wave pattern which contribute considerably to the total resistance. Therefore ship designers try to minimize the wave making of ships. For inland water vessels, the wave making is in addition an environmental aspect. The waves must not damage banks of rivers or canals, nor should other floating objects - such as pontoons used as waiting stations of public ferry services, yachts, etc. - be excited to unacceptable motions amplitudes. These waves are called in the jargon of shallow-water hydrodynamics 'wash'.

There are various approaches to limit wash:

- Speed is an important parameter. With increasing speed the wash will usually also
increase nonlinearly until it approaches the critical depth. For low number $F_{wh} = 1$. Overcritical speeds show then again lower wash, but inland water vessels almost exclusively operate at undercritical speeds.

- Slender hulls usually produce less wash. Catamarans with two slender hulls may then become an attractive option for medium to high-speed shallow-water operation, especially when designed to have low-wash.

Very unconventional catamaran hulls have been proposed recently by pure hydrodynamicists, involving S-shaped demi-hulls operating purposely on transcritical depth Froude numbers, i.e., needing constant speed adjustment with varying water level, Chen and Sharma and Chen (1997), or with demi-hulls shifted by half a hull length versus each other, Söding (1997).

- Wash increases with displacement if the form is kept constant. There are various ways to keep the displacement at design speed low:

1. light-weight construction optimizing the hull structural design and using light-weight materials.
2. building smaller ships.
3. hybrid ship designs which use either air-cushions or hydrofoils to create additional lift, thus reducing the displacement.

Bertran (1994b, 1997) discusses the issue of wash and possible procedures to predict it in the design stage in more detail.

### 3.2. Propulsion

There are several reasons to discuss the issue of propulsion for inland water vessels:

- The ducted propellers used for inland water vessels today have only rather modest efficiencies.

- New inland water vessels or new routes will require hull forms with small drafts. Conventional propellers will then be severely restricted in propeller diameter leading to bad propeller efficiency. In addition, a small-diameter propeller with high propeller jet speed may have unacceptable environmental impact on river and channel beds.

For extremely shallow water depths, there will remain only a narrow gap between ship and river bed. A high-RPM ducted propeller will not work well under these circumstances.

- Conventional propellers must operate fully submerged. This requires aft trim for partially loaded cases.

Unconventional propulsors can overcome these problems, Fig.1:

1. **Paddle wheels** were historically the first propulsors for inland water vessels, yet feature much higher efficiencies than propellers, Krappinger (1959). The disadvantages of paddle wheels are the very low RPM, large dimensions and the high price. A height-adjustable twin paddle-wheel would be a superior choice as propulsor, also in terms of stopping and reverse motion.

2. **Surface-piercing propellers** have better efficiencies than conventional propellers for inland water vessels, Strunk (1986). Recent experiments at HSVA confirm this statement. Surface-piercing propellers can operate at low RPM and pose less problems for gears than paddle wheels.

3. **Pumpjets** are the latest proposal, but have so far insufficient efficiencies. Nevertheless, the manufacturers praise them as ideal shallow-water propulsors as they can act as manoeuvring effectors at the same time. At present, our experience is insufficient to evaluate pumpjets properly.
There is no differentiation to special purpose carriers as in sea shipping. Special containerships, ro/ro ships, car transporters, paper transporters, etc. are rare exceptions; liquid gas carriers are not found at all (there are not even regulations for inland waterways liquid gas carriers). This situation is usually explained by an insufficient cargo volume, but this may be a vicious circle. We propose to contemplate a stronger differentiation of inland water vessels in:

- dry bulk ships
- tankers
- containerships
- ro/ro ships
- liquid gas carriers

In addition, passenger boats or ferries will operate on rivers as before, although they may differ in technical concepts and appearance from the passenger boats of the past.

Surface-piercing propellers or paddle wheels as discussed in the previous chapter may help to open new waterway traffic routes for conventional dry and liquid bulk. These ships can operate on lower drafts than today customary and may thus transport goods on rivers not yet used frequently for shipping (as the Elbe) or during periods of low water depth.

4.1. River containership and ro/ro ships

Goods that are today transported in containers or trucks to supply our industries 'just in time' (which means on time and not fast) are much lighter than the usual bulk cargo transported by inland water vessels. Subsequently, ships transporting containers or trucks have much lower drafts than usual inland water vessels. Furthermore, a constant medium-speed cargo transport is much easier to realize with many, relatively small ships. The higher slot costs are partially compensated by lower waiting times and storage costs. The problem lies rather in finding convincing solutions for the times where the ships cannot operate at all, e.g. during winter times when rivers are ice-infested. But new river ice-breakers are under development and trains and trucks may be available to compensate during the winter months, albeit at higher costs.
inland water vessels compared to a conventional GMS inland water vessel. Muehlbacher (1996). These ships have not yet used the potential for reducing ship weight. The Elbe river is scheduled to be extended to a minimum water depth of 1.60m during 345 days a year. This would allow shipping of trucks or ‘almost’ two layers of containers based on the average container masses in sea shipping. This estimate is conservative as container masses for inland shipping are some 10% lower on average.

Furthermore, container- and ro/ro inland water vessels could be constructed much lighter than the today's multi-purpose designed for bulk goods. Containerships would need neither bottom nor double side hulls. Ro/ro hulls could be constructed as rather primitive pontoons with propulsion and lashing capabilities on deck. Even with 3 container layers such ships could operate during 8 to 9 months each year. During the 20 days with water depths below 1.50m operation with partially loaded containerships – carrying approximately 60% of the maximum load – would have to be supplemented by road or rail container transport. Probably it is quite feasible to design special ships for light container or ro/ro cargo with drafts of less than 1.50m.

Muehlbacher (1996) has designed such a containership for Elbe transport from Hamburg to Prague, Fig.3, Table I. The ship is equipped with a paddle wheel for propulsion. The speed suffices to cover a return voyage to Prague in 8 days. The paddle wheel is designed to be adjustable in height to follow different drafts. While not yet available, such a technology appears at least feasible.

Table I: Main dimensions of container inland water vessel

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>85.00 m</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>9.50 m</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>1.50 m</td>
<td></td>
</tr>
<tr>
<td>TEU cap.</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>$C_B$</td>
<td>0.88</td>
<td></td>
</tr>
</tbody>
</table>

4.2. River liquid gas carrier

Liquid gas is carried in ocean-going ships and in trucks, but not yet on inland water vessels. Both transport efficiency and safety aspects speak in favour of transporting liquid gas by ships and
not by trucks. Such a design was developed at IRS with the assistance of the company Messer-Griesheim, Table II and Fig.4.

The transport route was Zeebrugge (Belgium) to Berlin (Germany), Fig.5. At present the transport of refrigerated LNG is not permitted on West-European inland waterways. However, experts in the German ministry of transport see no reasons why a special permit should not be given to a double-hull tanker. The chosen route is the shortest possible for pure inland water vessels, avoiding additional regulations imposed by classification societies for ship operating partially in open seas. Two to two-and-a-half roundtrips Zeebrugge - Zeebrugge per month are feasible. Further development requirements were identified for the Messer-Griesheim tank system.

Table II: Main dimensions of LNG inland water vessel

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>82.00 m</td>
</tr>
<tr>
<td>B</td>
<td>9.50 m</td>
</tr>
<tr>
<td>D</td>
<td>3.40 m</td>
</tr>
<tr>
<td>T</td>
<td>1.30 m</td>
</tr>
<tr>
<td>V</td>
<td>850 m³</td>
</tr>
<tr>
<td>LNG cap.</td>
<td>430 m³</td>
</tr>
<tr>
<td>C_v</td>
<td>0.86</td>
</tr>
</tbody>
</table>

4.3. River passenger boat

As streets in and near large cities reach their capacity limits, rivers are rediscovered as medium of transport both for commuting and leisure travel. Passengerboats should be designed both functional and appealing. Fischer and Gruner (1997) designed a future passengerboat for the Berlin region in two variants differing only in outer styling, Fig.6. Among the innovative features of these designs are:

- A hydraulic control unit can open the forward half of the passenger cabin. This 'cabrio' design serves not only for pleasant natural ventilation, but also allows quick disembarkment.

- The air-conditioned cockpit, manufactured in modular fashion, can be adjusted over the complete height of the stem while the helmsman still keeps the required overview. This allows passing under bridges without leaving the helmsman in the open as is found in the operating passengerboats in the region.

5. CONCLUSION

Specialized designs are deemed necessary to compete successfully with land-based transport. Especially on the Elbe river, ships with low draft are required to operate for most of the year. In this regard, surface-piercing propellers should be investigated in more detail, as they may be a cheap and relatively efficient propulsor for shallow-draft ships.

ACKNOWLEDGEMENTS

Part of the work presented here was based on the independent study projects of S. Altheuer and M. Bergande which are only internally documented.

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Fig. 3: Container inland water vessel, Muehlbacher (1996)

Fig. 4: LNG inland water vessel
Fig. 5: Transport route Zeebrugge - Berlin

Fig. 6: Modern river passenger boat, two design variants
Paper 4

Prof A Incecik
Prof. Atilla Incecik,  
Department of Marine Technology,  
University of Newcastle upon Tyne,  
Newcastle Upon Tyne, UK.

Investigation of the Hydrodynamics of a Manoeuvring Ship in Deep and Shallow Water

Summary

The Universities of Newcastle and Glasgow have recently completed a theoretical and experimental investigation of the Hydrodynamics of a Manoeuvring Ship in Deep and Shallow Water. The paper describes the equipment and procedures used in carrying out side force and yawing moment, pressure distribution and vorticity measurements with models of different ship hull forms travelling at a constant forward speed at various drift angles.

The paper presents results from the measurements carried out both in deep and shallow water.

1. INTRODUCTION

The prime importance of ship manoeuvrability is its role in achieving safety in navigation. For the past three decades a considerable amount of effort has been expended on theoretical and experimental simulation of the behaviour of a ship during a manoeuvre. In view of the complexity of the flow structure involved, it is not surprising that most manoeuvring simulation programs are based on semi-empirical formulae for the estimation of hydrodynamic derivatives (Inoue et al 1981). However, these semi-empirical formulae become inappropriate when examining new hull forms which have characteristics outside the range of their parameters.
2. EXPERIMENTAL INVESTIGATION

The experimental part of the project aimed at measuring side forces, yaw moments, hydrodynamic pressure and vorticity distributions. Flow visualisation around the models was also carried out. The experiments were carried out in the Hydrodynamics Laboratory at the University of Glasgow with four different hull forms as summarised in Chan et al 1993, Varyani et al 1994a and Varyani et al 1994b.

2.1 Experimental Apparatus

The total side forces and moments acting on the models were measured by strain gauges attached to two aluminium bars which connected the ship model to the towing carriage. Pressure distributions on the wetted body surface of the Mariner model were measured at 23 sections using diaphragm-type pressure gauges. There were a total of 380 pressure taps on the Mariner model. A vortex meter of four unpitched blade rotors of 10mm diameter was used for the wake measurements. Pictures of the streamline flow patterns were taken by an underwater video camera. The streamlines were traced by injecting a dye agent through pressure taps onto the hull surface. In order to reduce diffusion of the dye tracer, slower towing speed and flow rate of the dye tracer were taken. Table 1. shows experimental conditions and main apparatus used for the Mariner form (Chan et al 1993).
2.2 Wake Flow Pattern Measurements

It is well known that the flow field around a ship hull is very complicated even in straight running condition without any drift angle. The wake flow around the hull is rotational and generated by flow separations (Tanaka et al 1983). These consists of bilge separation, bow-separation, bow-wave breaking, stern-wave breaking and bow-necklace separation as sketched in Fig. 1. In addition to these flow separations, cross-flow separation is inevitable when the ship is running at a drift angle. The study summarised in this paper investigated the bilge-separation and cross-flow separation in the stern region of four different hull forms Chan et al 1993, Varyani et al 1994a and Varyani et al 1994b.

As an example the stern vortices in the stern region of the Mariner model will be described. The vortices around the model were investigated using the method of flow visualisation and vorticity measurements. The structure of the stern vortices can be roughly described by stream lines, which roll upward from the bottom and separate at a separation line along the bilge as shown in Figs 2-5. The equi-vorticity contours for a zero degree drift angle at two different stations of the Mariner hull form are shown in Figs. 6 and 7 respectively. Figures 8 and 9 show the equi-vorticity contours at station 18 $\frac{1}{2}$ for drift angles of $+2^\circ$ and $+4^\circ$ respectively. The circulation values $\Gamma$ given in these figures are obtained from the following equation.

$$\Gamma = \iint \omega dA$$

where $\omega =$ Vorticity in rad/s

$$= 2 \times \Omega \times 2\pi$$

$\Omega =$ Rotation speed in Hz.

$DA=$ Differential area element

The surface integral given in the above equation was calculated using Simpson's quadrature method. From an examination of the vortex contours given in Fig. 6 for station 18 $\frac{1}{2}$ it may be concluded that the vortex contour on the top of the figure may shed from the fore region of the ship whilst the bottom core may shed from the stern bottom. The circulation values for the zero degree drift match well with those measured by Tanaka et al (1983) for a different ship hull form. Tanaka et al expressed the circulation values as a function of the non-dimensional flat-bottom area coefficient $C_w =$ Area of Flat Ship Bottom / (Ship Length x Ship Beam). The value of $C_w (0)$ for the Mariner hull form is 0.28. It is observed in vorticity contour figures that vorticity increases at station 19 $\frac{1}{2}$ are most likely to be due to the presence of the propeller-boss and the circulation strength increases as the drift angle increases. These figures also indicate that the vorticity on the down-stream side of the hull section is about twice as strong as on the up-stream side when the ship is running with a drift angle. The vortices on the down-stream side are reinforced by cross-flow separation while the vortices on the up-stream side are reduced and swept down-stream.
2.3 Hydrodynamic Pressure, Force and Moment Measurements

The hydrodynamic pressure, side force and yaw moment measurements were carried out with captive models travelling at constant speed and various drift angles in calm deep and shallow water conditions. Figures 10 and 11 show the comparisons of the measured side force and yaw moment coefficients for the Mariner hull form with those obtained at Haslar (Clarke & Hearn, 1992). With the exception of the yaw moment coefficient measured at a drift angle of 12° there is a good correlation between the results of the two sets of experiments. Figure 12 shows side force and yaw moment coefficients for the Mariner and British Bombardier hull forms.

Fig. 13 shows the variation of side force coefficient with drift angle at different water depths for the British Bombardier. Fig. 14 compares the lateral force coefficients for various drift angles at different water depths for the Pram Bombardier model. Fig. 15 shows the variation of side force coefficients with Froude number at shallow water depth for the same ship. These results indicate that the magnitude of the side force coefficients increases as water depth decreases.

Figs. 16 and 17 show the non-dimensional values of the measured gauge pressure $p$ on the wetted surface of the Mariner hull form running at three drift angles $0^\circ$, $2^\circ$, and $4^\circ$ with a constant forward speed of $F_r = 0.259$. The pressure coefficient $C_p$ in these figures is defined as:

$$C_p = \frac{p}{\frac{1}{2} \rho U^2}$$

with positive pressure normal outward of fluid domain. It is evident from the present pressure measurement that change in pressure is more significant in the bow region than in the stern region. In general pressure increases with an increase in drift angle on the windward side and decreases on the leeward side. In the bow and stern body the hull experiences positive pressure while it encounters negative pressure along the middle body.

3. CLOSING REMARKS

The experimental part of a joint project between the Universities of Newcastle and Glasgow on hydrodynamics of a manoeuvring ship in deep and shallow water summarised here yielded a large amount of data which has been used to improve the existing prediction methods (Hearn et al. 1994) and can be further used for improving our fundamental understanding of flow around various hull forms and for validating numerical and experimental results.

ACKNOWLEDGEMENT

The project summarised here was financed by the Engineering and Physical Sciences Research Council of the U.K. through the Marine Technology Directorate Limited. The author is grateful for this support.

The experimental investigation could not have been concluded successfully without the untiring assistance of skilful technical staff at the Hydrodynamics Laboratory at the University of Glasgow.
REFERENCES


Table 1: Experimental Conditions

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Fn</th>
<th>Drift Angle</th>
<th>Measurement Apparatus</th>
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</thead>
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<tr>
<td>Sway Force &amp; Yaw Moment</td>
<td>0.26</td>
<td>0°, 2°, 4°, 6°, 8°, 10°, 12°, 15°</td>
<td>Strain Gauges</td>
</tr>
<tr>
<td>Pressure Distribution</td>
<td>0.26</td>
<td>0°, 2°, 4°</td>
<td>Diaphragm-type Pressure Gauge</td>
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<tr>
<td>Wake Measurement</td>
<td>0.26</td>
<td>+0°, +2°, +4°</td>
<td>Rotor-type Vortex meter</td>
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<tr>
<td>Flow Visualisation</td>
<td>0.01</td>
<td>0°, 2°, 4°</td>
<td>Underwater CCD Camera</td>
</tr>
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</table>

Fig. 1 Sketch of Flow Separation
Fig. 2 Development of Separating Sheet

Fig. 3 Flow Separation at Bilge
Fig. 4 Bilge-Separation Vortices

Fig. 5 Stern Vortices
Fig. 6 Contour of Vorticity at STN 18 ½ for Mariner

Fig. 7 Contour of Vorticity at STN 19 ½ for Mariner
Fig. 8  Contour of Vorticity at STN 18 ½ for Mariner

Model length $L = 2.5$ m  
Model speed $U = 1.283$ m/s  
Drift angle $\beta = 2^\circ$  
Circulation $\Gamma_{UL} = -0.167 \times 10^{-1}$ (S.)  

Model length $L = 2.5$ m  
Model speed $U = 1.283$ m/s  
Drift angle $\beta = 4^\circ$  
Circulation $\Gamma_{UL} = -0.897 \times 10^{-2}$ (P.)

Fig. 9  Contour of Vorticity at STN 18 ½ for Mariner
Fig. 10  Variation of Lateral Force Coefficient with Drift Angle at Fn=0.26

\[ Y' = \frac{Y}{\frac{1}{2} \rho L^2 U^2} \]

Fig. 11  Variation of Lateral Force Coefficient with Drift Angle at Fn=0.26

\[ N' = \frac{N}{\frac{1}{2} \rho L^2 U^2} \]
Fig. 12a  Comparison of Variation of Lateral Force Coefficient with Drift Angle

\[ Y' = \frac{Y}{\frac{1}{2} \rho L^2 U^2} \]

Fig. 12b  Comparison of Variation of Yaw Moment Coefficient with Drift Angle

\[ N' = \frac{N}{\frac{1}{2} \rho L^2 U^2} \]
Fig. 13 Variation of Lateral Force Coefficient with Drift Angle and Water Depth for the British Bombardier at $F_n=0.173$

Fig. 14 Variation of Lateral Force Coefficient with Drift Angle and Water Depth for the Pram Bombardier at $F_n=0.173$

Fig. 15 Variation of Lateral Force Coefficient with Froude Number and Drift Angle for the Pram Bombardier
Paper 5

Dipl-Ing Th Guesnet
Dr-Ing A Gronarz
Manoeuvring in Shallow Water

I have taken the liberty to aim my lecture on the subheading: “Manoeuvrability of vessels in shallow water - criteria, test methods and prediction”.

As a general rule, ship manoeuvrability decreases when the vessel operates in shallow water.

On the other hand, shallow waters as rivers, ports and channels are most often crowded waters. Ships of different course, size, speed and manoeuvrability are navigating in waterways of restricted breadth. In order to assure the smoothness and safety of the traffic, any vessel admitted on these waters must show a good performance regarding the manoeuvrability.

“Good performance” being quite a general term, objective criteria and simple test methods are needed to proof the manoeuvring qualities of each vessel.

1. The criteria

The criteria developed to asses the manoeuvring performances of vessels in European inland waterways are regarding the vessels sailing on cruising speed. The manoeuvring capacities qualities with low or zero speed are also important for the ship performances, as for example it is important for many ships that they can execute berthing manoeuvres in a fast and smooth way. But as these manoeuvres with low or zero speed do not affect the smoothness and safety of the traffic on the waterway, they are until now not considered by the regulations.

The manoeuvring tests are normally performed during the acceptance trails of the vessel. No specific test or measurement devices can be used for these tests. The result of each test must be ready and understood immediately after the test. This explains why the regulations for these tests should be simple and clear.
1.1. Stopping Ability

is considered to be the most important admission criteria. On the river Rhine, a long established rule requires:

Any ship sailing downstream must come to full stop in relation to land within a given distance.

This rule is, in a modified form, also valid for the Danube River.

The stopping ability should not be a problem for a ship equipped with a suitable propulsive device, as a propeller rotating in counter- direction produces enough backward thrust to stop the ship and to built up backward speed. Problems start when the propeller begins to suck in air with the backward water flow as this will immediately reduce the thrust to zero. To prevent this, the lines must often be especially designed, and often the ahead performance of the ship will suffer from this.

Also the stopping criteria is not reached when it is not possible to keep the ship on a straight course during the stopping manoeuvre. This means in many cases that an auxiliary drive, for example a bow thruster is needed during the manoeuvre.

1.2. The “Lane Changing Ability”

has recently been introduced as an admission criteria for vessels on the river Rhine. This rule is not so easy to understand as the stopping rule, so here I propose here a very simplified expression:

Any ship sailing on an initial straight course must be able to take up a given rate of turn in a given laps of time, and then, inverting the action of the rudder, reduce the rate of turn to zero again in a given laps of time.

The meaning of the rule is that a vessel cruising in a waterway is easily able to change the course in order to avoid a ship with opposite course or to avoid an obstacle in the waterway.

The main advantage of this rule, which needs about three pages of regulations to be described in detail, is that the corresponding "rate-of-turn" test is rather easy to perform and to evaluate. We only need the "rate-of-turn-indicator", which we will find on any commercial craft and a stop watch. The manoeuvre will be performed with different rudder angles and rates of turn and the only test record is the laps of time required for the change in rate of turn. The results will be compared with the requirements of the regulation for the specific ship in order to see if the criteria is fulfilled.

In practise, almost all the ships navigating today on the inland waterways do fulfil the rule. Problems sometimes occur when vessels have a low length-to-beam ratio combined with high propulsive power. These ships are sometimes not so willing to go on a straight course again once they started to turn on one side.
2. Prediction Methods for Manoeuvring Performances on Shallow Water

In the design phase of a new vessel, it is important to consider manoeuvrability from the very start as this criteria will influence:

- The choice of the lines for the aft body of the ship
- The choice and design of propulsive devices
- Rudder type and size
- The choice of auxiliary propulsion

a) Comparison with existing vessels
This is certainly a reliable and the most common way to evaluate the manoeuvring performances of a vessel in the design stage. But this method fails when there is no data available from ships with comparable dimensions or design.

b) Model tests
Model tests are still regarded to be the best way to determine the propulsive performances of a new design. The manoeuvring tests can be executed in addition to the propulsion test with reasonable expenses. Both the stopping and the rate-of-turn model test give an accurate full scale prediction. The model tests should be performed in an adequate shallow water condition, as there is no method known to extract a full scale shallow water manoeuvring prediction from a deep water model test.

For the case that the model tests shows an insufficient manoeuvrability, the model can be modified, for example with additional fins, until the criteria are reached.

c) Computational Methods
Hydrodynamic coefficients can derived from special model tests carried out at the VBD. A simulation method using these coefficients was recently presented by A. Gronarz in his thesis. It is now possible to perform simulations using mathematical models for different water depths and to obtain useful predictions for the types of ships generally used on the European inland waterways.

Anlage 1: Diagramm Stoppmanöver
Anlage 2: Simulation z- Manöver
Anlage 3: Diagramm z –Manöver
Stoppversuch

Selbstpropulsionspunkt

\( V_0 = 12 \text{ kn} \)

\( h/T = 4.0 \)
\( n = 66.9 \text{ 1/min} \)

\( h/T = 1.6 \)
\( n = 88.1 \text{ 1/min} \)

\( h/T = 1.2 \)
\( n = 95.4 \text{ 1/min} \)
Simulation of a 30°/4° Zigzag-test

Standard barge train
4 Ellb barges (76.5mx11.4m)

Big barge train
4 Elll barges (100mx14m)

dt = 25 s
Simulation of 30°/4° Zigzag-tests for an Inland Cargo Vessel
Paper 6

Dipl-Ing R Reuter
Reinhold Reuter  
Director Engineering & Quality  
SCHOTTEL-Werft  
Josef Becker GmbH & Co. KG

"Manoeuvring in Shallow Water"  
"Manoeuvring with Steerable Propulsion Systems"

Summary

The manoeuvrability of ships represents a particular challenge that is influenced by a great many factors. This paper deals with steering units and propulsion units, in particular SCHOTTEL Rudderpropeller (SRP), SCHOTTEL Pump-Jet (SPJ), SCHOTTEL Twin Propeller (STP) and SIEMENS-SCHOTTEL Propulsor (SSP). In addition to system considerations, the installation and operation criteria are also analysed and illustrated. The results of measurements in model and full-size tests complement the descriptions and demonstrate the advantages of these compact propulsion systems.

1. Introduction, general remarks

When used in a nautical engineering context, the term "manoeuvring" means to bring a ship into a different orientation and/or a changed position. A manoeuvre is initiated by steering forces or steering moments acting on the ship through the so-called steering units.

Steering units are subdivided into "ACTIVE" units, where active energy is used to generate the steering forces, and "PASSIVE" units, which use external energy sources.

The rudder, which enjoys an unrivalled position of supremacy as a steering unit and generates the steering forces from the pressure distribution of the flow around it (from the inflow and propeller jet), is not the subject of this paper.
Nor is consideration given to transverse thrusters that do not serve the additional purpose of propulsion.

A few brief remarks on the steering properties of ships would be useful before continuing:

Manoeuvrability means executing the desired manoeuvre with the aid of steering units. The tests shown in the following chart can be performed for the purpose of assessing manoeuvrability.

Turning ability means following the steering commands quickly and turning in small circles. Course stability and turning ability are mutually exclusive because the positive effect of the one property has a negative effect on the other.

This is tested in so-called turning circle trials, which are shown in the illustrations below.

![Manoeuvrability chart](image)

Yaw stability means being able to keep to a course straight ahead without the use of steering units. This property is evaluated by means of the so-called spiral test, which is shown in the diagram below.

![Yaw stability](image)

Course stability is the ability to keep accurately to the set course.

The value of lateral plane area multiplied by ship length, divided by displacement is also specified as a criterion. A value ≥ 9 for a "normal hull form" means that large steering forces are required while the
course stability is relatively good. With a value ≤ 7, small steering forces are sufficient for steering the ship, but larger stabilising surfaces are needed to achieve course stability.

Other assessment criteria are the coefficient of fineness, bow and stern form, position of propeller and rudder, direction of propeller rotation, wake, operating conditions etc.

It is the aim of this paper, however, to deal more intensively with the active steering units, focusing on steerable propulsion systems, which besides their propelling function also cause the steering forces to act directly on the ship.

For inland waterways, systems are required whose propulsion and steering units generate adequate thrust and steering force in extremely shallow water operation and which are also capable of operating with sufficient effectiveness in deep water.

These applications are the domain of propulsion systems that are capable of producing both longitudinal and lateral forces and whose installation on the ship does not pose any problems with regard to the available draught. [1], [2], [3]

2. Steerable propulsion systems

The distinguishing feature of a steerable propulsion system is its ability not only to convert the engine power into thrust but also to make this thrust available in all directions by rotating the propulsion unit through 360°.
2.1 The SCHOTTEL Rudderpropeller as steering and propulsion unit:

The power transmission train of the Rudderpropeller comprises two 90° angle gear units consisting primarily of bevel gears. Besides transmitting the power, these gears also reduce the engine speed to the propeller speed and, in the underwater gearbox, serve to support the propeller.

At the propeller the power is converted into thrust which is transmitted to the ship through the axial bearing of the propeller shaft, the gearbox, the steering tube and the foundation.

In the underwater area, the hydrodynamically optimum configuration of the gearbox is an important requirement that has to be met. In addition to generating thrust, the Rudderpropeller also accomplishes the task of steering the ship. By means of a steering mechanism, the underwater gearbox is turned about the vertical axis together with the propeller, the full magnitude of the thrust being available in all directions.

Installations with fixed or controllable-pitch propellers and ducted propellers are possible; nozzles partly integrated into the hull are particularly suitable for inland shipping applications on account of the draught limitations because this allows a larger propeller diameter to be implemented.

The most important aspects of Rudderpropeller operation in shallow water can be summarised as follows:

Since the Rudderpropeller combines both propulsion and steering functions, it is possible to do without a rudder, for which the necessary space is either hardly available or can only be achieved with a loss of displacement. Owing to the compact construction, less space has to be provided than for conventional shaft and rudder installations. This allows a higher deadweight capacity. Much shorter stopping distances and times can be attained by means of quick reversal, especially in operation in confined spaces with frequent encounters. The steering forces of a rudder are low when the ship is moving slowly. The Rudderpropeller accomplishes these manoeuvres better even in difficult operating conditions.

2.2 The SCHOTTEL Pump-Jet as steering and propulsion unit:

Designed as a shallow-water drive, the SCHOTTEL Pump-Jet operates on the principle of a centrifugal pump. An impeller sucks in water from under the hull through the intake funnel and forces it into a pump housing. The outlet nozzles of the Pump-Jet are arranged in the bottom plate in such a way that the jet can also be
installed in a flat-bottomed hull. In accordance with the momentum theorem, the thrust is generated in a direction opposite to that of the ship's motion.

The SCHOTTEL Pump-Jet works in shallow waters with the same or better efficiency than a corresponding propeller of small diameter that is adapted to an installation situation of this nature.

Special features of the SCHOTTEL Pump-Jet:

Use of the SCHOTTEL Pump-Jet permits relatively simple, full stern lines (no loss of displacement due to tunnelling). The Pump-Jet is of compact construction. Its smooth running minimises the requirements for sound-proofing measures. Depending on the size and arrangement, the Pump-Jet allows extremely shallow draughts of less than 0.5 m. The Pump-Jet is installed flush with the contour of the hull; it is robust and is not liable to damage by grounding or drifting woods or similars.

The SCHOTTEL Pump-Jet clearly differentiates itself from the use of conventional, commercially available water-jet drives, as the latter are designed for a very high speed and the Pump-Jet is optimised for the range of 0 - 18 knots. The Pump-Jet is not only installed as a main propulsion system, but also has a very good effect as a bow unit over a higher speed range and allows the full magnitude of the thrust to act on the ship over a range of 360°.

The most important aspects of Pump-Jet operation in shallow water can be summarised as follows:

The Pump-Jet was designed and optimised for special applications. As a main propulsion unit, the SPJ will always remain a special-purpose drive without becoming a rival for the propeller wherever a draught can be achieved that allows a sensible propeller diameter and the risk of damage to the propeller is calculably low.

Operation exclusively with Pump-Jet systems is possible and indeed sensible depending on the individual requirements and operating area. The maximum speeds that can be reached in extremely shallow water are not very high and the associated power requirement of the propulsion units is comparatively low. The higher power required by the Pump-Jet as opposed to a propeller is outweighed by the advantageous properties of the Pump-Jet, such as the virtually non-existent risk of damage and the resultant operational reliability or the impressively smooth and quiet running.

Investigations on cargo vessels, conducted by the VBD amongst others, have shown that it is always recommendable for the Pump-Jet - irrespective of the main propulsion system in the stern - to be operated as a bow unit that can additionally be used to provide forward thrust. The dynamic trim is positively influenced and
the overall power optimally distributed, the manoeuvrability is increased and critical points, e.g. bridge spans with a locally higher velocity of flow, can be negotiated better. [4], [9]

2.3 The SCHOTTEL Twin-Propeller as steering and propulsion unit:

Using two contra-rotating propellers to increase the efficiency by reducing the rotation losses and distributing the power over two propellers instead of just one is a technology that has actually already been known for a very long time.

The mechanical construction of this system - two coaxial propeller shafts with complex bearings and seals as well as a double reduction stage - is feasible today but very costly.

This prompted SCHOTTEL to investigate whether it would be possible to achieve hydrodynamic improvements of our Rudderpropellers with reduced mechanical complexity and thus higher reliability. The result is the SCHOTTEL Twin Propeller: the STP is a 360° steerable Z-type drive with two propellers mounted on a common shaft and rotating in the same direction, and with guide fins integrated into the complete system. Its outstanding performance characteristic is an efficiency up to 20% higher than Rudderpropellers with only one propeller.

Mechanical characteristics:
- Compact construction
- Easy installation and removal
- Steerable around 360°
- Reduced steering torque due to torque absorption before and behind the rotational axis
- Use of 2 propellers with the same direction of rotation and with the same diameter, mounted on a common propeller shaft and driven through only one reduction stage.

1 Upper gearbox
2 Power input
3 Steering gearbox
4 Well
5 Underwater gearbox
Unconventional profiles with optimised length/thickness ratio have been used without exception for the construction of the underwater components. The camber and inclination of the profiles have been optimised to prevent flow separation. These measures have resulted in an extremely low form drag and extremely low noise generation.

Furthermore, the inhomogeneous wake distribution caused by the housing is much less pronounced than with conventional rudderpropeller housings of present-day design. There is consequently only a slight change in the propeller characteristics as compared with the free propeller. As regards the interaction with the fins, it has been established on the investigated configuration that there is no loss of efficiency in relation to the free propeller, i.e. a propeller not impeded by a housing or similar.

Special propellers with a small number of blades and a low disc area ratio were designed to minimise surface friction. The resistance to cavitation is ensured by the design and the low loading of the individual propellers. Moreover, the max. propeller diameter was also selected for the second propeller in order to obtain the maximum efficiency in the overall arrangement.

The jet contraction of the front propeller has to be taken into account in the design of the second propeller because the actual flow cross-section of the outflow from the front propeller is smaller than the propeller diameter itself.
Pressure variations and cavitation in the area of the jet limit are prevented by an advanced blade geometry (special pitch distribution). Being of the same size, the second propeller offers the following decisive advantage: it takes in not only the water that has already been accelerated by the front propeller but also additional external water and converts this too into thrust. SCHOTTEL developed this propeller design in close cooperation with the Potsdam Shipbuilding Research Establishment (SVA) and optimised it in a series of tests.

An appropriate skew is also provided for the purpose of further decreasing the pressure variations. The rake and tip clearances in relation to the housing and the hull were increased in order to reduce pressure variations and vibrations. The distance between the propeller planes and the relative blade positions of the two propellers, i.e. their phase, have an influence on the torsional vibration behaviour, the cavitation and, to a minor extent, also on the efficiency, and are therefore important variables in the design of the hydrodynamic components.

The good efficiency of the SCHOTTEL Twin Propeller is the result of successfully optimising the complete Rudderpropeller system. SCHOTTEL has developed this innovative propulsion concept by conducting a long series of theoretical preliminary studies, by systematically devising favourable design and manufacturing features and by carrying out hydrodynamic investigations at SVA.

The model tests and calculations have been confirmed in full scale tests and practical operation.

- Lower steering torque and lower steering power
- No steering forces acting on the vessel due to the propellers rotating when disengaged
- Higher variability in selecting the characteristics

<table>
<thead>
<tr>
<th>Improvements compared with single propeller</th>
<th>SCHOTTEL Twin Propeller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher efficiency with the same propeller diameter</td>
<td>SCHOTTEL Twin Propeller</td>
</tr>
<tr>
<td>Smaller propeller diameter with the same efficiency</td>
<td>SCHOTTEL Twin Propeller</td>
</tr>
<tr>
<td>Smaller pressure variations and lower risk of cavitation</td>
<td>SCHOTTEL Twin Propeller</td>
</tr>
<tr>
<td>Lower noise emission</td>
<td>SCHOTTEL Twin Propeller</td>
</tr>
</tbody>
</table>
Improvements as compared with single propeller in nozzle:

- Higher efficiency with the same propeller diameter
- Smaller propeller diameter with the same efficiency
- No nozzle (overall diameter possibly smaller, lower hull-appendage resistance)
- Smaller pressure variations and lower risk of cavitation
- Lower noise emission
- No steering forces acting on the vessel due to the propellers rotating when disengaged
- Lower weight, depending on size
- Lower steering torque and lower steering power
- Higher variability in selecting the characteristics

Typical applications:

Passenger and car ferries, passenger ships, supply vessels, icebreakers, cargo vessels, high-speed boats, minesweepers, hydrographic research ships.

The most important aspects of Twin Propeller operation in shallow water can be summarised as follows:

First of all, the SCHOTTEL Twin Propeller has all the properties of a conventional Rudderpropeller. In addition, implementation particularly on vessels with a limited draught is a typical application of the Twin Propeller. With high thrust load coefficients, as undoubtedly exist in the case of small propeller diameters required for reasons of draught, the rotation losses are high and it is advisable to recover these losses by means of recovering of the spin and to distribute the power. The gain in efficiency as compared with the conventional Rudderpropeller is greatest with a high power and small propeller diameter. [5]

2.4 The SIEMENS-SCHOTTEL Propulsor as steering and propulsion unit:

As its very name implies, the SIEMENS-SCHOTTEL Propulsor is a joint development of SIEMENS AG and SCHOTTEL-Werft.

The two pillars of this propulsion unit are firstly the Twin Propeller technology and secondly a new electric motor, which drives the propellers directly rather than through a mechanical right-angle gear unit. The motor is a permanent-magnet longitudinal-flow motor (LFM) characterised by its high efficiency and extremely slim-line construction. The high efficiency is achieved through the use of a new material for the permanent magnet, eliminating the need for external
excitation, which is subject to losses and higher energy requirements.

3. Presentation of various test results

The test results presented below in diagrammatic form are intended to document some of the principal aspects of implementing steerable propulsion units.

a.) The following polar diagrams show the thrust vector in direction and magnitude for the Rudderpropeller with nozzle and for the SPJ as a function of steering angle, inflow direction and ship speed. These diagrams are used for rating the system with regard to the steering forces that are required.

The slim-line construction of the motor allows a streamlined, pod-like design of the underwater housing, which does not obstruct the propeller area to the same extent as conventional podded drives (PoD).

In combination with the Twin Propeller technology, it is possible, with minimised space requirements both in the machinery room and under the ship, for extremely high power outputs (5 - 30 MW) to be transmitted for propulsion and steering with high efficiency and all the advantages of progressiv motor control and energy management. [10]
c.) The following diagram shows a comparison of the STP with a conventional Rudderpropeller in terms of propulsion and steering forces at slow speed and with a high load (resistance, e.g. in towing operation) as a function of the power input. Both systems have the same design point (normal operation: 10 - 12 knots).

b.) When performing a steering function, the propeller on the Rudderpropeller requires a higher power input than on a normal straightahead course on account of the oblique inflow. The drive motor must possess adequate reserves and the Rudderpropeller itself must also be rated for these overload conditions. This relationship is illustrated in the diagram below.

d.) The next diagram presents the results of an investigation regarding the increase in safety when using a Pump-Jet in the bow. The ship involved here is a conventionally propelled tanker. The following diagram shows the reduction of the turning circle radius due to use of the bow SPJ.
In the following diagram the turning circle in advance and transverse distance is shown plotted against time.

[7]

e.) The next figures and the diagram presents Zig-zag test with a double-ended car ferry which was equipped with two SCHOTTEL-Rudderpropellers type SRP 330. This kind of ship generally has a low yaw stability and is necessary to steer these ships with large rudder angles. [8]
Zig-Zag Tests with a Car-Ferry

VBD - Model No. 1541 with original Skegs and additional stabilisation Flaps

- Z = 1.50 m
- V = 2.81 m
- Y = 11 4 x
- Change Angle = 2

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Paper 7

Dipl-Math F Arendt
Logistics and telematics promoting river-sea and short sea shipping

Summary

Telematics solutions can support the improved integration of short sea shipping (SSS) and river-sea shipping (RSS) services into intermodal transport chains.

This paper will discuss why it is necessary to consider such telematics solutions, what challenges and opportunities can be derived from such approaches and what kinds of services SSS/RSS operators may offer in the future.

In a last chapter the focus will be on the BOPCom project, co-financed by the European Commission's Transport Directorate. In this project an innovative approach for linking existing EDP systems of partners in the transport chain as well as including SMEs without appropriate application systems will be developed and demonstrated. The BOPCom approach and results are well suited for being applied to the services discussed in the first chapters.

1 Introduction

The importance of telematics, which is the integration of telecommunication and informatics, for the whole industry and also for the transport sector is steadily increasing.

Modern logistical concepts and innovative telematics are very closely related to each other. But this relationship is not a one-way road, meaning that logistical concepts lead to new telematics requirements and concepts, but also the other way round: some logistical concepts (as JIT, On-time-delivery) have only been enabled by new telematics services.

Whereas the logistical requirements are on a huge part of organisational nature set up by the producers and shippers of goods, the telematics offering technical solutions to implement efficient ways to meet or support the fulfilment of these requirements.

2 The Requirements

The move towards thinking in a global way, in complete transportation chains requires essential exchange of information along the transportation chain. The trend goes towards the preplanning of whole transportation chains instead of thinking in separate independent pieces.

The trend to one-stop-solutions with one party (e.g. a Multimodal Transport Operator (MTO)) organising the whole transportation chain puts the responsibility and coordination to that one party but still the parts in the chain have to
behave well and expectable in order to get a smooth operation.

Outsourcing trends for logistical functions and tasks (as organising procurement and distribution chains but also taking over storage and transhipment functions) from the shippers, e.g. to MTOs, have the consequence that also telematics functions for the fulfilment of these tasks will be outsourced.

Just-in-time concepts, on-time-delivery concepts, the reduction of stores (and related hereto the shifting of cargo to trucks or vessels which can be seen as „rolling stores“ resp. „swimming stores“) can work efficiently only with high requirements concerning data flows such as
- Timely availability of information without delays
- High quality/reliability of the information
- Coordinated operation
- Speedy reaction at planning deviations
  - trying to shift to fallback solutions with other transport modes, carriers, etc.
  - coming to new agreements between the transport organiser and the clients

New concepts for distributed production (e.g. completely knocked down (CKD)) require well designed planning and a lot of coordination efforts requiring sophisticated telematics systems in order to obtain a maximal transparency on the actions performed and on the planning of the whole production process.

The requirements for being integrated in information chains applies for all players involved in the transport chain, among them the suppliers of SSS/RSS services. Without this integrability the acceptance of users will decrease.

2.1 Interconnectivity

Modern planning and resource management requirements has led to the separation of the information flow from the physical cargo flow in such a way that the information concerning the transport will be exchanged in advance. This enables the participants in the transportation chain to include the operation resp. transport of the cargo into their planning schedules - assuming that this information will be available in high quality and actuality so that e.g. changes in the planned operation can be recognised immediately.

The exchange of information is performed using different technical means today: starting with the most historical (but still most used) telephone, telex and fax. All these transmission means allow, of course, to exchange information, however, it cannot be used for further electronic processing. Therefore, the exclusive use of these transmission is not suitable for requirements derived from advanced logistical concepts.

The development of EDP systems in the companies forced the structuring of information used in that business. Additionally, the information exchanged with others could be produced as outputs - but still in written form. This information is sent to the communication partner - e.g. by fax - and is retyped again into the EDP system of that partner. It is said that about 70% of the information produced (printed) by one computer serves as inputs for other computers. It is obvious that manual processing has certain disadvantages being time consuming, cost consuming offering reduced actuality caused by time lags at the data input side and reduced reliability caused by input errors.

But still the majority of companies use such „isolated“ systems, either for inhouse processing or for the own intra-company network, where problems arise by communicating with partners located outside this network.
But on the other hand, all transporters have strong requirements for the development of interfaces to their clients.

2.2 Interoperability

Interoperability means not only the exchange of data (via Filetransfer) but also the direct reaction of one system on the action another one is performing (online communication).

If looking at transportation chains, there is often the situation that the operation of one partner is dependent on the operation of another one - in most case the one which is just before in the transportation chain. Thus, besides the transportation chain and the information chain, a third one can be defined: the planning chain.

This planning chain is affected today by a lot of unreliable and inaccurate information upon which the resource planning and management of one operator is based upon. The high degree of uncertainty due to inaccurate input information (e.g. order start and end, ETA, etc.) leads to inefficient and costly operations ("waiting on one order", non-avoidance of peaks leading to waiting times, etc.).

Due to this lack of updated information, deviations from intended plans often cause problems and confusion. Qualified data for re-planning are not available; therefore, ad-hoc decision making will be based upon vague information; a fact that decreases the service quality. Furthermore, agreements with clients on re-planning are difficult - mostly inefficiently performed by phone.

The requirements for cooperative resource management seem to be quite obvious for exchanging planning information/proposed schedules for negotiations/agreements, exchanging planning information/schedules for improved resource management as well as exchanging deviation messages negotiating changes in operation aiming at the improvement of the cooperation along the transportation chain, the improvement of the resource management of each individual partner (e.g. operating ports, trucks, rails, barges, SSS/RSS vessels), the increase of the transparency and the ability of the partners to react on deviations in a flexible way either by solving the problem itself or in cooperation with other partners of the transportation chain.

2.3 Tracking and tracing

Modern logistical concepts depend on exact information about the location of cargo. Tracking and tracing systems are already used as an intra-company system showing, e.g., the location of the trucks of one truck operator.

The supervision resp. monitoring of the performace and the status of transport operation along complete transportation chains enables fast re-planning whenever operational problems in one link occur. If there will be a deviation from the original planning, it must be tried to find fallback solutions, to communicate to the client in order to agree on new delivery dates, etc.

For production plants relying on JIT concepts it is very important for their production planning to know exactly where their parts and raw materials are in order to make predictions on their arrival, to rearrange production plans as soon as delays are known or possible, to come to new arrangements with the transport organiser, etc.

One of the most important items in this area is the control over the chain without any gaps.

3 Telematics solutions

To effectively overcome the dominant problems of information exchange in an efficient, fast and reliable way, the introduction of EDI (Electronic Data Interchange) enables communication partners to exchange (structured) information in an electronic way - either directly from computer to computer - or using electronic mailboxes with store-and-forward technologies without any manual interference necessary.
But EDI as such is only a method for information transmission, not a solution in itself. A lot of problems arise as regards interconnectivity of EDP systems of different companies:

- data structures are different
- operating systems are different
- transmission services are different
- organisation of data is different
- organisational differences between companies.

Thus, if a company A wants to perform EDI with company B, they have to agree on all the issues mentioned above, resulting in an enormous effort to establish individual links to all communication partners. The possibility of such solutions depends on the size and resources of these companies. When looking e.g. at port community systems the situation is quite different; in that case the system provider defines the message format and all potential participants have to apply to that message format. The same applies if the data have to be sent by law. This leads to the fact that e.g. shipping agents have to supply their (identical) information to every port they are serving in a different format.

A first step towards a general solution was the definition of standards for data structures. There have been several lines for standardisation. Some branches as the automotive industry (ODETTE) or the chemical industry (CEFIC) developed standards on their own for communicating with their suppliers. National developments followed.

A general international approach is the well known set of standard messages which was defined under the EDIFACT (EDI for Administration, Commerce and Transport) framework. EDIFACT contains descriptions for the agreed message structures (e.g. invoice, order, booking) as well as a methodology how to group information and how put the basic information in "envelopes" which contain for example the name and communication address of the recipient of that message.

This solution is feasible as long as all communication partners adapt their in-house processing to the agreed EDIFACT standards. This conversion could be performed either by own programming efforts of the companies or using "converters", a software which enables the user to set up his conversion tables without software coding.

Solutions for other system incompatibilities exist only as individual solutions for special requirements. For a full user-controllable communication interface which can be installed individually for each communication link, a first prototype is available as discussed lateron.

Today it is in the hands of the user how systems will be linked with EDI because the organisation of information flows are not be seen as an own service.

Ports - or transhipment centers in general - are located in strategical points of international transportation chains. Physical cargo as well as information related to the physical cargo flows are handled at these locations.

During the last two decades the larger European ports developed and implemented information systems for port operations and for linking port users with "Port Community Systems" (e.g. INTIS in Rotterdam, SEAGHA in Antwerp, DAKOSY in Hamburg, BHT in the Bremen ports). But the acceptance of such systems is decreasing because companies prefer to communicate directly.

Recently, advanced telecommunication tools enable the automatic exchange of information for a variety of purposes. The scope is not only within one port community but also with other ports, customs, hinterland transport operators in order to ensure a smooth transportation chain especially in the mode change locations.

4 Development levels

Telematics applications in itself are mode independent. However, the implementation for the different modes as well as the requirements,
progress and levels of implementation are different.

Independently of the transport mode, EDP systems exist in different levels of technical sophistication, covering different parts of business operations which can be found in all sectors, i.e. order processing, client management, resource and personnel management, monitoring of operation, financial management and statistics.

Besides these mode independent functions, also mode specific applications can be found such as stowage planning, container stuffing and stripping, etc.

At present, the general situation is that bigger companies (especially shipping operators, ports) are further developed with EDP systems than small and medium-sized ones (SMEs).

Larger shipping companies have their individually developed internal EDP systems and networks which enable them to communicate electronically with all their operation centres and agents, often on a worldwide basis.

Shipping companies, specialised in container liner shipping, also increasingly develop and organise complete transportation chains. This enables them to take care of inland transport, either by truck, rail or barge. If they do not operate own equipment in inland container transportation, there is again a need to cooperate with inland transport operators in order to agree and guarantee reliable transportation chains.

The introduction of telematical applications for SMEs in shipping is delayed or even impeded by one basic fact: standard software for supporting shipping planning and operations are scarcely available on the software market whilst the development of individual software either by own staff or using external consultancy is often much too expensive and will not be taken into consideration by the companies' management. Therefore, short sea shipping operators are - similarly to comparable SMEs - sometimes a bit old-fashioned in operations and planning and operation support by telematical applications. This intensifies the impression to be a "slow and unreliable" transportation mode.

For truck operators, where the equipment can be planned and operated much more flexible than e.g. in short sea shipping, several software packages for fleet management, route planning, tracking and tracing are available on the software market. Moreover, due to the flexibility in operation, the negative effects of shortcomings in planning and coordination (and in relation to this, inefficient or even missing telematics applications) are not so evident compared to other transport modes because errors can be adjusted more easily.

The potential of short sea shipping for implementation of interesting telematical applications for raising the competitiveness is dependent on organisational changes within the companies. Instead of concentrating on the one transport link they are offering, global cooperative thinking, the provision of services organising complete transportation chains, lead automatically to requirements for EDI connections to the partners in the transportation chain as well as to efficient inhouse applications for optimising the whole planning and operation as discussed above.

5 Telematics services for SSS/RSS

5.1 Short Sea Shipping compared to Deepsea Shipping

In maritime traffic where deepsea shipping companies increasingly operate in Carrier's Haulage improving the speed, smoothness and quality of the whole chains and MTOs take over outsourced logistical functions such as storage, transhipment and final distribution. Furthermore, Shipping companies and MTOs have many communication partners (clients, forwarding agents, port operators, port authorities, truck operator, rail operator, barge operator, customs, etc.) exchanging a lot of different information such as orders from the
SSS/RSS has the potential for taking over the creation and link of applications in the SME area.

Shipper can treat SSS/RSS to act as swimming stores which can be optimally integrated into their procurement and distribution chains (with JIT or on-time-delivery concepts) if a reliable organisation is behind it and if the agreed spaces and delivery times are guaranteed.

5.2 Potential services of SSS/RSS

If SSS/RSS wants to be competitive to other modes it has to bring telematics services to a similar level as of the other modes and use their potential to offer additional services.

SSS/RSS can only take over cargo from other modes if SSS/RSS is better integrated. This integration can be obtained by following measures which all include telematics aspects to support them:

1. new forms of cooperation - supported by telematics systems
2. technical improvements
3. the integration of SSS/RSS services into distribution and procurement procedures („swimming store“)
4. the implementation of other adjustment mechanisms as compared to road transport (road: no possibility to look for alternatives in traffic jams because seldomly known in advance)
5. the possibility of exact monitoring and control of transport performances including the existence of reliable, alternative systems as fallback solution and information interconnection (e.g. to clients and other transport providers) for troubleshooting (e.g. low water -> shift to road transport!), using an open information system.
6. offering permanent available and updated status control, cargo tracking and location information (SSS/RSS tracking and tracing) not only for shipping operators, but also for the clients

7. matching more effectively the supply/demand, where SSS/RSS has to become more transparent to make the decider (i.e. the shipper/freight forwarder/MTO) knowing all possibilities and constraints (low/high water, availability, free space) enabling also a direct booking service

8. offering a reliable service guaranteeing transport, especially delivery times as they have been booked with fallback solutions if one link fails

9. improved coordination with resource management departments of other members in the transportation chain as well as coordination with Freight Traffic Centers (FTCs). SSS/RSS has to establish also new services as support and to control complete distribution chains to which all other actors can be linked. These systems must be open simultaneously to all other participants and the information must be highly confidential and thus protected.

For that reason, SSS/RSS has more potential than just increasing the speed of cargo movements. It could also offer services which are

- fully preplanned
- smoothly integrated in transport, information and planning chains
- customer oriented and individualised.

The flexibility to meet customers' requirements, which is said to be matched today only in road operations, have therefore to be extended not only to logistical services but also to telematics services.

These telematics services have to support logistical services and also to offer new functions, e.g. for outsourcing telematics functions. Some of these new requirements for telematics services identified could be met by SSS/RSS, e.g. for the preparation of freight papers or the fulfilment of reporting obligations, e.g. to send advance information to the port authorities, the port operators, the VTS stations, the port community systems, etc. This is especially the case if dangerous or hazardous materials are shipped.

Cooperation should become more open and flexible. Every partner must be able to communicate to all others in order to avoid "closed clubs" as the situation is today with fixed long-term cooperations.

6 The BOPCom project

6.1 Background and Objectives

In the transport area, many problems arise from the fact that the missing electronic data interchange is preventing intermodal transport including short sea shipping from being a competitive alternative to other transport modes.

BOPCom's main objective is to raise the efficiency of sea transport in Europe by developing a new telematics concept for the port and transport area including the support of SMEs offering low-cost solutions.

The direction is to do the step from isolated applications, separate communication links and manual interaction in data transmission towards integrated applications, central information bases per company or institution and automatic operation in data transmission along the complete transport chain.

BOPCom - with total costs of 5 Mio. ECU and a Community Contribution of 2.5 Mio. ECU - is one of the biggest projects in volume in maritime transport in the European Commission's 4th Framework Programme for
6.2 The BOPCom Application Modules

The capabilities and benefits of using the BOPCom Interconnectivity Manager will be demonstrated in several port related applications. All applications will be designed along common guidelines in order to make the results to be portable and transferrable to other ports.

For each of the applications scenarios will be defined involving users without appropriate application systems as well as computerised users for integrating their systems. Demonstrations will be made in the Baltic region, the Mediterranean and the Atlantic Arc starting in 1997.

Within the BOPCom project, an innovative concept for communication called „Interconnectivity Manager“, is in development. The Interconnectivity Manager will be able to link any kind of application systems so that they can interact automatically. Additionally an Internet/World-Wide Web links for users without appropriate application systems will be offered, e.g. for SMEs in the transport business.

Differently from existing value added services or port community systems the BOPCom Interconnectivity Manager can be installed and operated directly by a company or authority - having the control in their premises. However, if desired, it could be operated also by a service provider.

6.3 The BOPCom Interconnectivity Service

BOPCom does not stop with the transmission and conversion of data. The future is seen also in the support of companies and authorities for establishing and maintaining the EDI links to their communication partners.

Therefore, BOPCom focuses on two different lines:

The BOPCom concept foresees
- not only physical data transmission
- but also support for the establishment of bilateral communication links
6.4 BOPCom Highlights

In BOPCom an Interconnectivity Manager will be developed in order to link existing applications in the port and transport area without the necessity to adapt them.

The BOPCom Interconnectivity Manager enables the participation of SMEs without appropriate EDP systems in EDI using Internet/World Wide Web technology.

The BOPCom Interconnectivity Manager can be installed in a company or authority. BOPCom is not aiming at the development of a new Port Community System or a new central database. BOPCom will demonstrate the use of the Interconnectivity Manager in several port related applications in different European ports.

7 Summary and Outlook

There are some promising telematics services which could be offered by SSS/RSS.

- SSS/RSS could offer the organisation of transportation chains as MTOs perform today. An interesting aspect is the aspect of offering a service with guaranteed delivery times including fallback solutions if the envisaged transport route fails. It should be evaluated which levels of reliability requirements for delivery times are existing. These discussions should include organisational and telematical aspects, e.g.

for organising alternative transport routes as fallback solutions (internal adjustments) or to negotiate alternative delivery details with the clients (external adjustment).

- SSS/RSS could offer the organisation of information chains. Therefore, SSS/RSS has to offer services to interconnect with other members in the transportation chain. These services have to ensure a high level of flexibility and should be open to any other system. The development of interconnectivity tools for that purpose should be envisaged.

- SSS/RSS could offer the organisation of planning chains. Cooperative resource management with other partners in the transportation chain in order to obtain a maximum tuning of the planning and the operations along the chain is a service for interoperation. The development of a general approach applied in pilot projects, e.g. between SSS/RSS operators and port operators or between SSS/RSS operators and truck/rail operators should be envisaged.

- Tracking and tracing capabilities are important for the information and planning chains but should be seen as a real intermodal aspect covering not only one transport mode but the whole chain. Existing tracking and tracing applications for road and rail should be combined with maritime tracking and tracing systems (which only partly exist) in order to extend the coverage to multimodal transportation chains.

The concept of the Interconnectivity Manager developed in BOPCom is well suited to support also the integration of SSS/RSS into intermodal transport chains.

By improving this integration, transport organisers may include SSS/RSS into their considerations for being a reliable and predictable alternative to other transport modes. Therefore the acceptance and competitiveness of SSS/RSS can be increased.
Paper 8

Prof Dr P Engelkamp
Paper 9

Prof J T Pedersen
Improved Port/Ship Interface (The IPSI Project)

Summary

The IPSI project is a project funded by the European Commission under Transport RTD program in the 4th Framework Program for research. IPSI focuses on improving the interface between ships and other means of transport in an initiative to contribute to moving transport of cargo from land to sea in Europe.

The efficiency of the port/ship interface is considered crucial when introducing intermodal transport concepts with waterborne transport as important elements.

The paper divides Short Sea Shipping into three types of transport. Direct services, feeder services (not to be mixed with intercontinental feeder services) and inland waterway transport.

IPSI requirements for these types of interfaces are presented.

Context

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

Figure 1

Since cargo must be moved between ship/barge and land transport systems twice, the efficiency of the port ship interface in the multimodal context of a door-to-door logistic chain is of vital importance.
The challenge of the ports is that they must become more important interfaces in the transport chain as efficient and cost effective logistic hubs where all available modes of transport can be effectively interconnected. This applies to sea, rail, road, and to inland navigation as well. The interconnection of modes of transport must be based on competition and flexibility, i.e., interchanges between the various modes of transport must be possible wherever necessary and applicable.

In order to encourage Short Sea Shipping, ports must offer better and cheaper services to shippers and forwarders than other modes of transport by optimising their logistics facilities and procedures.

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

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

The IPSI project focuses on this integrated cargo-handling and vessel design.

Goals
The IPSI project objectives are:
- Developing new concepts for flexible and efficient port ship interfaces.
- Developing methods and equipment for effective transfer of cargo and information about cargo with focus on high efficiency and low investments. The equipment shall be developed to the extent that production documentation can be easily derived.
- Demonstrating the port-ship interface concept to verify the effectiveness of multimodal cargo exchange in a "door-to-door" context. The demonstrations are limited to computer simulation of the cargo handling system.

The Consortium
The consortium participating in IPSI comprises:
- Kvaerner of Norway - supplying high technology ships and systems for cargo handling and navigation globally. Kvaerner is the consortium leader.
- SAGA of France - transport and port operators in Europe and Africa
- PTC (Port and Transport Consultants) of Germany - owned by Bremer Lagerhaus Gesellschaft
- Jebsen Eurocarriers of Norway - specialist short sea shipping company
- SINTEF department of production and quality technology of Norway - contributes JIT and scheduling expertise
- MARINTEK of Norway - contributes logistics expertise, marine operations and vessel technology
- Fraunhofer Gesellschaft of Germany - contributes logistics expertise, computer technology, communication, and automation.

Work Breakdown Structure
Figure 2 shows the work breakdown structure of the IPSI project. The workpackage WP1000 is completed, and provided the basis for deriving the requirement specifi-
In IPSI, we have come to the conclusion that the types of cargo containment units described in this section shall be supported effectively. Furthermore, the IPSI project will actively investigate ways and means for cargo that normally does not utilise such units, to change to unitised, waterborne transport.

- **The ISO-container.** This is a family with a constantly growing number of members. In common they have the requirements for top-lift handling, stackability and the outer width dimensions. The most common dimension for length is 20 feet and 40 feet. The height is between 8 feet to 10.5 feet. The breadth is 8 feet.

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

- **Road Vehicles.** The trailer and the chassis are the most common natural

The workpackages WP3200, WP5000, and WP6200 constitute 50% of the IPSI project budget.

**Cargo Containment Units.**

In order to be efficient, the Short Sea Shipping concept must be based on handling a minimum set of standard cargo containment units. Ideally, only one type of unit should be used. However, the development of containment units on land and at sea has been going on for a long time, and there is a significant population of cargo containment units in circulation. Hence, it is unthinkable that anyone may be able to introduce a widely-accepted service for Short Sea Shipping if the condition was made that all current cargo containment units must be discarded.
containment units for the Inter European ro/ro traffic. The only «standard measurement» for this family of units is a max. breadth of 2.5 m (with some exceptions up to 2.6 m). The total length and weight/axle load varies. A standard is under development. The trucking units can participate in sea voyages as attended units, i.e. including truck and driver, or unattended.

- **The Swap-Body.** The swap-body is an effective containment unit made for trucks with adjustable air suspension. The principle for its handling is that the driver without external assistance can load and unload the unit. The swap-body exists in a few «standard-lengths» (e.g. 7.15 m and 7.82 m) and has an internal width permitting two Euro-pallets abreast. Although European recommendations go for the 7.15 and 7.82 units, in practice there exist a broad variety of lengths.

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

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

The CPC-box has gained an increasing market share and coverage across Europe. Several users are considering this to be a containment unit with high prospects for intermodal transports within Europe. About 20,000 CPC-units exist today in Europe (namely 40' and 45'). EU recently approved the 45' unit for road transport. The fact that the 45' CPC container is approved for road transport makes it the most interesting cargo containment unit in the IPSI project.

- **Heavy Duty Cassettes.** This group covers a broad variety of dedicated and some semi-standardised units designed mostly for high-density industrial cargo. The semi-standardised units applied in particular in Scandinavia and the Baltic are the cassettes. They can be described as heavy-lift flat-racks, or «rolltrailers without wheels». A normal carrying capacity for a cassette is 50 to 60 tonnes.

The cassettes have been popular as containment units for cargoes with high density like paper and steel. A common dimension is 2.5 m width and 12.5 m length. The cassette cannot be transported by truck and - for the moment - nor by rail. For the latter an intensive development is going on in Sweden. It is at the time being well suited for, but limited to, sea going transports - terminal to terminal.

**The Geographical European Network of Ports**

Before trying to derive the actual requirement specification for the handling of cargo, the IPSI project spent significant resources and time to try to understand the nature and potential of Short Sea Shipping in Europe. One of the tasks completed was to propose a network of ports that could form the basis for linking land and sea.
In addition to the most important intercontinental gateway ports - intercontinental feeder services may provide a base cargo volume for a future Short Sea Shipping network, the selected ports for Short Sea Shipping should satisfy the following criteria:

Based on these criteria, the network of ports in Figure 3 has been extracted.

The Short Sea Shipping Hierarchy
When trying to derive the requirements for handling of cargo in the context of Short Sea Shipping (SSS), it became clear that we had to distinguish between different types of SSS services. Using the illustration in Figure 3 as a background, we divided a future Short Sea Shipping concept into 3 types of services: Direct, feeder, and inland waterways. The motive for this division is to make sure that the specified requirements are unambiguous and clear, and that we are able to target the different needs of waterborne transport.

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

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

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

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

- **Inland waterways.** With inland waterway services we mean all transport service using rivers and canals in Europe. For the purpose of IPSI specifications, we will be handling these services as one group, despite the fact that there are large variations in capabilities, infrastructure, etc.
Cargo Handling Requirements

To establish unbroken chains, the cargo handling system should provide efficient means for moving cargo containment units between the various transport modes used in the transport chain. This results in the following set of interfaces:

- Sea - sea (between feeder and main leg and between main legs)
- Sea - land (between sea and rail and between sea and trucking)
- Sea - inland waterways (sea - barge connections)
- Inland waterways - land transport (barge - rail or truck connections)

The requirements will be linked to two interrelated aspects:

- The physical handling of the units
- Loading operations (Loading and lashing)

Unloading operations
Terminal support operations:
- Terminal movements of containment units
- Storage and stocking of containment units in terminals

For all operational aspects above, the system should provide:
- Required safety level for people involved in the operations
- Required low level of risk for cargo damages
- Safety requirements for handling of dangerous cargo

- The cargo management process: To be able to operate on a high level of effectiveness, IT support will be necessary to achieve the required speed in managing:
  - Positioning of cargo onboard

Figure 3
transport units and in terminal areas:
- Sequencing of loading and unloading operations
- Control functions related to cargo
- Handling of associated trading and transport documentation

The rest of the paper will deal with physical handling of cargo only.

In accordance with the previously described hierarchy, the specification of cargo handling requirements will be divided into three classes:

- **Direct line connections**, supporting the main legs.
- **Feeder lines** - feeding the direct lines.
- **Inland waterways**.

For each of the three scenarios, the IPSI project specifies the following types of requirements in detail:

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

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

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

In addition, general requirements related to shocks, vibrations, other transport environmental requirements (temperature, humidity), ISO equipment standards, handling of dangerous cargo, and safety level of people involved, are provided in the IPSI documents.

To give an insight into the way the IPSI requirements are formulated, two examples will be provided. Both are related to loading operations (unloading operations are approximately symmetric to these).

- **Direct line connections**. Here the main challenge is to make sure that
the frequency of direct lines can be supported. This leads to high demands regarding speed in the cargo handling processes to reduce port times for vessels to a minimum.

In terms of operational efficiency, the loading capacity should be increased compared with present levels of streamlined operations. This means that the targets for the loading capacity should be in the level of 400 TEU per hour or more, and for the cost of operations the level should be at 25 ECU per TEU or less. An equivalent way of expressing this requirement is to indicate that a ship with 200 trailer loads should be turned around in port in 2 hours. Operationally, the terminal movements and positioning of cargo after the actual loading should be direct without breaks in the work process and physical movements.

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

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

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

Table 1 summarises the most important requirements and indicates how the realisation of each individual item can be measured against the requirement.

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

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

For inland waterways, capacities and cost levels should be similar to those indicated for Short Sea Shipping feeders.

**Next Phases**

The current status of the JPS1 project is that a number of alternative cargo handling concepts and vessels designs are being elaborated. All cargo-handling concepts that are further developed are based
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Target</th>
<th>Measurements</th>
</tr>
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<tbody>
<tr>
<td>Loading capacity</td>
<td>400 TEU hour</td>
<td>Actual loading capacity</td>
</tr>
<tr>
<td>Cost of operation</td>
<td>25 ECU per TEU</td>
<td>Actual loading cost</td>
</tr>
<tr>
<td>Impact on carrying capacity of vessels</td>
<td>No loss in payload capacity</td>
<td>Deviations from target</td>
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<tr>
<td>Positioning of cargo within vessels</td>
<td>Automated planning capabilities</td>
<td>Coverage of automated capabilities</td>
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<td>Automated lashing and stowing</td>
<td>Automated lashing and stowing systems in vessels</td>
<td>Deviations from target, Time and cost of lashing operations</td>
</tr>
<tr>
<td>Lashing of cargo on heavy-duty cassettes and roll-trailers, and within containers</td>
<td>Depends on cargo (differentiated targets to be set)</td>
<td>Time and cost of lashing</td>
</tr>
</tbody>
</table>

Table 1. Requirements example. Direct line connection.

on horizontal movement of cargo.

The initial designs of the vessels and cargo handling concepts will be completed late in 1997.
Paper 10

Prof dr ir J J M Evers
DiTrans: a program for the development of an integrated system for robotized large scale container transport

1 Summary

1.1 The motive for the DiTrans R&D project

The combination of large-scale water and land transport, industry and metropolitan residential areas is characteristic of the mainport Rotterdam. In 1991, the mainport contributed about 50 billion guilders to the gross national product. The total port associated employment covered circa 300,000 jobs. All current transport modalities are present for freight traffic in 1990, sea-bound transshipment amounted to circa 290 million tons.

The modal split for the hinterland was: inland water transport approximately 47%, railway approximately 3.5%, road approximately 24%, pipelines approximately 20%, and sea approximately 5.5%. Bulk transport (coal, oil, oil products, ore, raw minerals and raw building materials) is by far the most extensive; the share of container transport is circa 30%. Though the majority of the containers are directly shipped in transit, this transport segment is the most important for the additional value in the form of production, distribution and other services. The mainport to hinterland transport of containers is now circa 65% by road, circa 25% by inland water transport and circa 10% by rail.

The liberalization of trade, the opening up of Eastern Europe, and the increase in and spreading of prosperity will lead to a sharp rise in international goods transport, especially with respect to transport by container. If Rotterdam can manage to keep its competitive position and provided there is sufficient expansion and improvement of transport connections with the hinterland, a tripling of container transport is to be expected in the next 15 to 20 years, amounting to 6 million TEU per year (1 TEU is one 20 foot container). Currently, road transport is a bottleneck. It is an important cause of congestion on the road network and burdens the environment. It is far from sustainable, in the sense that it is more damaging to the environment and uses considerably more energy than inland water transport and rail transport. The policies of European and Dutch authorities are therefore aimed at reducing road transport. Because 65% of container transport is currently by road, this might threaten the competitive position of Rotterdam. The policy in the Netherlands therefore aims at stimulating transport via inland waterways and by rail. For this, the necessary direct link with the German railway network is being prepared (the Betuwelijn) and the harbour railway line is being provided with electrical overhead lines and doubled in size. Possibilities for improving transport via coastal and inland waterways by scaling up and introducing adapted transshipment techniques are also being sought. This does not change the fact that road transport will increase and that substantial expansion of the trunk road system is being considered.

Two R&D projects have been formulated based on this background, namely CombiRoad and DiTrans. CombiRoad concerns the development of an automatic conveyor track with switchpoints and automatic tractors. The tractors ride on
pneumatic tyres, are electrically powered and run at no more than 50 km/h. The individual vehicles offer much more flexibility than the railway and make intensive use of equipment possible. Due to the low speed, energy consumption and noise level are also low. The continuous character of automatic transport means that it has a high capacity.

DiTrans, short for "Delta Integrating Transportation", concerns the development of an automated transport system which provides intraterminal and interterminal transport that is fully coordinated over a large area (up to 100 kilometres). The integral coordination means that current terminal facilities and vehicles can be used as effectively as possible and the number of transshipment operations can be kept to a minimum. In this case, the entire network of terminals functions as a single, large-scale terminal. The project includes integral control, the design of multifunctional vehicles and the introduction of these vehicles. Although the projects were initially independent (CombiRoad run by Hollandia Industrial Company N.V. and DiTrans within the Department of Transport Technology at the Delft University of Technology), the further development will be coordinated with the intention of strengthening both projects. Under CombiRoad infrastructure, vehicles and control systems are developed for transport over longer distances. DiTrans aims primarily at the integral control of the transport operations at and between junctions, the design of a multifunctional vehicle and its introduction.

The R&D programme presented here only concerns DiTrans. The project has a long history, starting with a number of doctoral projects executed by the Technical Mathematics and Informatics Faculty [Kuij], [Dek], [Tal], [Baa] and the Mechanical Engineering & Marine Technology Faculty [Bos], [Hogl], [Hog], [Koo], [Mey], [Kop], [Bes]. In this project there was close cooperation with ECT bv, NV Airport Schiphol, EECV bv, Pax bv, Stim bv, NedLloyd bv, ICHLogistics bv and ARB bv. The programme was further expanded by the TRAIL Research School [Eve]. The inclusion in the "ICES Transport technology" fund gave the decisive push. Funding and support from the Ministry of Transport, Public Works and Water Management (AVV service), means that "Combined Transportation" has been linked with the "Incomaas" and "Smartcart" projects, which are concerned with the structure of the Maasvlakte and the information/legalization involved in solving the container transport issue, respectively. The "ICES Transport technology" fund aims at realizing a knowledge infrastructure in the field of transport in such a way that the competitive position of the Dutch transport sector can be consolidated and the development of a sustainable and environmentally friendly transport system is encouraged.

1.2 The geographical field of study

In principle, the CombiRoad and DiTrans projects aim at the development of a generally applicable transport modality by land. The possibilities and the cost-benefit analysis of this transport modality are, however, examined on the basis of a hypothetical introduction in the Rijnmond area, running from the Maasvlakte up to Kijfhoek (between Barendrecht and Zwijndrecht); this area is shown in figure 1. In the Department of Public Works Maricor Study [Mar], the following developments have been mentioned for the rail and road network:

Extension of the A15 motor way (south of and parallel to the Nieuwe Waterweg) up to the Maasvlakte by reconstructing the current Europaweg.

Following the completion of the A4 (Benelux/The Hague), the realization of the second Benelux tunnel.

Construction of a southern continuation of the A4 linking up with the A29 at Klaaswaal, for a connection with Antwerp via Bergen op Zoom.

Construction of the Betuwelijn with doubling and electrification of the harbour railway line (south of and parallel to the Nieuwe Waterweg).

![Figure 1 The AIT-zero option](image1)

Figure 1 illustrates the expected situation in the future should the connection via CombiRoad not take place. This will be referred to as the "CRNuI" option.

![Figure 2 The AIT-EW option](image2)
The Maasvlakte itself will consist of several terminals: the transport could take place via a system similar to DiTrans. The loading/unloading of containers for rail and road transport will happen at the Rail Service Center (RSC) and the Truck Service Center (TSC) respectively. The CombiRoad infrastructure can be implemented in several ways; two options have been indicated in figures 2 and 3.

In the CRNul option, the RSCs and the TSCs concept that is sufficient for each scale of extent. This option may lead to a substantial reduction of road transport in and round the Rijnmond area.

1.3 The critical feasibility factors and the object of the research

At present the Delta terminal is the only operative automated terminal in the world. The terminal has 48 centrally guided robot vehicles. To make the DiTrans function effectively, at least 800 vehicles, to be used in coordination, will be needed. This makes higher demands upon the integral management concept than can be handled by the present Delta terminal. This is particularly true for the coordinated use of the scattered storage capacity, the coordinated deployment of vehicles and for integral vehicle guidance. This is one of the main points of the DiTrans programme. New control concepts offering good results are used as a starting point. The R&D programme provides an effect and verification based on simulation. The challenge is to develop a control concept that is sufficient for each scale of extent. Another critical aspect concerns the robot vehicle. The vehicle used at the Delta terminal is equipped with high pressure aeroplane tyres and has no springs; this is possible because a low speed is maintained. This concept has been chosen because such a vehicle can be located more accurately than a vehicle with springs, which offers advantages for use in a robotized environment. In relation to interterminal transport, such a high speed is necessary for the DiTrans concept that suspension systems are also necessary. This means that the coherent position problems should at least be charted carefully. A second problem is the multifunctionality that is required of the vehicle. This concerns the drive and the option to use standardized trailers which are also suitable for the normal road traffic.

On the interterminal connections (the CombiRoad infrastructure) the vehicle is electrically powered. However, electricity cannot be supplied on the highly frequented terminal. So a diesel engine will be necessary. As mentioned, two variants of the robot vehicle are being considered: one carrying the container itself, and one towing a trailer. The first variant fits in best with the robot vehicle of the Delta terminal. The variant to be driven with trailers - a robot tractor - has special control problems. The robot tractor/trailer combination has to be able to be controlled quickly and accurately, also when driven in reverse. Moreover, the trailer has to be automatically (dis)connectable. The DiTrans project provides the development of a conceptual design of such vehicles and verification based on simulation. This corresponds to the vehicle design that is being developed for specific use on the CombiRoad infrastructure within the scope of the

![Figure 3: The A1T-KH/ZB option](image-url)
CombiRoad project. In principle, the standard product range of the automobile industry is used as frequently as possible for both types of vehicles. A third critical aspect is the possible integration and realization of DiTrans, especially the feasibility of managing realization, the safety, the integration and social acceptance and decision-making. The feasibility of managing realization is being considered on the basis of a cost-benefit analysis and is done in cooperation with CombiRoad. To this end DiTrans is developing a generic simulation model. In this model the input of a DiTrans configuration must be possible, as should a confrontation with future scenarios on transport demand. Next, a check-up using simulation should also be available to discover the capacity required of transport vehicles, the extent to which this capacity can be used effectively, and the extent to which road transport can be reduced. Conclusions can be drawn from this that will affect financial exploitation. Studies on simulation will be conducted on the options mentioned in § 2.2. The case studies will be carried out in cooperation with CombiRoad. Safety, reliability and the way in which it is possible to prove that the system meets the demands made are all critical elements in the acceptance of the large-scale transport system in view. For a new transport facility a model approach will be necessary which can be applied to the vehicle, the infrastructure and the guidance of the vehicle. A systematic approach for incident handling will also be required. Within the scope of CombiRoad the legal standards will be tested. Under DiTrans this will be translated into a general approach on the basis of mathematical probability models, which will be applied on DiTrans case by case. The integration and social acceptance, and decision making have to be regarded as critical elements. Important aspects of implementation are the transport market and the physical route of realization. With respect to the road transport market, the important aspects are the operational communication (notification at the moment of arrival), the rate structure and level, and the link-up with management, where regulations governing driving hours or the possibility of organizing regular shuttle services may be considered. The connection to railways and inland water transport also have to be charted in this way. For the physical route of realization, it is important phases be selected that allow exploitable and payable situation to arise in each phase. The first step will have to be the creation of an experimental section of line, which could later be included as part of an exploitable (intermediate) stage. In acquiring socially acceptable safety (group risks and individual risks), the natural environment (spatial integration) and sustainment are very important. These aspects can only be evaluated in connection with and against possible alternatives, which include road, rail and inland water transport. Another element is the actual social decision-making and social implementation of the decisions made. This concerns a complicated managerial issue, where a systematization is needed that is able to support the progress of such processes. The DiTrans project provides for the development of a general systematic approach to integration and acceptance which, in connection with the CombiRoad project, will be elaborated for the CombiRoad infrastructure.

1.4 Results in view and planning of the R&D programme

The aim of the programme is to increase knowledge and insight in the field of large-scale automated transport processes, especially for the transport of containers, in such a way that it contributes to the knowledge infrastructure in the field of transport, infrastructure and logistics. The objective is a general one in the sense that the developments are considered in coherence with applications in other fields of transport. Naturally, the primary objective is the DiTrans concept itselfs. The development of concepts, analyses, performance studies and possibly the development of special methods contribute to knowledge and insight. These contributions to the knowledge infrastructure are made through the development of (in principle) practical software modules, the development of a generic laboratory, and not least by establishing lasting cooperation within the transport sector and with the creative industry in this sector. In the DiTrans project six subprojects have been identified, for which the following results are planned:

(i) Logistics coordination and deployment of capacity:
   - The conceptual model and the performance indicators.
   - Integration with the general control model.
   - Optimizing procedures and software modules.
   - Systematic behaviour and performance research based on simulation.

(ii) Traffic control and vehicle guidance:
   - The conceptual model and the performance indicators.
   - Integration with the general control model.
   - The performance indicators.
   - Procedures for traffic control and vehicle guidance and software modules.
   - Communication technology.
   - Systematic behaviour and performance research based on simulation.
   - The development of principles for the design of layout and traffic control.

(iii) Laboratory for DiTrans configurations:
   - Set-up of the general DiTrans control
model.
- The conceptual model based on the general control model.
- Definition modules for layout, control modules and structure of the demand for transport.
- Parametric modules.
- The simulation modules with aggregation levels adjustable in a differentiated way.
- Evaluation modules.

(iv) The robot vehicle:
- Function analysis and performance indicators.
- Modularized conceptual design.
- Generic models for internal control, the dynamic behaviour and energy consumption.
- Options for materialization based on the assortment of the automobile industry.
- Cost price and exploitation analyses.

(v) Safety of modular configurations:
- Inventorization of safety standards concerning the robotized transport.
- The conceptual model.
- Mathematical analyses.
- Incident simulation for modular configurations.

(vi) Integration and social acceptance:
- Management integration in the transport sector.
- Phased structure of a DiTrans network.
- Systems of acceptance and social decision-making.
- Implementation scenarios.

The concept in question, i.e. the R&D programme DiTrans, serves as starting point of the research. Each subproject starts with a conceptualization phase in which the projects presented here are elaborated, tested for consistency and (general) practical usability and, if necessary, adjusted. The resulting conceptual model will be presented in a report to be published. The conceptualization phase will, in general, have to be completed within six months. Thereafter, the further elaboration of this will be completed within three years. In principle, the results will be published. Special attention will have to be given to the coherence of the subprojects i, ii and iii, conceptually as well as through further elaboration. Also the subprojects ii, iv and v have to be coordinated, at least on a conceptual level.

2 The DiTrans concept

2.1 CombiRoad: the design and the relation with DiTrans

CombiRoad is a transport system which creates the possibility of having unmanned, automatically guided vehicles moving on specially constructed tracks - so they do not use the existing rail and road network. As represented in figure 4, the track is provided with rails, either side of which is an even road surface on which vehicles with pneumatic tyres can ride. The robot truck rides on pneumatic tyres, allowing directional control by rail. The grip of the tyres on the road surface is substantially greater than the grip of steel wheels on rails. As a result, approach roads and exits can be steeper (and thus shorter) than those of the railway. The also shortens the braking distance considerably.

![Figure 4 Combi-Road track](image_url)

Figure 4 Combi-Road track

The robot tractor is electrically powered and moves at a maximum speed of 50 km/h. Because of the use of pneumatic tyres, the noise level is considerably lower than the legal maximum standard. The robot tractors are automatically controlled. As a result of this control, the vehicles maintain a fixed minimum distance from each other: about 100 m for the connecting level routes and about 50 m for approach roads, exits and switchpoints. At the switchpoints themselves, when moving at a low speed (5 km/h), the vehicles ride on accumulators. This automation leads to a great reliability and safety, reduces the dependence on conditions of employment (e.g. the regulations governing driving hours) and leads to lower labour costs. A robot truck transports the containers separately; i.e. no more than one vehicle at a time. The container is put upon a semi-trailer car towed by the truck.

The transfer at switchpoints takes place between current transport modalities: e.g. an exchange between an electric robot truck. Because the robot vehicles ride separated from each other at an ample distance, the track is burdened far less than when trains are used. As a result, roadways and foundations can be much lighter and consequently less expensive than road or railway. Also the possibility of building steeper gradients and sharper bends leads to lower costs of construction, lower space occupation and less visual pollution.

DiTrans concerns the development of an automated transport system with which
intraterminal and interterminal transport is completely coordinated over a large area. Such a transport system will have to make use of an automated infrastructure for transport between the junctions.

It is obvious that CombiRoad's aim is to develop such an infrastructure, especially with respect to the road and traffic control system on the roadway. In the DiTrans concept, however, the operationally limited switchpoints of CombiRoad are extended to terminals which, in principle, can provide the complete scale of transfer and storage facilities in such a way that all transport and transfer operations are integrally coordinated. Thus the number of transfer operations and empty transport runs can be reduced to a minimum. So this coordination or control is considerably more complex than the control required for CombiRoad. Higher demands are also made on the functionality of the vehicle. At the terminal, instead of using a mono track to drive on, a network of traffic lanes is used on which a large number of robot vehicles operate simultaneously. This requires a powerful vehicle guidance system, by which the separate vehicles are equipped with an intelligent control system. It is not possible to provide electric energy from the track and the distances to be covered at the terminal (or the junction) are too large to make use of accumulators. This leads to an electric-hybrid drive: a diesel engine takes over propulsion at the terminal for which a speed of 20 km/h is sufficient. Movement on CombiRoad takes place electrically at a maximum speed of 50 km/h. It should be mentioned that at present, besides individually operative AGVs (automatically guided vehicles), a so-called multi-trailer transport system is also used at ECT's Delta terminal. In such a system a trail of five trailers is towed by a tractor that connects them automatically. The advantage of this for individually operative vehicles is that it allows a (expensive, in this case manned) tractor to transport more containers at a time. The disadvantage is that the containers encounter delays, because the formation of a trail takes time. In practice it turns out that a transport is often executed with an incomplete trail and that the equipment can be used much less intensively, also due to extra waiting times, than with individualized transport.

The multi-trailer system is difficult to combine with individual container transport as it is desirable in an automated system that has maximum flexibility. It cannot be combined with the CombiRoad concept as outlined before. For this reason the multi-trailer system is not taken into consideration. The R&D route for CombiRoad and DiTrans, as settled in the coordinating R&D programme Combined Transportation, reduces the time it will take to realize the CombiRoad project to two years and that of DiTrans to 3.5 years (DiTrans starting 6 months later). The technical knowledge developed in the CombiRoad project is passed on to the DiTrans project. DiTrans supplements this technological development and extends it in such a way that it is applicable to the operations at the terminal. Joint research is also carried out in the fields of logistics integration, cost-benefit analyses and implemental policy. Combined efforts are planned in the area of knowledge transfer and a social knowledge infrastructure in the field of transport technology.

2.2 Transport operations from the DiTrans point of view

From a technological point of view the DiTrans project aims to develop an effective control system for the vehicles and further elaborate the design of the vehicle such that it can meet the demands made on it within the context of a (semi)automatic transport, transfer and storage system. Only those transport processes and implements are taken into consideration which are relevant to this aim. With a view to functionality then, two types of vehicles for use at the terminals and on CombiRoad are, in principle, considered: An interactive guided tractor able to tow a connectable semi-trailer car and an interactive guided vehicle carrying the container itself.

These vehicles, which are not supposed to be used on public roads will in future be referred to by the term terminal vehicles. The straddle carrier - a manned, free riding, portal shaped, self-hoisting vehicle for transporting containers in a hoisted state - will not be considered here. The reason for this is that this vehicle does not fit in well in a robotized transfer system and presents problems with respect to reliability and labour safety. The external vehicles in this connection are ships, trucks (with semi-trailers) and railway wagons, all vehicles that make use of the usual infrastructure. In current practice transfer takes place exclusively through terminal vehicles and largely via the stack (storage depot); so there is no direct transshipment from ship to train or the other way around: The reason for this is that the dynamics of the supply and transport of containers is so very different that uncoupling for storage (of short duration) is largely unavoidable. Moreover, the physical layout of the terminal imposes restrictions. Direct transfer between external modalities, therefore, will not be considered.

In constructing the Delta terminal, the plan to have the internal transport carried out by manned tractor/trailer combinations was abandoned, because it cannot be sufficiently controlled and, moreover, presents problems with respect to reliability and labour safety. The combination of a standardized semi-trailer with a robot truck.
however, can be reliably controlled and can, in principle, meet the current safety criteria, provided the coupling/uncoupling can take place automatically. Of course, trailer/robot tractors should be used in places where the manned road tractors and robot tractors are interchangeable. This transport modality is taken into consideration in the R&D project within the context of CombiRoad and the integral transport objective of DiTrans. In designing the Delta terminal, the possibility of constructing rails as an internal transport facility was abandoned after an extensive study. The most important reason for this was that it would greatly limit the flexibility of the physical layout and that, due to the large bends necessitated by railway tracks, the site would be structured less efficiently. Apart from the moving equipment described so far, the terminal also provides for the storage of loaded and empty containers and the parking of terminal vehicles. In the DiTrans project the following concepts are assumed:

- Automatic stacking facility (ASF):
  - depot for loaded (or possibly empty) containers with relevant interactive guided stacker crane (one or more).
- Automatic depot empties (ADE):
  - depot for empty containers (empties) with relevant interactive guided stacker crane (one or more).
- Packing place for operational terminal vehicles.

The automatic storage facility as currently used at the Delta terminal consists of a fast riding portal crane over the stack, where transfer takes place at the ends of the crane track. Another concept concerns a slow riding portal crane which reaches both over the stack and the track of the terminal vehicle and where the transfer occurs on the side of the stack. The storage of empty containers differs in a number of aspects from that of loaded containers. So, stocked empty containers need not necessarily be selected individually, whereas this is the case with loaded containers. Besides, because of their low weight, empty containers can be stacked much higher than loaded containers. Even though the transfer company is familiar with a considerably greater assortment of implements, in view of the R&D objectives the set-up outlined is sufficient to serve as a starting point for the DiTrans project.

2.3 The structure of DiTrans configurations

For the development of techniques for integral control, an abstract model of terminals and the CombiRoad connections between the terminals will do. At the level of the terminal this model has to provide the function characteristics of the transport facilities mentioned in § 2.2, the interaction characteristics, the condition space and condition transitions, and the control characteristics. In support of the design process it is necessary to be able to visualize the geographic structure from the outlined point of view such that a picture is created of the spatial situation of the facilities, the internal tracks and the connection(s) to the DiTrans network. Figure 5 gives an example.

![Figure 5 Scheme of a terminal](image)

The tracks indicated at the terminal for the robot transport, many in no way be fixed in the form of physical tracks or physical guidance provisions. For example, ECT's Delta terminal operates using the flexible navigation technique FROG (Free Ranging On Grid), developed by Industrial Contractors Holland B.V. The location in this system is controlled with the help of odometry, combined with verifying the position of a grid pattern of transponders put into the road surface. Odometry is a technique used to estimate the distance covered via wheel rotation and position. When a vehicle rides over a transponder in this system, this is activated by an antenna located under the vehicle, through which the exact position of the vehicle is passed on, thereby verifying the positioning system. This system is particularly flexible because the layout of the tracks can be arranged by means of software and, if required, dynamically. In this way the positions and lengths of the sea vessels present can be taken into account at every moment to the benefit of the routing along the quays. The terminal models can then be included in a network for automated interterminal transport (CombiRoad).

In the interest of surveyability, a higher abstraction level will have to be used for this purpose. Figure 6 gives an example.

![Figure 6 Layout scheme of a DiTrans configuration](image)
In this representation, areas can be indicated in which several terminals are possibly situated. This is the case for the Eem/Waalhaven area and the area of the Maasvlakte in this example. In order to be able to use such schemes in designing terminals and then use them in analyzing transport, it should be possible to configure and parameterize them and then generate a simulation programme based on this. Configuring at the level of the terminal means that the representations of the various terminal facilities are adopted in combination with the possible tracks and connections. At the level of the DiTrans network this configuration takes place by introducing the CombiRoad connections, the crossings, the parking places and such, and the relevant terminals. In parameterizing, transport facilities are further specified if necessary. For an automatic stack of containers, for example, specifications are needed for dimensions, stacking height, transaction times and such. The schemes are suitable to both generate simulation models and represent the results of simulation experiments conveniently arranged or, if desired, can be used as a basis for animations.

2.4 The DiTrans facility scheme

For the structure of the activities surrounding the transport of containers as represented in DiTrans, the so-called TRAIL facilitation model [Eve] forms a suitable starting point. This model, aggregated for DiTrans, is represented in figure 7. So, the DiTrans system is conceived as consisting of four layers; in figure 7 these are printed in capitals. Every underlying layer provides service to the layer above it; the layer lying above makes demands upon the service provided by the underlying layer.

The thus layered system as a whole provides service to the container transport market and relies on resources such as the available space, the industrial environment, the natural environment, investment funds and, finally, social acceptance. The coordination between this support and the supported layer takes place in the interfaces; these are indicated in small print. Within the DiTrans context, the layer infrastructure includes the tracks with relevant fixed provisions from CombiRoad and the terminals; the control hardware and the organizing institutes are counted as part of the infrastructure as well. The layer means of conveyance pertains to the facilities indicated in § 2.2. For the R&D programme DiTrans, the terminal vehicle and perhaps the relevant standardized trailer are especially important. The layer transport units refers to the containers, insofar as these are found in the physical process of transport or which the provider of transport services anticipates during operation. Apart from the loaded containers, this also pertains the so-called empties (empty containers). The layer freight indicates the object being transported which, being included in transport units, has to be moved by the system and thus determines the origin and destination of the relevant transport units. Essential for the functioning of the whole are the interfaces: here the coordination and control activities take place. The interface market positioning concerns the interaction between the (potential) customers and DiTrans as provider of services. In this connection the spatial situation of the DiTrans network is relevant, as are the integration with the other transport modalities (including the protocols for exchange of information, taking over and liability) and the applied tariff systems.

Figure 7 The DiTrans facility scheme

Within the intermediate layer logistics coordination, the tactical/operational interaction between the containers available for transport and the transport services occurs. This concerns the coordination of capacity at an aggregated level (so starting from numbers of containers split up according to origin, destination and coarse-meshed time frames) and the issue of individual transport, transfer and storage tasks. At this stage, however, it is still independent of the way transport is carried out. The quality of the logistics coordination can be improved, and with it the quality of service provision, by using real time protocols for information exchange (EDI). The choice of the terminal (or stack) for the storage of a container is relevant in this connection. Namely, suppose a container has been supplied at terminal “MV1” at the Maasvlakte and that this container will be collected per trailer at the “TSCE-em/Waalhaven” half a day later at the earliest. This instruction can be executed in two ways: (1) by terminal vehicle from ship to stack at “terminal-MV1” and on-call by terminal vehicle from stack at “terminal-MV1” to the “TSCE-em/Waalhaven”, to be delivered immediately at the tractor, or (2) by terminal vehicle from ship to stack at “terminalEem/Waalhaven” and on-call by terminal vehicle to the “TSCE-em/Waalhaven”, to be delivered immediately to the tractor. Both operations take up just as much transport capacity. However: (1) is preferable if there is a peak load at “MV1” (for instance, because all
In allocating depots, future restacking should be prevented as much as possible; restacking is necessary if a container has to be hoisted from the stack upon which another container has been placed previously, necessitating this first container to be put aside. When issuing trip orders, the movement of empty vehicles between successive operations should be avoided as much as possible for the sake of efficiency. This will be further elaborated in chapter 3. Within the context of the DiTrans project, the interface traffic control pertains to the generation of suitable routes for the terminal vehicles (for which the starting point and destination, with time conditions are known as part of a driving order) and the implementation of priority rules for the critical zones (crossings and guarded sections) such that collisions are avoided, waiting times are restricted as much as possible, and a sequence conditions required are dealt with (included in the driving order and originating in the ship loading plan). This will be further considered in chapter 3. The interface resources management initially concerns the spatial situation of terminals to be constructed or extended and the choices of route for the CombiRoad infrastructure to be built. It then handles the implementation scenarios. Starting points for the spatial situation are, in this case, involve concern for the living environment and the natural environment. Starting points for the development of implementation scenarios are the phasing in of exploitable partial implementations, which include obtaining potential markets, financing, a social basis, social decision-making and the elaboration of the design for the building instructions to be issued. Through various ways of elaboration, the DiTrans project pertains to all interfaces and the multifunctional terminal vehicle. Moreover, with respect to the vehicle and vehicle guidance, attention should be given to safety, both preventive and incident handling (reception and restore).

2.5 The integral DiTrans control model

Along the line of the DiTrans facility scheme, the integral control of the DiTrans process covers the interfaces logistics coordination, allocation of capacity and control of equipment. As indicated in the function diagram in figure 8, integral control is to be divided into five segments, indicated as: (1) "handle the demand for transport"; (2) "coordinate the deployment of capacity"; (3) "generate driving orders", (4) "control traffic & vehicles" and (5) "control storage and transfer". The first two segments belong to the interface logistics coordination; the third segment is typically allocation of capacity; the last two segments belong to control of equipment. Here the point of view is that of control at an operational level. The segment
Figure 9  Experiment with DiTrans configurations

"handle the demand for transport" concerns receiving operational information from external input in the conveyor chain (including orders from customers), the translation of this into internal orders of transport and carrying out external and internal instructions, and following the separate containers. This is elaborated in §3.1 (figure 12). The segment "coordinate the deployment of capacity" includes the use of DiTrans capacity at an aggregated level, the control of the transport process at a supervising level, the identification of exceptions (incidents) and the handling of exceptional situations. A linear programming model for the coordination of capacity allocation is given in §6.2. The segment "generate driving orders" deals with the (semi-real time) deployment of (robot)vehicles such that the instructions are executed in time and the vehicles are as efficiently as possible under those conditions. This matter will be dealt with in § 3.2 and § 3.3 (figure 15).

The activities under "control traffic & vehicles" concern the guidance of many robot vehicles within a complex infrastructure in such a way that waiting will be avoided as much as possible, that a high degree of implementation reliability is achieved and the capacity of the infrastructure is utilized as efficiently as possible. This is the subject of chapter 4 (figure 21). The segment "control storage and transfer" deals with controlling/instructing the transfer implements at the service centres and (automatic) depots. As one of the first phases, the R&D programme provides for the elaboration and validation of the integral control model such that the further elaboration of modules for logistics coordination, deployment of capacity and control of transport modalities can take place in perfect agreement with this. This model forms the basis of the simulation model within the "DiTrans lab".

2.6  Set-up of a DiTrans laboratory

The aim of the laboratory is to examine, via simulation, the operation of real, hypothetical or still to be designed DiTrans configurations with which various perspectives or objectives serve as starting points. A DiTrans configuration is therefore understood to be the coherent (formally consistent) functional pictures of terminal layouts, interterminal networks, information supply and control protocols. The simulations to be carried out involve the following functions:

(i) spatial structure and dimensioning;
(ii) validation and verification of control procedures and/or software;
(iii) research of behaviour and performance;
(iv) research of the logistics integration;
(v) exploration of measures to be taken when dealing with incidents;
(vi) training, e.g. in connection with incident handling;
(vii) real time anticipation for the, (short) prior identification of undesirable situations.

The objective of the studies of the types (i) to (iv) inclusive is supportive within the scope of designing transport facilities or making policy decisions and is, therefore, of a strategic or tactical nature. The simulations of types (v), (vi) and (vii) take place at an operational level; (vi) and (vii) even "real time" with the (simulated) physical processes. In view of the limited means available, the R&D programme cannot provide the elaboration of all functions mentioned.
However, the development is considered to be of a conceptual model which, in principle, includes these functions. The starting point for this is the function model for control according to figure 8. The functions to be provided by the laboratory in view are indicated in the SADT diagram of figure 9.

Under the title "configure physical objects" the functions define spatial structure configurations (layouts) (see § 2.3) with the relevant implements (see § 2.2). This takes place on the basis of a library of software modules in which the "behaviour" of the physical objects is represented. In setting up such a configuration a hierarchical structure is followed, in the sense that configurations defined previously are to be reincorporated as part of an enclosing configuration, provided of course that certain composition rules (to be developed) are observed. In this way a "layout file" can, if desired, be drawn up and the objects in it can then be used in different ways. For the traffic infrastructure a similar construction is described in § 4.2 and § 4.3. In addition to the regular "behaviour", "exceptional behaviour" could be included in these software modules as well, e.g. failure behaviour. This provides starting points for the set-up of experiments in the field of safety, reliability and incident handling. The title "configure control and the demand for transport" refers to functions that add certain "software" elements to selected physical configurations, such as: (1) control and information protocols; (2) protocols for incident handling; (3) modules for the communication with external players, such as transporters; (4) modules for the dynamics and the development of transport demand. This also takes place via a software library and here, too, it would be useful if a file of similar configurations could be kept. Starting points for control and information protocols have been formulated in chapters 3 and 4. Under the title "create a set-up of an experiment" the functions can be found to select configurations and provide them with further specifications, such as values for the parameters, the possible use of certain historical data, or a possible real time connection to certain physical processes, etc. in such a way that the model to be tested will then be completely specified. The parameters may relate to the external communication (degree and time of pre-information), the control horizon (the future time that is "projected into" with the deployment of capacity, driving speed and rapidity of transfer), chances of the occurrence of exceptional situations (failures), or parameters for demand as an average, trend, week/day fluctuations, etc. It may be useful to keep the specific information in a data file. The functions continuing the simulations have been located under the block "run experiment & evaluate". The output of the simulations concerns the evaluation (performance and behaviour), incident identification (on behalf of real time interactions) and animation. The simulation process has to be controlled in different ways. So it is desirable to simulate, at choice during the simulation run, certain locations (terminals or parts of a terminal) as a black box instead of completely differentiated. This facility of adjusting levels of aggregation through differentiation is useful because there is often much interest in the specific functioning of a certain field within the context of the whole, where aggregated results regarding the context will do. In this case the run time can be reduced considerably by simulating the environment to a configuration of black boxes and only including the object area as differentiated.

It should be noticed that the set-up of the traffic control system outlined in chapter 4 is very suitable for this. It is also necessary to concentrate a possible animation at places to be indicated by the user during the run, e.g. as a reaction to a identified incident. The outlined set-up proceeds from the practical demand that the variables (i.e. configurations, protocols and parameter specifications) can be adjustable in groups and that various experiments can be compared and evaluated in pairs. Suppose, for instance, that there is a desire to study two physical configurations (F[1, F[2]) under "similar circumstances", with which two control configurations (C[1], C[2]) and two specification collections (P[1], P[2]) are taken into consideration. The eight different experiments can then easily be characterized by combinations of the type (F[1], C[2], P[1]) and, in that way, also be compared. Within the categories F[ ], C[ ] and P[ ] a segmentation will also be possible. Therefore, the definition/specification device has to be handled flexibly. In order to be in a position to honour these user demands and to be able to set up model files, the laboratory will have to be based on a data model with a clear structure, accessible to the (engineer) user. A second starting point proceeds from the demand that there must also be a way to experiment with models of newly developed components as implements, vehicles, or control procedures. The process dynamics of such a similar component will then have to be represented in the form of a software module and added to the object library. This requires an open modular structure of the system, in which clear distinctions have to be made between the interface (integration of function and conditions for use) and the execution at every module. Within the set-up of the interface, various modes of execution will then be available. The software modules developed for this purpose will consequently be 'object-oriented'.
3 Logistic coordination and the issue of work orders

3.1 The logistics coordination of the transport operations

Goods are largely transported in groups. Such a grouping is often structured such that it consists of subgroups, while such subgroups themselves are also possibly composed of subgroups. In that way a ship or train cargo of containers can be regarded as a transport group composed, for example, of subgroups for certain destinations or certain shippers. Also the cargo of the containers will in general be composed of transport groups. From the DiTrans point of view, however, the container is considered to be the fundamental "transport group", consisting only of the container itself. Following Damen [Dam] and Vermunt [Ver], the operational demand for transport is described here in terms of transport groups. The integrated transport at the terminal and the CombiRoad network between supply and transport could be thought of as being built of the following elementary processes: splitting up a transport group, buffering (at the stack), individual transport of the basic transport group (the container) and the composition of groups (grouping).

![Figure 10: Split and compose of transport groups](image)

A particular aspect of the (inter)terminal transport in the DiTrans concept is that the grouping is mainly of an administrative nature, in the sense that the physical transport of a group is realized on the level of the separate containers. This means that the transport of different groups could physically be mixed up and that the coordination within the group only occurs via the information system. This coordination can impose a certain order of arrival at a quay crane, for instance. The concept transport group is a powerful, simple and generally applicable aid to coordinate transport. In a structured set-up a general transport group is to be specified by the following data:

Information about a transport group:
- group identifier;
- coordinating group (group identifier, group position);
- origin: location, ET (Earliest Time), LT (Latest Time);
- destination: Location, ET (Earliest Time), LT (Latest Time);
- list of composing transport groups (group identifiers, group position).

The attribute "group position" of a composed transport group can, in the case of a shipload, refer to a slot or zone in the hold. The attribute "group position" can also be used to indicate the sequence of conditions between composing transport groups. Not all data are relevant for each transport operation. Sometimes the data about the destination or the composition list only become available during the execution of the transport. It is important to use standardized forms for the specification of transport groups, thus making EDI possible.

A description is to be added to a transport group of the transport actions to be executed. For such descriptions preference is also given to the use of a standardized form, e.g. a structured "transport script". As indicated in figure 11, the transport script creates the possibility of choice, parallel execution, repetition and, of course, the possibility of indicating sequence relations. A transport action can also be composed in the sense that it represents another transport script in itself.

![Figure 11: Example of a transport script](image)

The "elementary" transport operations may concern physical actions such as "transfer from ship to vehicle", "ride to stack", or "placing on the stack". Although for logistics coordination it may be more practical to summarize such a trio in one composed transport action (say): "transport and placing on stack S1". The choice might be placed in the transport script between, for instance, "transport and placing on stack S1" and "transport and placing on stack S2". Within this scope administrative actions as declarations are also to be regarded as transport actions. This implies that some transport actions can take place parallel to one another (not necessarily simultaneously). Some transport operations are repeated. This is, for instance, the case when transport groups are split up (the unloading of a train) and during grouping (the loading of a train).

With the help of the concept "transport script", it
is in principle possible to describe the transport of a transport group throughout the route, at the terminal, between the terminals, from shipper to receiver - on every specific level desired. Within an (inter)terminal configuration the transport scripts for transport actions can be extensively standardized. Scripts can also be set up for incident handling (reception and restore). For the electronic interchange of data a standard format is required; thus the script of figure 11 could be specified as follows:

- info transport script:
  - script identifier: Fig 11;
  - script: ([A1, A2], A3, [A8, A9], <A10>, A4);
  - operational condition: A2, A3.

In this [...] shows a range of choices, [...] shows a range of actions to be executed in parallel, ... shows a repetition and [...] shows a sequence. The operational condition is to be indicated via a list of completed actions. A possible general logistics set-up of the activities for the coordination of transport has been outlined in figure 12. Under "follow containers" the location of the separate containers is continually kept up to date. For instance, whether it is on the way, at a certain point of transfer, on a certain vehicle, or at a certain place on a stack. Other logistics status information can also be kept, such as an indication of a transport group in which the container has been grouped. As indicated with the arrow "container data", this file is constantly being updated.

Included under "receive & monitor transport orders" are: (1) the connection to the external container logistics, especially with regard to orders from customers, arrival of "transport groups" and the arrangement of the collect/dispatch process and (2) monitoring the settlement of the external transport orders, to which also belongs the update of the "order file". In terms of the concepts "transport group" and "transport script" introduced before, the preparation of connecting transport within the DiTrans system comes under the activity "compose & follow transport groups". From this information on the transport actions for the separate containers can be deduced according to a strict procedure. This has been indicated under "compose & follow container transport instructions". A container transport instruction (CTI for short) is, within this context, to be regarded as a "transport group" consisting of the container itself, combined with a script, which would lead to the following characteristic information:

- Information CTI (Container Transport Instruction):
  - container identifier;
  - coordinating group (group identifier, group position);
  - script;
  - operational condition.

Here it should be mentioned that the execution of a CTI could already be initiated without knowing beforehand the data which are required later at the relevant moment; these can still be added afterwards.
3.2 The issue of driving orders as a critical success factor for DiTrans

In the DiTrans facility scheme of § 2.4 the issue of internal transport assignments has been classed under the interface logistics coordination. This also includes the issue of trip orders, i.e. orders for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These springs from the task allocation and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best".

The point of time exhibits a lot of chance fluctuations and is known are allocated the first task to containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best" arrival have to be observed for the transport of individual containers from one DiTrans facility to another, stating the latest completion time (LCT: latest completion time). Often certain sequence conditions concerning the arrival have to be observed for the transport of containers to a quay. These spring from the tasks and vehicles save the "best".

The allocation algorithm in the anticipatory allocation protocol is much more complicated and can only be executed on the basis of real time mathematical programming techniques. It comes down to the fact that projection is so far ahead in time that usually twice as many tasks fall within the planning horizon than the number of vehicles available or that will soon become available. From all possible combinations of successive task pairs or separate tasks and vehicles available, the "best" are constructed and only those vehicles actually free are allocated the first task to be executed from this. The other allocations will not be effectuated, which implies that relevant tasks and vehicles are on again for the next round of allocations. Because the list of tasks in this next round often includes newly added tasks and accidental stagnation in the running task execution are also possible, thus changing the list of available vehicles, the new allocations may turn out to be different from what was arranged in the previous round of allocations. In this respect "anticipating allocation" is dynamic or adaptive. To minimize the driving distances applied to the example in the issue of driving orders I and II in the example in figure 13, in the first round this gives an effectuated allocation of task1 to V1, a noneffectuated allocation of task2 (after task1) to V1 and no task to V2. If, in the meantime, no tasks are added, V2 stays available and, in the end, V1 is also definitely allocated task 2; so V2 remains at terminal A.

![Figure 13 The issue of driving orders](image)

The myopic allocation protocol functions as follows: (1) to each vehicle becoming available, a task that is still open is immediately allocated. Every time a task is chosen whose point of departure is closest to the place at which the vehicle will become available, this task will also be executed by the vehicle in question; (2) if there are vehicles waiting, then the first available assignment is allocated to the nearest vehicle. In the example of figure 13 this results in the allocation of task1 to V1 and task2 to V2. So, both vehicles ride to terminal B, with V2 riding the track unloaded. The allocation algorithm in the anticipatory allocation protocol is much more complicated and can only be executed on the basis of real time mathematical programming techniques. It comes down to the fact that projection is so far ahead in time that usually twice as many tasks fall within the planning horizon than the number of vehicles available or that will soon become available. From all possible combinations of successive task pairs or separate tasks and vehicles available, the "best" are constructed and only those vehicles actually free are allocated the first task to be executed from this. The other allocations will not be effectuated, which implies that relevant tasks and vehicles are on again for the next round of allocations. Because the list of tasks in this next round often includes newly added tasks and accidental stagnation in the running task execution are also possible, thus changing the list of available vehicles, the new allocations may turn out to be different from what was arranged in the previous round of allocations. In this respect "anticipating allocation" is dynamic or adaptive. To minimize the driving distances applied to the example in the issue of driving orders I and II in the example in figure 13, in the first round this gives an effectuated allocation of task1 to V1, a noneffectuated allocation of task2 (after task1) to V1 and no task to V2. If, in the meantime, no tasks are added, V2 stays available and, in the end, V1 is also definitely allocated task 2; so V2 remains at terminal A.

![Figure 14 The issue of driving orders II](image)

It is clear that an anticipatory allocation turns out to be much better, in this case, than a myopic allocation. The difference in dynamic behaviour of both allocation protocols is to be illustrated with the example of figure 14 where, after the first allocation round, task3 is added to the situation of figure 13. The myopic protocol is not adaptive, with the result that V1 (charged with task1) and V2 (empty) are on their way to terminal B, after which (probably) V1 will be charged with task3 and will, therefore, first have to return empty to terminal A for the execution of task3. After completion both vehicles are at terminal B. In the anticipatory protocol V2 initially remains available and is, therefore, available in the second round for the execution of task3, which, consequently, will be effectuated in the second round. So both vehicles will ride loaded, shortly after each other, from A to B. In this case, the
The total distance covered with a myopic allocation will be almost twice as long of that covered with an anticipatory allocation. When the transport system includes many vehicles with which many tasks are dynamically carried out, the anticipatory protocol seems to perform considerably better than the myopic one [Loo]. Other allocation protocols have been examined as well [Kui]. It is to be expected that the anticipatory protocol will perform better in the DiTrans context and, although more complex, will be manageable in real time. The allocation protocol outlined here is, therefore, chosen as a starting point for the control system yet to be developed.

3.3 The set-up of the module for the issue of trips and driving orders

As indicated in the SADT function diagram of figure 15, the module for the dynamic definition of the vehicle deployment is to be split into three submodules: (1) "compose list drives & vehicles", referring to the dynamic setting up and keeping up of route and vehicle information; (2) "determine cost coefficients", for stating the basic costs related to the driving distances for the execution of the routes and (3) "allocate & monitor route orders", for optimizing allocation of routes to vehicles. This module operates in real time in the sense that it interacts directly with the physical transport processes; the latter have been kept out of the function scheme of figure 15 and will be dealt with in § 4.3. The list of available routes is constantly being updated: the completed routes of the previous allocation round will be removed from the current list and those new routes within the horizon are added. Therefore the routes on the list and vehicles not yet allocated remain on the list and will therefore be reconsidered for allocation. Each route is provided with information about the departure and destination points (and therefore with information concerning the nature of the ride). With respect to the point of departure this is, in principle, the earliest and latest departure time (Earliest/Latest Departure Time, EDT and LDT for short); with respect to the destination this is the earliest and latest arrival time (Earliest/Latest Arrival Time, EAT and LAT for short). It is possible that relationships between the routes themselves, such as the order of execution, also have to be added insofar as these are not to be taken into account in the specification of points of time as mentioned above.

The points of time and the possible sequential relations arise from both the external demand for transport (as a result of logistic coordination) and the terminal's internal condition such as possible waiting queues at any means of transfer (quay cranes, stacker cranes, tractor cranes, dockside cranes, etc.). Because unforeseen circumstances sometimes occur during transport and transfer (operational accidents or incidents), this information must always remain current. If taken from optimized allocation, even including only two successive tasks, a classification of routes can be deduced from this information as to possible executions in the first or second round. Thus, the following possibilities for execution of each route can be determined:

(i) necessary execution in the first allocation round;
(ii) optional execution in the first or the second allocation round;
(iii) necessary execution in the second allocation round;
(iv) optional execution in the first or the second allocation round, or postponement;
(v) optional execution in the second allocation round, or postponement.

This classification is supposed to be drawn up in connection with the dynamic availability of the vehicles. It is possible to use the information about the functional condition of the terminal (see "info internal condition"), it to make an actual estimation of the point of time at which each vehicle is available for the execution of another task (Expected Release Time, ERT for short). If a vehicle is available, then this time is zero (as this is counted from the current point in time). This information and that concerning routes to be executed give an indication of the actual availability of a vehicle: immediately before the first allocation round (and therefore also for the second round), or only for the second allocation round (and therefore too late for the first round), or not available (and therefore also too late for the second round). In reality, the division of the allocation rounds is determined by, on the one hand the classification of the routes and, on the other hand, by that of the vehicles.

Of course, these classifications concerning the departure times and arrival times (EDTs, LDTs, EATs, LATs), the times of availability (ERTs) and the expected duration of the vehicle-independent part of the execution of the routes, should be inherently consistent. The (expected) total vehicle-independent route time (Total Route Time, TRT for short), is the sum of the expected loading time, the expected driving time and the unloading time; these times include (current) estimates of normal waiting times. Various protocols are considered for research for the formulation of the round classifications. The activities described above come under the heads "make list routes & vehicles" and "fix task times" of figure 15. The activities under "fix cost coefficients" concern the "costs" that result from the first and second round which are to be minimized; in both cases it is assumed that the vehicles are functionally identical with respect to the execution of the routes, are and that the costs to be minimized primarily concern driving while empty. In this case, the specific costs in the first round spring from the distance to be covered while empty by a vehicle in order to come from the place where it becomes available (or is available) to the place of departure of the new route. This leads to a matrix of "drive-up costs" versus the routes for the vehicles. Any other elements may be included in this cost matrix. If, for example, a specific vehicle/route combination is not (quite) possible in connection with the ERT of the vehicle, the TRT of the ride and the EDT/LAT of the container, the relevant final amount can be increased by adding a fine. A cost minimizing allocation algorithm will try to avoid such fined vehicle/route combinations. The specific costs for the second allocation round arise from the distance to be driven empty between the destination of the first route and the place of departure of the route to be driven by the same vehicle in the second round.

This leads to a matrix of "connection costs" between rides of the first and the second round. Here as well, undesired combinations can be fined. Generating the driving orders takes place on the basis of cost minimization, based on the information outlined above. The anticipating allocation technique is to be formulated as a zero-one linear programming problem with a special structure. For this structure, a fast resolution algorithm is to be developed [Eve] in such a way that real-time optimization of a system with a large number of vehicles is made possible. This has to be further elaborated and verified.

4 Traffic control as a critical success factor for DiTrans

4.1 Starting points for the traffic control

The task of traffic control is to control means of transport (vehicles) on the physical infrastructure, such as roads, rail and waterways, crossings, parking facilities, (automatic) stacker cranes, automatic depots and the like. For the "moving traffic" the following is to be distinguished:

- With respect to the available information about the vehicle concerning origin, destination, frame of arrival, the route to be followed (or alternative routes) and the condition of the vehicle:
  - known at the traffic control;
  - not known at the traffic control;

- With respect to the degree of autonomy of the vehicle concerning the choice of route and timing, possibly based on information or directives issued by the traffic control:
  - completely autonomous;
  - autonomous within the finite choice given by the traffic control;
  - complete automatic control (and therefore completely predictable) by the traffic control.

Various control concepts might be considered for each situation. A similar distinction, in an adapted form, is also applicable to other means of transport. It has been found that an adequate control concept grafted on a same basic model, i.e. that of the network of interacting nondetermined automata (developed in the
mathematical automaton theory), can be applied to all cases of automatic or semiautomatic control in spite of the variety in means of transport and the coherent physical infrastructure. The starting points for this set-up are outlined in § 4.2. Two concepts can be distinguished for the distribution of the control system: Central Traffic Control (CT control for short) and Distributed Traffic Control (DT control for short). It is a matter of CT control if no intelligence is available (in the sense of substantial information processing) at the vehicular level, neither on the level of control zones placed on the infrastructure; this implies that all vehicle movements are controlled directly by a central channelizing island. In the DT control system an autonomous information processing system has been added to each vehicle, making it able to combine an own action programme effectively with environmental impulses and information / directives provided by a supervisory guidance system. In addition, the various control zones on the infrastructure (as controlled crossings) can be equipped with an autonomous control system in a similar way. In a centrally controlled system, the communication with the supervisory guidance can thus be restricted to the incidental issue of instructions; the task of such a supervisor is coordinating rather than controlling (real-time). It should be mentioned that the autonomous control systems described above need not necessarily be placed completely on the vehicle or control zone itself; complete or partial placement in a control centre with relevant communication facilities need not reduce the functional autonomy.

The current systems for automatic vehicle guidance, which require that more vehicles have to be guided simultaneously on the same infrastructure are generally based on CT control and a control zoning of the infrastructure, completely introduced, where the principle of exclusive seizure is constantly applied, that is to say that no more than one vehicle is admitted to a distinct control zone. The principle of exclusive seizure is attractive because it allows the development of reliable and relatively simple control systems. In principle, however, more vehicles should be admitted to the various zones, up to a maximum number fixed for each zone; this may be defined as the capacity of the relevant zone. In such multiple access system, the vehicles themselves will always have to observe a certain distance with respect to each other, and will therefore have to equipped with reliable distance sensors. The advantages of multiple access to control zones with regard to exclusive seizure can be illustrated with the example given in figure 16.

In the first case, the route has been divided in four exclusively accessible sections, while in the second case the route is controlled as a whole. It is obvious that, in the first case, much more wireless communication is required. Moreover, the vehicles will have to make more stops. The latter reduces the average passage speed and thereby the throughput. In this respect multiple access zones are preferable. This is even more clear from the situation outlined in figure 17.

Figure 16 Exclusive versus multiple access

Four roadways lead to a single exclusively accessible zone, which contains a crossing. Not all vehicles will obstruct each other; vehicles turning right, for example will not hamper each other. In principle, multiple access seems possible, provided that, in one way or another, the traffic control is able to distinguish the direction of the vehicles.

ECT's Delta/SeaLand terminal is automated on the basis of central control and exclusively accessible zoning and includes 48 automatically guided vehicles for the transport of containers. Although the terminal functions properly, it appears that critical limits have been reached as to the wireless communication and the complexity of the central control system. The DiTrans concept, however, takes coordinated container transport for granted, where the number of vehicles to be controlled is an order larger, and where the passage speed is considered to be a critical factor for success. An exploratory study, executed by Evers and Koppers in cooperation with IC/h Logistics on behalf of the container terminal to be constructed in Singapore [Eve], shows that DT control with multiple accessible

Figure 17 Crossing as an exclusively accessible zone
zoning offers perspectives in this respect. The control concept used here is outlined in § 4.2 and is, (for the time being), considered to be the starting point for the control system to be developed. At any rate, the following demands have been made with respect to the traffic regulation system:

- the transport is executed efficiently and in conformity with the demands;
- wireless communication is used as little as possible;
- the control concept enables maximum use of the infrastructure capacity;
- the control system avoids collisions and gridlock, even in exceptional situations;
- the control system provides incident handling (reception and restore of exceptional situations).

In this context, the DiTrans R&D project aims at developing and testing a technically feasible control concept fitting into the DiTrans facility model of § 2.4 which can be connected to the system for issuing driving orders and is to be combined with the vehicle concept to be developed.

4.2 The concept structured network for traffic control

Although traffic networks show a great diversity, a common structure can be seen at a certain level of abstraction. This is based on only four types of entities: node, section (or track), admission signal (or semaphore) and area (zone). An area is a configuration of nodes, sections and perhaps (sub)areas as well; an example without subareas is given in figure 18. In this example, the sections are drawn as lines, where ends always lead to a node. The sections represent roads, whereas the nodes represent crossings or road connections. The dotted line indicates the system boundary. All nodes are internally accessible; only nodes 1, 2, 5, 6 and 7 are in principle externally accessible and are therefore called external nodes. A semaphore (admission signal) serves as a point of interaction between the vehicle and the infrastructure, with which the access of a vehicle to a section or a zone is controlled; in the figure, the semaphores are indicated by flags. A semaphore has a current number value which indicates the space still available. In figure 18, s2 and s3 function as internal semaphores, which means that these are invisible to vehicles outside the defined area.

The semaphore concept is derived from informatics (automaton theory [Dij], [Ben]) and can be formally defined as a numerical variable, such as S, on which only two operations are defined, i.e.:

- Wait(S); if \( S > 0 \) then set \( S := S + 1 \) (and admit vehicle), else block the access at semaphore S.
- Signal(S); if vehicles are blocked at this semaphore, then admit one of these, else set \( S := S + 1 \).

Figure 18 Example of an area without sub-areas

It should be mentioned that operation Signal(S) activates one of the waiting vehicles, without indicating which of the waiting ones. An "access protocol" therefore has to be added to each semaphore. An example is the often applied rule "First In First Out". An initial value representing the semaphore's capacity has to be added to each semaphore.

No matter how often the operations Wait(.) and Signal(.) are repeated in the application context, the value of S will never become negative and will always be equal to the remaining capacity of the semaphore (and therefore to the capacity of the guarded area). There are a number of variants on the concept semaphore; an interesting extension is offered by the concept monitor [Hoa].

A control zone may also include subzones; an example is given in figure 19. This combined principle is hierarchic: subareas may include subareas within themselves, etc. The example in figure 19 shows a zone with two subareas "A" and "B", each composed as indicated in figure 18.

Figure 19 An example of a coordinated area

From the combined zone in figure 19 the internal structure of "A" and "B" is irrelevant, in the sense that the access to "A" and "B" is being regulated via the external nodes and semaphores of "A" and "B". Within the whole of the combined zone, the external entities of the subzones can be indicated by a combined label, consisting of the name of the subarea and the name of the entity within the subarea; in the example this leads for the nodes to
inductions as "A.7", "B.7", etc. In principle, this structure device can be carried through to a large extent. Thus, in a DiTrans configuration a terminal as a whole could be seen as a subzone linking up with a CombiRoad connection. In addition, a DiTrans configuration as a whole could be seen as a zone. The operation of a subzone in the context of its environment is determined by the number and function of external semaphores and their tuning to internal semaphores. The double crossing in figure 17 could, for instance, be regulated via an external semaphore with capacity 1. An example of a different regulation is given in figure 20.

![Figure 20: Occupation of semaphores](image)

Four external semaphores have been placed (s(1), s(2), s(3) and s(4)) each with capacity 1, the occupation of one or more semaphores depending on the direction of movement; this has been indicated in the table. Compared to an arrangement with one external semaphore, this arrangement gives an average throughput that is two to three times greater. Different rules are considered for the access protocol, i.e. the regulation of access priorities. Giving a vehicle causing the least obstruction at the crossing; for instance. In addition, priority rules that are accepted in production logistics can be introduced, such as: random, FirstInFirstOut, preference for a vehicle in the same direction (reduces "switching loss"), preference for a vehicle with the first planned time of departure from the zone in question, preference for a vehicle with a direction having the shortest waiting queue in the next zone ("work in next station"), and a flexible combination of rules. A common characteristic of these rules is their application requires that little or no information about the area where they are applied. Starting from this, every access protocol will, in principle, have information available about: (1) the condition of the semaphore itself; (2) the condition of the neighbouring semaphores; (3) the driving or waiting vehicles (mission, route, priority indication), and (4) the instructions given by the surrounding zone. An infrastructure with many sections, crossings, parking and service places, intense traffic will require a large number of guarded zones for control. After all, the many simultaneous vehicle movements will have to be coordinated. Under these circumstances, a central traffic control system becomes very complex. In fact, there is need for a concept in which the real-time complexity increases little or not at all with the extension of the infrastructure and/or a growth of the traffic intensity. The concept of decentralised control, where the (control) zones described before are equipped with "local" intelligence for defining the capacity of semaphores and possibly the control of choice protocols, will meet this requirement. In fact, the semaphore mechanism itself is to be conceived as a form of local intelligence; this is also the case for the distance-keeping provisions on vehicles.

4.3 The implementation of traffic control in the DiTrans concept

The operational implementation of traffic control and vehicle guidance systems concerns communication with the vehicles and control of the infrastructure. Starting from the concept of a structured traffic control as mentioned earlier, the control zone functions as a control cell for the infrastructure. Communication always concerns the condition of communicating players. In light of the rapidity and intensity of the communication, it is useful to distinguish between the parametric condition and the process condition. The parametric condition does not change frequently, whereas the process condition changes constantly. Because of this, the following conditional components are of importance to the vehicles:

- Information about a vehicle:
  - vehicle identifier;
  - parametric condition:
    - condition classification (bd/true/occupied empty/occupied loaded, normal/exception),
    - container identifier,
    - mission (origin, EDT, LDT, destination, EAT, LAT, priority indication);
  - vehicle guidance instructions (route to be followed);
  - process condition:
    - driving condition (riding/waiting for access/waiting for vehicle in front),
    - place (zone, section, node),
    - vehicle observed ahead (yes / no driving / yes stopping / yes standing).

Aside from the condition classification, the parametric condition is determined by the driving order, provided by the module issuing driving orders. This concerns the identification label of the container to be transported (this being the case), the mission and the route to be followed; the latter could be modified during execution of the assignment.
The process condition is constantly updated via wireless communication in the transition of one zone to another. These are also the moments when stop and go signals are passed on from zone control. If the vehicle (with the help of distance sensors) can determine the distance to a possible vehicle in front by itself, a component in the process condition is also needed here. The list mentioned above makes a suggestion for this under the heading "vehicle observed ahead". The information about the vehicles is, in principle, to be stored in a central database of which protected (partial) copies are transferred to the vehicle in question and to the relevant control zone when necessary; in the first case this has to take place without wire connections, while in the second case, this can take place via a cable link. It should be mentioned that the communication for tracking vehicles, as arranged in the FROG system (see § 2.3), can be left out of consideration in this context. The condition of a generic zone could be characterized as follows:

- Information about a zone:
  - zone identifier;
  - parametric condition:
    - configuration (filling in a flexible layout);
    - directives from the surrounding zone (semaphore capacities, access procedure, etc.);
  - process condition:
    - list of vehicles waiting for access, for each vehicle:
      - vehicle identifier;
      - vehicle condition;
    - list of vehicles within the zone, for each vehicle;
    - vehicle identifier;
    - semaphore condition, for each semaphore:
      - value (therefore residual capacity),
      - list of blocked vehicles,
      - vehicle identifier.

The scheme proceeds from a decentralised zone control, as outlined in § 4.2. From this point of view, the function diagram in figure 21 shows segmentation of the functions to be provided for traffic control and guidance of vehicles: (1) instructing and tracking vehicles; (2) guiding traffic at the zone level; (3) communication with infrastructure at zone level and vehicles; (4) guiding the vehicle.

The function diagram is restricted to control; the real physical processes have not been taken into consideration. The arrows indicate the exchange of information, as this links up with the characterization of the condition information indicated above. The information under "driving orders" links up with that of "Generate driving orders" in § 3.3; these are the driving orders themselves as well as the feedback in the form of progress information. The "instruction zone control" information functions as a control factor and also as an output factor of "control zone traffic". As a control factor, this indicates the instructions provided by the surrounding control zone; as an output factor this refers to the instructions given to a subzone. The scheme fits into the general "Control transport process" scheme in § 2.5 and is to be elaborated on further in connection with this.
5 The robot vehicle

5.1 Functional starting points for DiTrans vehicles

The vehicles in view have to function both on the connecting infrastructure and at automated terminals. Moreover, it is desirable to create the option to use the vehicle in a nonautomated environment. This could be realized by equipping this vehicle with a system for following a manned pilot vehicle at a short distance. This tracking system can be executed servomechanically or electronically. The connection infrastructure is seen as a neutral facility in the sense that, in principle, each vehicle meeting an accepted standard is admitted to and included in the system at a fixed fare. This standard concerns geometry, energy supply, driving behaviour, communication between vehicle and infrastructure, vehicle identification, the moving script, traffic control and, moreover, the real-time protection of the condition. The openness of the system makes demands upon the form of this interface standard (see also § 5.2): it should be structured clearly and be minimal, in the sense that the admission conditions do not go further than strictly necessary. This might imply that the traffic control system used at a certain terminal is structured differently from that of the connection infrastructure; such a variety must be possible within the interface standard. An important CombiRoad option is the transport of standardized trailers, which should also be fit for normal road traffic. In addition to the connections with terminals and transshipment nodes, CombiRoad will have to provide so-called switchpoints where robot tractors and manned tractors can be changed. A suggestion for this is given in figure 22.

![Figure 22: Combi-Road Switchpoints](image)

A trailer is driven by a robot tractor from CombiRoad to a "horizontal" parking lane. After uncoupling it rides empty "along the top" to the backtrack, and is then available to take a trailer from the vertical parking area by reversing this robot tractor into the "vertical" parking lane and coupling the trailer. A manned tractor collects a trailer by reversing into a "horizontal" strip and coupling the trailer. Two types of vehicles get attention: (1) the robot tractor for trailer transport as a load carrier and (2) the robot carrier which carries the container (and anchors it), and is therefore unfit for trailer transport. The vehicles have to cover a number of primary transport functions. In addition, they have to perform a number of supporting functions, such as handling failures as necessary. The following are distinguished as primary transport functions:

- **Driving:**
  - free driving (including gradually changing direction and speed),
  - car queuing (including gradually changing direction and speed),
  - accelerating and stopping (in order change speed quickly);
  - manoeuvring (taking sharp turns, driving backwards, turning, etc.),
  - positioning (accurate positioning for transfer or coupling).

- **Waiting:**
  - active waiting (ready for immediate execution of assignments),
  - attentively waiting (ready after restricted reactivation).

- **Coupling/uncoupling** (for robot tractors only);
  - mechanical support,
  - wiring system (brake lines, electric wires),
  - check (for automated verification of coupling/uncoupling).

- **Load receiving and delivering:**
  - acceptance/release (optional, for robot carriers only),
  - check (for automated verification of receipt/delivery).

These functions are supported in different ways. A tracking system is required for covering the desired track: using an indirect servomechanical or electronic induction system. Tracking is wireless at an automated terminal; an example of this is the FROG system of ICH logistics. It is possible to use a manned pilot vehicle in a nonautomated environment. The other support is provided by the vehicle guidance system. This system regulates the admission of traffic and transshipment to controlled zones and, in this context, also provides starting points for determining position and wireless information exchange.

A third support is provided by the system for detecting distance with respect to other vehicles. From a functional point of view, three distance frames are to be distinguished here: (1) long distance (100 to 25 m), necessary for keeping distance on the CombiRoad sections; (2) short distance (30 to 10 m), for driving at the terminal and in low speed areas on CombiRoad, and (3) critical distance (10 to 0 m), used at "creeping speed" or in making an emergency stop.
support is necessary in the form of the energy supply. On the CombiRoad sections, this is electricity provided by an electric rail (supported by a help function to serve the current consumer), whereas a diesel generator provides power at the CombiRoad switchpoints and at the terminals. Four values are functionally distinguishable for the driving speed: (1) about 0.5 m/sec as maximum and cruising speed on the CombiRoad sections; (2) about 5 m/sec on terminal tracks; (3) about 2 m/sec at transfer and switchpoints and in manoeuvring, and (4) about 0.2 m/sec as creeping speed during positioning operations. The DiTrans vehicle will have to meet all functional requirements listed above. The following functions are probably to be considered as technological criteria: (1) keeping standard distances autonomously using distance detection; (2) tracking trailers on CombiRoad sections, in bends and with fresh sidewinds; (3) accurate and effective manoeuvring with trailers and (4) automatic (un)coupling of trailers. The ability to maintain a standard distance independently is necessary to allow the simultaneous admission of multiple vehicles to guarded zones (see chapter 4) and to be able to drive in queues. It is therefore critical that the distance detection systems are reliable in all weather and environmental conditions.

The other critical points concern the semi-trailer. If, as is the case here, a standardized semi-trailer also fit for container transport on the road is assumed, then the special provisions for the use on DiTrans should be placed on the robot tractor and not on the trailer. A solution to the problems mentioned above concerning tracking on CombiRoad and effective manoeuvring could involve a controlled transverse movement of the trucks supporting centre with a maximum swing of perhaps 50 cm. The control of this transverse movement would, of course, have to be completely integrated with the wheel control. It should be mentioned that all wheels on the automatically guided vehicles at the DeltaSeaLand terminal are controllable, because of which transverse driving (crabbing) and very short turns are possible. In developing the robot carrier and the robot tractor, it has been assumed that this is not necessary; the correctness of this assumption should, of course, be verified. As to the fourth critical point, automatic coupling, the difficulty lies in the wiring system. The law prescribes that, for road traffic, this has to happen manually.

5.2 The modular construction

Modularity is characteristic for machines. The well-known assembly hierarchy is found over and over again: part, component, machine. Following this line, the concept of an installation as a combination of interactive machines is found. When applied to the DiTrans system, the robot vehicles, together with the traffic infrastructure can be conceived as an installation within the logistically coordinated whole of the "DiTrans installation". The assembly hierarchy is also a concept suited for immaterial constructions; examples of this are the control concepts outlined in chapters 3 and 4. In addition, modern computer software is modular ("object-oriented"). The use of the term "component" hereafter will refer to a part of a whole. In modern technology, complicated assembly structures can occur. These structures can be of several different natures, for example:

- one and the same component type may occur at various places and on various levels;
- variants of a component type may occur, each having various versions of its own;
- sometimes, different components can be placed in one place within certain interface conditions;
- assemblies may also be immaterial, meaning an abstract structure.

Interchangeability is important because with a small number of different components and/or component variants, a multiplicative variety of the assembly is obtained. This can meet the divergent needs of end users and, by replacement of components, modifications can be added later on. To be able to control such product varieties, a powerful recording device is needed, which leads to the product database concept [Mey]. A product database has to be capable of supporting a product's entire life cycle (machine, installation, information system, etc.), meaning:

- design (product structure, standardization, use of standard components);
- testing (by component and in combinations);
- specification (choice of components and variants by user desire);
- production (on behalf of purchase, planning and registration of components);
- failure handling (diagnosis, reception and restore);
- maintenance (inspection, maintenance, repair, replacement of components);
- dismantling (reuse or discarding of components).

Various starting points for the modularization (or product structure) are considered. The higher assemblies (main modules) should preferably have a function oriented definition since these contribute most to the end use. For the structure on a more detailed level, technological considerations such as production, inspection, maintenance and technical standards are often applied. Use of standard parts is preferred, whereas the standardization option (and thereby
the flexibility for use in a somewhat different application), should be considered in developing new modules.
Based on these grounds, the following main components are under consideration for the robot vehicle:

- wheel construction:
  - wheels and tyres,
  - (driving) axles,
  - suspension,
  - brake mechanism,
  - steering mechanism;
- drive:
  - electric motor(s),
  - diesel set (diesel engine and generator),
  - control of the drive;
- turntable (for the robot tractor):
  - mechanical support provision,
  - swing mechanism for the point of support (to be considered),
  - accessory coupling (brake lines, etc.);
  - clutch control;
- chassis and casing:
  - chassis (sec),
  - slip mechanism,
  - shock absorption (bumper),
  - slip provisions;
- tracking mechanism:
  - for CombiRoad,
    - tracking wheels with suspension (in case of direct mechanical tracking),
    - servo control (in case of mechanical hydraulic control),
  - at the terminal (and possibly CombiRoad switchpoints),
    - wireless track guidance (as FROG of ICH Logistics or the ARB system);
- internal vehicle control (see § 5.3);
- internal diagnostics;
- communications unit (for wireless communication);
- distance detection.

Two aspects are to be distinguished in standardization: interface standardization and executive standardization. Interface standardization is aimed at the functional and formal fitting in and is therefore extremely important for the design's structural set-up. Within the conditions of the interface or interface standard, more designs (variants) are, in principle, possible. This starting point known as the principle of "open architecture" in informatics, also has to be observed as much as possible when designing the vehicle. The following process aspects are important in characterizing a module's interface:

- characterization of the function and its interaction with the environment;
- specification of the regular condition limits;
- specification of the exceptional condition limits (failure limits);
- external observability;
- external controllability (or control limits) within regular condition limits;
- external handling of exceptional conditions and repair (return to regular condition).

At the current state of transport technology, observability, controllability, backup recovery and receive little attention. Yet these aspects form a direct starting point for modern control techniques (based on informatics and telematics). In addition, probability models (Markov models, for example) can be defined for integral safety analysis; this is further elaborated on in § 6.1. In designing the robot vehicle, the outlined approach has to be systemized and expanded in order to...
arrive at an "open" concept design for the robot vehicle, representing product standardization and offering starting points for systematic safety analysis. It should be mentioned that this approach is also applied to the developments in the field of logistic coordination, deployment of capacity (chapter 3), vehicle guidance and traffic control (chapter 4), DiTrans laboratory (§ 2.6) and the software created here.

5.3 The internal vehicle control

A schematic representation of the vehicle's internal control is given in figure 23. The starting point here is the organisation of the control using as much software as possible. It is for this reason that the "vehicle control processor" is placed in the centre. This starting point offers maximum flexibility.

This means that the control is simple to reprogram (if desired during operational use) and can thus be made suitable for various vehicle guidance systems. Such a module for internal control can also be adapted to various vehicle configurations, which is extremely important in the experimental phase of the development process. The scheme is based on a stratification of instructions and information, i.e.:

- instruction: external assignment
- information: external layout
- instruction: ride and transshipment script
- information: operations info
- instruction: primary functions for transport and support
- information: internal structure
- instruction: elementary internal instructions

The external assignment gives the object of transport (container identification or empty), the data of departure and arrival (place and time frames and instructions for execution, if any). The external assignment is translated into a route and transshipment script and, together with the external assignment, is stored in the "action script" memory segment. Information for this translation action is supplied by the "external layout" memory segment. The route and transshipment script will then be translated into a real time script of primary functions for transport and support, as outlined in § 5.1. The structural information for this (in the form of predefined standard operations) is supplied by the "operations info" memory segment together with information from the "external layout" segment. The primary functions in this script are then converted into real time elementary instructions to the relevant vehicle components. The structural information for this is to be found in the "internal structure" memory segment; the current information travels via the external communication module and via the internal tracking system, which also carry the feedback from the various vehicle components. Figure 24 represents this set-up in the form of a function diagram.

Thus, the permanent memory includes four segments. Information about the infrastructure and the relevant equipment for vehicle guidance and traffic control is located in the "external layout" segment. This concerns sections, crossings, parking and sorting lanes, transshipment sites, etc. The "internal structure" segment includes information about the relevant vehicle components, such as the control response.
and the interpretation of internal observations. Important components in this respect are wheel control (position and rotation), drive, brakes, distance sensors, trailer coupling, internal securities and possibly the internal compass (used by ARB bv, among others). The "operations info" segment concerns the formal specification of standard operations. In this case it concerns the primary transport and assisting operations as mentioned in § 5.1. Furthermore, this segment also contains the operations applicable to the various external elements. The "action script" segment includes the actual external assignment; the elements communicate with the external control system via EDI using standard format. In addition, an execution report and a report on the vehicle's internal condition is stored in this segment. In the further development of the conceptual model for the internal vehicle control, this set-up has to be evaluated and expanded to generic practical applicability. This should then lead to a coherent interface structure of (object-oriented) software modules conforming to the starting points formulated in § 5.2.

5.4 The development of the vehicle and the set-up of a simulation environment

The development of the robot vehicle concerns the vehicle concept, the conceptual design, a concept for possible developments with respect to the assortment of the automobile industry, conceptual evaluation and behavioral research with the aid of simulation and, if required, the development of suitable simulation models. The development from the function environment (issuance of driving orders and vehicle/traffic control) and the development of a method for the analysis of safety is performed in separate projects where, of course, interaction 'is', of course, kept in mind. In the first instance, the results of the vehicle design were used as a starting point, as this fits within the scope of the CombiRoad programme, whereas this development is supported from the DiTrans programme later on. The conceptual design is evaluated for its generic practical applicability and further developed to the level of the interface structure. This concerns the starting points formulated in § 5.1, the set-up of the primary transport and help functions, the modular set-up as indicated in §5.2 and the set-up of internal vehicle control as indicated in § 5.3. The principles formulated in §5.2 are observed here: special attention is paid to the "openness" of the system and the possible acceptance of proposed interface standards. A definite answer about the points considered critical in § 5.1 is given at an early stage. The possibility of developments with the help of parts from the assortment is always checked during the development process. As far as possible, the evaluations and the behavioral studies take place with the help of generic computerized expansions of the conceptual design and the appropriate simulation models. These concern: (1) energy management; (2) physical dynamic behaviour under various circumstances such as bends, slopes, wind, driving with or without trailer, and failure behaviour, such as in case of a flat tyre; (3) internal vehicle control; (4) manoeuvring and positioning behaviour and (5) queuing (of cars). A modular (object-oriented) approach is also kept for the computerized elaboration and simulation models.

6 Acceptance: safety, market and social decision making

A critical element in the realization of a new spatial transport system such as CombiRoad and DiTrans is social acceptance, by the transport sector as well as by society. This chapter deals with three important conditions: safety, implementation in the transport market and social decision making.

6.1 Safety

As all technical installations, transport systems have to meet a large number of safety standards. Many of these are imposed by the government, but the reliable rendering of a services also demands maintenance of a high level of safety. As defined here, safety refers to an (almost) impossible occurrence of undesired process effects in the form of injury and/or harm to persons, groups of persons, the environment, the rendering of services, or material equipment. In the context of a technical installation, safety is to be maintained by distinguishing process conditions which are undesired because of the occurrence of such effects or an unacceptable risk of these effects. Of course, the design and management are organized in such a way that such situations occur rarely or not at all: Thus, in this context, "exceptional situations" (exceptions) or "incidents" are referred to, in contrast to so-called "regular" situations. Safety plays a part during the life of a machine or installation. A number of lines of approach are to be distinguished in the prevention of accidents or exceptional situations:

- design:
  - choice of tested standard components,
  - built-in failure reception (fail safe),
  - secure man / machine interface;
- protecting and recording the user condition:
  - on-line measuring and defect identification,
  - cumulative measurement of the work
coherent description, information and calculation point of view of calculating probability, a discrete
the problem is to develop a generic, formal and component into a
operationalized here to reduce the chance of composition formed in this manner, all
the infrastructure. From a technological point of system of correspondence chances with the help
an integral approach with respect to vehicles on systems of chances of condition transition and a
relations outlined in §5.2 can be used as starting point: the facility chances of condition transition of the composition
In this case, the modular structure described in § can be related to combinations of conditions.
tested components should be used and be generalized to a combination of several
risk analysis, risk estimates as known for the chances. As a matter of course, this approach is to
case for the DiTrans concept. It is obvious that, as selecting the condition space and correspondence
new range of tested components, of which only a systems of correspondence chances together with
analysis. A starting point here is the observation
that a new technical design consists mostly of a the application and it is possible to handle various
operation protocols; and to come to a systematic operationalization of the security and risk concepts. In principle, this
method has to be usable during the entire life span of a technical installation and during the reception
and repair of exceptions. A starting point for a possible approach is offered by the probability model, an example of which is given in figure 25.
For each component a number of situations are specified in the examples C' and C", C[1],...C[4] and C'[1],...C'[6].

Upon the occurrence of exceptional situations (or dangerous situations), the undesired effects
should be restricted as much as possible, whereas normal operation should be restored. The important elements include:
- back-up:
  - restricting the effects on machine or installation itself;
  - preventing or stopping chain reactions,
  - restricting environmental effects;
- recovery:
  - quick resumption of the environment function (provisional, if necessary),
  - repair of the relevant machine or technical installation,
  - repair of environmental damage,
- registration, analysis and reporting of exceptional events.

Safety analyses are usually based on analyses of earlier accidents. However, these have no or limited applicability for machines and technical installations under design. Therefore, safety has to be guaranteed on the basis of verifiable risk analysis. A starting point here is the observation that a new technical design consists mostly of a new range of tested components, of which only a few components, at most, are new; this is also the case for the DiTrans concept. It is obvious that, as to risk analysis, risk estimates as known for the tested components should be used and incorporated into the composition structure.
In this case, the modular structure described in § 5.2 can be used as starting point; the facility relations outlined in § 2.4 are to be added here for an integral approach with respect to vehicles on the infrastructure. From a technological point of view, the safety and risk concepts are operationalized here to reduce the chance of "exceptional situations" occurring. In this line, the problem is to develop a generic, formal and coherent description, information and calculation model for exception analysis and exception handling based on modular and facility structures

Figure 25 Example of a hierarchy of probabilities

Estimates of the period chances of condition changes have been made for all these situations: k'[...], k''[...], with k'[4,2] as the chance that condition C[4] changes into condition C[2], for example. The choice of conditions and the relevant estimated values of the chances of condition change offer starting points to incorporate the technical knowledge about a component in the context of the application. Combined with different circumstances, it is also possible to introduce different systems of chances of condition transition. Another element in this model results from the conditions of composition and so-called correspondence chances, by which chance relations between combinations of component conditions are to be specified and, the conditions of the composition.
In the figure 25 for composition S, the conditions S[1] up to S[7] can be distinguished; a condition combination of, for example (C[3], C'[5]), could result in condition S[6] with an estimated chance p[3,5;6] = 0.8. In addition, within the context of the application and it is possible to handle various systems of correspondence chances together with the available technological knowledge in selecting the condition space and correspondence chances. As a matter of course, this approach is to be generalized to a combination of several components; the correspondence chances are then to be related to combinations of conditions. The chances of condition transition of the composition can be calculated from the mutually compatible systems of chances of condition transition and a system of correspondence chances with the help of a simple algorithm. This implies that, for composition formed in this manner, all information is available to introduce it as a component into a "higher" composition. From point of view of calculating probability, a discrete Markov model should be drawn up for every level
of composition. For the practical application, it is necessary to elaborate this formalism conceptually, to support with an appropriate information model and to be concretised into the form of a software package which supports various safety analyses. Attention then has to be paid to the characterization and identification of the conditions: in general, the number of conditions will be substantial. In general, the number of components in a composition will be large, which leads to very large numbers of condition combinations. In general, however, only a small number of the condition combinations with a positive correspondence chance, will be related to a condition of the composition. The information and probability manipulation model will have to anticipate this.

In principle, it is also possible to incorporate the facility structure into the outlined model. In the case of the traffic infrastructure as outlined in chapter 3, the composition structure runs via the control zones. A control zone with vehicles is to be conceived as a composition with the control zone and vehicles, as components. In order to be able to handle such a structure efficiently, an adapted information model will be necessary in addition to computer support. The core model, however, remains applicable. The purpose of the outlined approach is to result in: (1) a generic model for the execution of mathematical probability analyses; (2) a test of the concept through application models concerning the vehicle and the vehicle movements on the traffic infrastructure; (3) elaboration in the form of software which is potentially usable for the entire life cycle of technical installations and also with the reception and restore of exceptional situations; (4) testing the practical usability via model studies of the robot vehicle and of the traffic situations.

6.2 Management and the logistic implementation

As to the structure of DiTrans, it is assumed that the connecting infrastructure operates as a neutral facility in the sense that every robot vehicle meeting certain standards for physical aspects, the control and the nature of the transport assignment is admitted to the system. The infrastructure then offers performance known in advance with respect to arrival at the destination and at standard rates. If applied to the network according to figure 3 (§ 1.2), this could, for instance, mean that a trailer with a container is loaded at the "Delfland" junction for transport to the "Zevenbergschen Hoek" junction. In fact, transport by CombiRoad then becomes part of a multimodal transport system. This type of service is only attractive in a geographically extended CombiRoad network with rather long transport distances.

The transport performances to be supplied by the DiTrans system are, from a logistic point of view, much more extensive than those of CombiRoad, as the services of the terminals are integrated in DiTrans. This also offers more possibilities for multimodal integration of the system. In this respect, all transport modalities are of importance:

- ocean traffic (deep sea),
- coastal navigation (short sea),
- inland water transport,
- rail,
- road transport.

With respect to DiTrans, the transporters operating on these modalities should be considered external players with more or less autonomous management. In the scope of DiTrans, these services are, above all, to be used complementarily with respect to the inland transport modalities: inland water transport, rail and road transport. A certain degree of competition with respect to the road transport will, however, be inevitable. It is therefore important to structure the DiTrans services in such a way that, especially for road transport, a win-win situation will arise.

Important elements in the multimodal context are:

- the objectives and performance indicators of the multimodal chain as a whole; the operational communication with external players; the tariff structure and tariff level. It is important to gain insight into the quality of transport performance that can be expected of the shippers and to achieve a consensus about this with the relevant players in the chain of transport. For the proper functioning of the chain, it is important to use these insights to formulate organizational structures and labour agreements and possibly in the formulation of measurable performance indicators. In fact, this provides concrete starting points for the structure of operational communication and rating. External communication concerns the information known before the actual transport takes place; the specification of the transport order and information for completing formalities (Customs). A large number of various players are involved in the effectuation and completion of container transport, and there is a tendency to standardize the information around container transport and, if possible, have this take place using EDI. The set-up of an integral information model for container transport is part of the "Smartcard" R&D programme. At this point, the development will be coordinated with the development of the DiTrans programme: a concept for the specification of the transport order is formulated in § 3.1. The tariff structure and tariff height are to be conceived as instruments for stimulation of the desired behaviour of players within the whole of the chain, and to express a win-win situation in
the financial exploitation as well. In the scope of "managerial implementation", these aspects are analyzed and expanded to a possible set-up. A prognosis of the possible share in container transport together with the development of the DiTrans network and service is the second element in the study of the logistic implementation.

A first impression can be obtained via a statistical analysis based on prognoses in the form of origin-destination matrices and splitting these up to the ratios of market share that can be expected. A more differentiated idea can be obtained by taking into account the day and week patterns of the demand for transport as these appear in the different transport modalities. In this way, insight is obtained into the peak loads and the possibilities within DiTrans. This provides insight into the size of the exploitation that can be expected. A dynamic analysis is to be carried out by simulating the transport process at the individual container level. Because the terminal processes are not involved here, a rather high level of aggregation can be maintained, as indicated in § 2.6. A different (perhaps better) approach is to represent the DiTrans system at the coordination of deployment of capacity level; the context is shown in figure 8 (§ 2.5). At this level, containers and vehicle flows are the basic units, which generates a global dynamic adaptive framework within which trip and driving orders are issued effectively; see § 3.3. The capacity coordination can be sufficiently accurate on an hourly basis, using a planning frame of four days progressing hourly for the planning of transport and storage capacity. Tuning can be done with the help of linear programming. A model with two terminals "A" and "B" has been outlined in figure 26, the linear secondary conditions have been indicated below it. The model is general for a network with several terminals.

![Figure 26](image)

**Figure 26** Coordination with the help of linear programming

(i) Upper limit for the number of vehicles available for a trip to B:

\[ u'[t] \leq v'[t] \cdot a' \cdot r'[t] + d'[t]. \]

(ii) Capacity of the vehicles driving from A to B:

\[ x'[t] + y'[t] + z'[t] \leq c'. \]

(iii) Upper limit for direct transport to B without storage in A:

\[ x'[t] \leq r[t]. \]

(iv) Upper limit for transport to B with direct transit in B:

\[ y[t] \leq d[t]. \]

(v) Formation of the new supply of containers in A for transport to B:

\[ w'[t+1] = w[t] - x'[t] \cdot y'[t] - z'[t] + r[t]. \]

(vi) Formation of the new supply of containers in B for transport in B:

\[ w'[t+1] = w[t] + x'[t] + y'[t] + z'[t] - d'[t]. \]

(vii) The new number of vehicles at B:

\[ v'[t+1] = v'[t] + u[t] - u'[t]. \]

(viii) Fixed capacity constraints:

\[ u'[t] \leq c', \quad \text{CombiRoad capacity;} \]

\[ w[t] + w'[t] \leq s', \quad \text{the stack capacity at A.} \]

The constraints are drawn up for the transport direction from A to B; from a symmetrical point of view, the same constraints are applicable for travel from B to A. 't' is used as the time index. All decision variables are non-negative. In constraint (i), the average duration of a ride at the terminal is to be calculated by choosing a proper value for coefficient a; if, for instance, the time base is one hour and an average terminal ride is 6 minutes, then a = 0.1 is chosen. The form of inequality of constraint (ii) allows for the possibility of empty rides. The connection between the variables over the hour periods goes via the storage information of containers (v) and (vi) and of the available DiTrans vehicles (vii). The relevant costs are:

(ix) decision-dependent costs for transport from A to B:

\[ (p' + p^0) \cdot (x'[t] + y'[t]) + (p' + 2 \cdot p^0) \cdot z'[t] + q' \cdot u'[t]. \]

Here, q represents the cost coefficient for driving an empty vehicle, p' the coefficient for the additional costs if a vehicle collects a container, and p^0 represents the costs of transfer at the stack; for the transport of type z'[.] the costs of transfer at the stack occur twice. For the development of a configuration model in which the transport performances of DiTrans in the dynamic context of the transport environment are to be checked, such a linear programming model offers a basis which can easily be implemented with the help of standard software.

### 6.3 Social acceptance and effectuation

Large scale projects in the field of the transport infrastructure with new technological and/or organizational elements seem to be difficult to realize at the social level. Recent examples include the Betuwelijn, the HighSpeed Line (TGV) and the expansion of Schiphol Airport. Many difficulties may also occur in the realisation...
of DiTrans or CombiRoad. In this respect, six aspects are to be examined:

- mobilization of independent R&D capacity (role of the technical universities);
- social communication about the problem definition and the project in view;
- granting licences and political decision making;
- purchase of land, expropriation;
- financing;
- the effectuation of the decisions taken.

The aim of the research is to systematically inventorize the route to realization of large scale projects in the field of transport infrastructure, to develop a methodical approach supported by software, developed for this purpose, and to apply this to a planned realization of DiTrans and/or CombiRoad. In this research, the course of affairs of a number of recent projects is monitored: the Betuwelijn, the HSL, the structure of the Maasvlakte, mainport Schiphol, the Channel tunnel. The development of the supporting software concerns the set-up of an information system with (TUD), van der Ham (ECT). The development of the supporting software concerns the set-up of an information system with integrated scenario methodology. In the scenario methodology, the description technique mentioned in § 3.1 (see figure 11) could be a starting point. The choice option can be used to indicate decisive points and to include chance developments.

Literature


Paper 11

Dipl.-Ing G Andersson
Paper 12

Dipl.-Ing H-G Bruckmann
Studying Ship Technology
Degree Course

Are you looking for a varied and broadly based technical degree course that is both exciting and truly state-of-the-art?

Then you might like to consider a degree course in

Ship Technology.

Where might you find employment after obtaining your degree in Ship Technology?

Firstly, in companies and organisations that have to do with ship technology, which include

shipyards,
the sub-contractor industry,
research centres,
trade associations and authorities, etc.

However, marine engineers are also popular in the area of mechanical engineering, amply proven by their frequent employment. This is hardly surprising as ship technology falls into the area of mechanical engineering. In principle, a ship is no more than a collection of many elements of mechanical engineering, all held together by a water-tight outer shell. However, an important fact should not be forgotten in saying this: ships constitute the most environmentally friendly form of modern-day transport!

What does studying ship technology comprise?

As already implied, modern shipbuilding draws on many elements of mechanical engineering. For this reason, just like for the mechanical engineering degree course, a solid foundation must first be built. This occurs during the four-semester foundation course, which covers the following subjects:

mathematics,
physics,
chemistry,
electrical engineering,
thermodynamics,
materials technology,
technical mechanics and structural theory, etc.

These are the basic subjects of every engineering degree course and are augmented by two basic ship-technology subjects, namely buoyancy and stability as well as ship's elements.

Apart from further mechanical engineering subjects, the second part of the degree course then deals chiefly with ship-technology subjects like

ship design,
ship construction and building,
ship hydrodynamics,
ship construction
marine engineering
In addition to this, further topics like shipping company management, port operation and model test and ship trials are also on offer.

Will the degree course leave me enough room for personal preferences and interests?

Very definitely. Owing to the university's special academic status as a "Comprehensive University", integrated degree course are offered with a choice between two different qualifications, the DI degree, after at least 7 semesters (comparable to a Bachelor degree) and the DII degree after at least 9 semesters (comparable to a Masters degree).

The decision in favour of one or the other is partly governed by the level of entrance qualifications you hold and partly by the way you prefer to work. Should you be more practically talented, the DI course would probably be best for you, while the DII course is recommended for all those who are more theoretically minded and leads to a classic, German engineering degree. However, this decision only has to be made during the run of the foundation course, which is largely identical in both cases.

The large choice of optional subjects also leaves ample room for the pursuit of personal interests. As the Institute of Ship Technology has its own workshop and own lab facilities, students can test models of their own design. However, tests can also be carried out on board ship or at the "Duisburg Ship Model Testing Tank, (VBD)", which is affiliated to the university.

Where can help be found during the course?

To start with, you can approach any one of the five professors of the institute or their staff who, owing to the small number of students, are able to deal personally with any problems or queries. However, the more experienced students in higher semesters will also be glad to offer any help. In this context, it is also worth mentioning that every student has his or her own drawing board in the Institute's special shipbuilding room where individual or group work can be completed. The sense of community the marine engineers are renowned for is a major advantage during the degree course, creating both a personal atmosphere and the opportunity to make friends.

What steps need to be taken in order to secure a place on the Ship Technology degree course?

The Akademisches Auslandsamt (AAA) of the Gerhard Mercator University of Duisburg is responsible for foreign students and should be contacted for precise details and requirements at the following address:

Akademisches Auslandsamt
Gebäude LE
Lotharstr. 65
47048 Duisburg
Tel.: ++49/203/379-2458/-2459/-3106
Fax: ++49/203/379-2470
e-mail: jaritz@unidui.uni-duisburg.de

In short, though, you will first need to contact the AAA for an Application for Admission form, along with which you will also be informed of the conditions of admission. At this stage, you are also recommended to state whether you would require a room in the halls of residence. Addresses can then be supplied for you to apply as soon as possible (places are limited).

Your completed application for admission would have to reach the AAA by 15 July in time for the winter-semester start of the degree course and contain the following documents:

- several officially authenticated copies of your school qualifications and, if applicable, detailed proof of periods of university attendance. Please never send original certificates, etc., as all submitted documents are retained by the university,
- officially authenticated translations of certificates if these are not in German, English or French,
proof of adequate knowledge of German. You will at least have to have passed the intermediate (Mittelstufe) level of the Goethe Institute so that you can attend preparatory courses (held in Bochum) for the PNdS exam, which all foreign students need to hold in order to be able to study at German universities. You can only be exempt from this requirement should you already be in possession of the PNdS qualification or of the "Kleinen" or "Großen Deutschen Sprachdiplom" of the Goethe Institute.

If you hold qualifications that would enable you to study in your home country, you would normally also be able to study in Germany. However, should your qualifications not be deemed equivalent to the German "Abitur", you would either have to submit proof of having studied successfully in your home country for a year or two or attend a German "Studienkolleg" school to attain the necessary qualifications.

On a general note, you would require in the region of DM 1000 per month to cover the cost of living and rent, etc. Owing to the fact that the Gerhard Mercator University of Duisburg unfortunately does not grant scholarships and that it is not always possible for students to work, guaranteed financial support is therefore of vital importance.

Prior to embarking on a course of study in Germany, you would also have to check on applicable immigration laws, especially if you come from a non-EU country. It would also be advisable for you to gather as much information about life in Germany as possible before starting on your degree course as it would no doubt help you to settle in more quickly.

Having said that, the degree course also requires you to complete 26 weeks of practical training. This is split up into six weeks of basic training in welding, filing, drilling, milling, etc. and 20 weeks of specialised training in ship construction and repair, etc. The basic practical training has to be completed by the end of the foundation course and the specialised training by the time you register your dissertation. We recommend you try to complete as much of this practical training as possible before starting on the degree course - semester holidays will need to be used to complete assignments and to revise for exams. Suitable, official vocational qualifications may be able to count towards necessary practical training.

How can I get further information about studying Ship Technology in Duisburg?

Easily! Just phone, fax or write so that we can get the ball rolling and ultimately invite you for a personal interview.

Gerhard Mercator University of Duisburg
Institute of Ship Technology (ISD)
Gebäude BK
Bismarckstr. 69
47057 Duisburg
Tel. ++49/203/379-1173
Fax: ++49/203/379-2779
e-mail: isd@nav.uni-duisburg.de
Ship Technology in Duisburg on Internet
http://www.uni-duisburg.de/FB7/ISD

What we all do at the Institute of Ship Technology in Duisburg

We are in a position to train students across the whole spectrum of ship technology, including the construction of seagoing and inland vessels. It is the latter, however, in which we have built up a particular position of strength. Besides the classic ship building and marine mechanical-engineering subjects, the mandatory electives like yacht building, harbour operation, shallow water hydrodynamics, shipping company operation, marine technology and ship's safety technology are also popular among students. The "Duisburg Ship Model Testing Tank (VBD)", which is affiliated to the university, and the "European Development Centre for Inland Navigation (EBD)" both play a very active role in the work carried out at the Gerhard Mercator University of Duisburg.

To date, many course assignments and dissertations have been completed, some even in cooperation with industry, on such topics as inland vessels, coastal ships, seagoing ships, marine technology, sports boats and shipyards.

At present, PhD-related research is concerned with inland vessels and dynamic loads during robust cargo handling, vibration loads due to the power plant and strain when sailing in shallow water. Further topics are ship's wake in shallow water and non-linear interaction between ocean waves and marine structures or ships. As the influence of shallow water, which ocean liners are also subjected to when navigating certain routes, is very difficult to quantify, research activities are both of an extremely high scientific and academic standard.

University excursions have so far taken ISD students to 11 European countries. In addition to this, the Duisburg Symposium on Ship Technology/Marine Technology, a by now traditional event that began in 1980, welcomes scientists and practitioners from many European countries to hold lectures and take part in discussions on a yearly basis.

Institute members are actively involved in the following international and national committees, societies and associations: "Deutsche Forschungsgemeinschaft" (DFG) (German Research Association), "Hafenbautechnische Gesellschaft" (STG) (Society for Port Construction Technology), "Society of Naval Architects and Marine Engineers" (SNAME), "Network of Shipbuilding Students" (NESS), "European Association of Universities in Marine Technology and Related Sciences" (WEGEMT), among others. The international contacts of the teaching staff and the students were further boosted by the 21st, 22nd and 23rd NESS Conferences in 1994 and 1995, both of which were held in Duisburg.

The 4th WEGEMT Workshop planned for 1997 will be the next Duisburg-based event in support of international ties. The excellent reputation of the ship-technology degree course offered by the University of Duisburg has
been more than justified by student activities, most notably at the international
pedal boat regattas, of which the 7th took place in Duisburg in 1986, and at the
Student Days of the Schiffsbautentechnische Gesellschaft (STG) (Shipbuilding
Technology Society) in Hamburg.
In 1980 the University began to honour special student achievements with the
Duisburg University Award, the sponsorship prize of the VDI Ruhr District
Association and the ISD prize. One or two ship-technology students have been among
the annual winners ever since.
Public relations work is also a key issue at the ISD. The institute has been regularly
represented at the "boot" trade fair in Düsseldorf, the exhibition of "Binnenschifffahrt, Küstenschifffahrt und
Befrachtung" (bkb) (Inland Navigation, Coastal Navigation and Freighting) in Duisburg and the "Shipbuilding, Machinery
and Maritime Technology" (SMM) fair in Hamburg. The ISD and its degree course in
ship technology are also given frequent radio and press coverage when of topical
interest.
Our students on the ship technology degree
course come from all over Germany and
from many different nations. Our graduates
go just as far once they leave us.
**Why not join us at the ISD?**
**It could well be worth your while to come and study ship technology in Duisburg**
with a team of fellow students, assistants
and professors.
The city offers an interesting cultural scene,
sports facilities, parks as well as a watersports recreation area. Duisburg's unique
geographic location at the junction of the Rhine and Ruhr rivers and its major inland
port make it perfect for combining theory
and practice.
The chances of employment as a graduate
engineer (bearing the title Dipl.-Ing.) are very
good.
If we have managed to peak your interest,
why not sound us out at the following e-
mail address? We will gladly provide you
with further details.
**e-mail: isd@nav.uni-duisburg.de**
**How Ship Technology came to Duisburg**
After the end of the second world war, the
Berlin Professor Sturtzel and the assistant
head of government department Brandt
applied for permission to found the first
post-war German Ship Building Research
Institute in Duisburg. The aim of the
institute was to provide technical and
scientific support for rebuilding the German
inland fleet. The research centre, founded in
1954, was first headed by Prof. W.
Sturtzel. At the same time, he was also
offered a chair at the RWTH Aachen
(Rhenish-Westphalian Technical
University) where courses in ship building
had begun to be offered. Even though this
was a period in which Duisburg did not
enjoy university status, it did have the
flourishing State School of Mechanical
Engineering (SISM). In 1950, college
lecturers submitted their application to set
up an Institute of Ship Building in Duisburg
with a staff of five lecturers. On 15 March
1954, the Institute finally opened its doors
to the first 25 students about to embark on a
five-semester degree course in ship
technology. The first Head of the Ship
Technology Department was the graduate
engineer, F.-W. Luther, the then head of
the planning department and building
control office.
The ancient Hanseatic and harbour town of
Duisburg finally founded its second
university in 1972. This event also marked
the start of negotiations and considerations
aimed at concentrating degree courses in
ship technology at one university in the
Federal state of North Rhine-Westphalia,
namely in Duisburg. With the ratification of
the examination regulations governing the
integrated degree courses in ship
technology (7 and 9 semesters) in 1989, the
final obstacles to the realisation of this idea
had finally been overcome. As a result, ship
building was taken off the teaching
programme in Aachen. The request
submitted by Duisburg's former State
School of Mechanical Engineering (SISM)
in 1950 regarding the foundation of an
Institute of Ship Building was also granted
with some delay. In 1994, the Faculty of
Ship Technology ceased to be and re-
emerged as a scientific establishment
bearing the full title "Institute of Ship
Technology Duisburg (ISD) of the Faculty
of Mechanical Engineering of the Gerhard
Mercator University of Duisburg" - or ISD
for short. The Institute works with a current
staff of five university professors, four
honorary professors, one external lecturer,
eight scientific assistants (of which four are financed by research funds) as well as four technical and administrative employees. With 134 students at present, the ship technology course offered at the Gerhard Mercator University of Duisburg is the second largest among all German universities.

The institute has a large shipbuilding room with the double name "Franz Haniel Saal" / "Mathias Stinnes Saal" designed to provide students with the necessary space for effective work and the "Carl Lehnkering Saal" for the scientific assistants. The rooms were named after prominent Duisburg shipping company owners.

The course has plenty of hands-on appeal, providing students with the opportunity to conduct practical tests on ship models at the shipbuilding laboratory, in the towing basin at the Duisburg Ship Model Testing Tank (VBD) and during test runs on ships.

**How the University got its name**

The famous Flemish cartographer, mathematician, instrument builder and surveyor, etc., Gerardus Mercator, lived in Duisburg from 1552 to 1594. During this time, he produced the collection of maps he called an 'atlas' as well as globes of the earth and the sky, all of which were then the best and most reliable the world had ever seen. However, world acclaim only came with the production of his orthomorphic map projection, later to be named Mercator's projection, which enabled the safe navigation of ships along a direct route from A to B by following a compass. Mercator used loxodromes, i.e. straight rhumb lines, to depict the earth's curved surface on two-dimensional maps.

Nowadays, Duisburg is a centre of Mercator-based research and the "Mercator treasure chest" containing a selection of his works is on exhibition at the Museum of Culture and Municipal History.

On 19 March 1994, in the 400th year of Mercator's death, the University was renamed Gerhard Mercator University of Duisburg. The ceremony in the Mercator Concert Hall and the ecumenical service held in Duisburg's Salvator Church were attended by Johannes Rau, who by now headed the State of North Rhine-Westphalia. The cavalcade of ships along the Rhine, organised by the Institute of Ship Technology, provided a suitable close to the festivities.

**How Duisburg gained university status**

The famous child engagement of the five-year-old Mary of Jülich-Berg and the six-year-old John of Cleves-Mark took place in 1446. This event also resulted in the formation of a grand duchy that was duly entitled to a university. As a consequence, William V, the duke of Cleves-Jülich-Berg, turned to the Pope in 1555 with the request to found a Catholic university in Duisburg.

Approval came from Pope Pius IV in 1564 and confirmation followed from Emperor Maximilian II in 1566. However, the general political climate at the time kept preventing a start from being made in Duisburg. Then, in 1641 - the duchy having by now lost just a little of its grandness - the remaining yet resolute estates of Cleves and Mark again turned to their sovereign ruler at the time, Frederick William, the elector of Brandenburg (and known as the "Grand Duke"), with the request to establish a university.

**The founding fathers of Duisburg's universities.**

The university's founding patent was again signed in 1654 and the university finally inaugurated in Duisburg's Gothic Salvator Church in 1655. It bore the official title of State University of Cleves and offered all four classic faculties: theology, jurisprudence, medicine and philosophy. Next to those at Frankfurt-on-Oder and Halle, the university formed one of the three Prussian seats of higher education. The large seal of the university depicted Emperor Maximilian II and Frederick William, the elector of Brandenburg.

Nowadays, miniature replicas of the ancient university's faculty seals adorn the Rector's chain of office.

Renowned professors taught at the university, including the medics J.G. Leidenfrost and C.J. Carstanjen. The list of famous ex-students includes such names as Doctor C.A. Kortum and the lawyer, politician and dramatist August von Kotzebue. The 1818 Stein reforms were responsible for the dissolution of the University of Duisburg and, in the same year, for the foundation of the University of...
Bonn, where Duisburg's traditions were henceforth continued.

In 1971 the town councillors of Duisburg and staff at Duisburg's Higher Technical and Teachers' Training Colleges submitted yet another application for the establishment of a university in Duisburg to Johannes Rau, who at that time was the Minister of Science of the State of North Rhine-Westphalia. The great day finally arrived in 1972. The Duisburg Department of the Teachers' Training College of the Ruhr and Duisburg's Higher Technical College formed the founding core of the Comprehensive College of Higher Education of Duisburg, on which full academic rights were conferred.

Nowadays, 10 faculties (having lost one of originally 11) offer 8-semester degree courses in the humanities, economics and the natural sciences as well as 7- or 9-semester engineering degree courses depending on whether the course emphasis is predominantly practical or theoretical. The Comprehensive College of Higher Education of Duisburg was re-designated Comprehensive University of Duisburg in 1980.