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REVIEW
NORWEGIAN MARINE TECHNOLOGY RESEARCH INSTITUTE

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Contents:



# LNG as fuel for ships in short sea shipping

**New stringent demand from IMO on $NO_x$ and $SO_x$ emission limits in the Emission Control Areas (ECA) will have an impact on fuel oil quality and vessel operation in these areas. In addition there is a growing focus on Particulate Matter (PM) and a demand for reduction of Greenhouse Gases (GHG) from ships.**

Natural gas fuels a combustion process that produces substantially lower $NO_x$, $SO_x$ and PM emissions that will be well below the forthcoming IMO limits. $CO_2$ emissions are also significantly reduced due to the lower carbon content of the fuel. Methane is regarded as an aggressive GHG, with a $CO_2$ factor of 22. Although some unburned methane is emitted from gas engines, it offers a potential net reduction in GHG emissions in the range of 10 – 20%. One assumption is high efficiency, and modern gas engine display higher thermal efficiency than their diesel counterparts. Natural gas, in the form of LNG, is therefore a very attractive means of reducing all key emissions from ships.

MARINTEK has a long history of developing gas engines for power generation and systems for small-scale distribution of natural gas in form of LNG. This knowledge and experience is being combined in order to encourage the use of natural gas as a suitable fuel for ships.

LNG is currently used to fuel domestic ferries and supply vessels. MARINTEK is involved in the development of concepts for cargo ships such as RoRo cargo vessels and coastal freighters.

The RoRo concept is being put into practice by the shipping company SeaCargo with its order of

*Cont. on page 12*


*RoRo cargo vessel on order for delivery in 2011 (Rolls-Royce Marine design).*

SINTEF

# Free-Fall Lifeboat Projects 2005-2009

**Offshore installation tests in calm water carried out in spring 2005 revealed an unacceptable structural degree of deflection of the roof in one type of free-fall lifeboat. Immediate remedial action was initiated by the Norwegian Oil Industry Association (OLF), including the study and documentation of the main performance factors for free-fall lifeboats at up to 100-year weather conditions, to develop relevant criteria for in-depth classification of performance, and finally to upgrade urgently, wherever relevant, all free-fall lifeboats operating on the Norwegian continental shelf to the agreed standards.**

OLF Lifeboat Projects have been managed by StatoilHydro. MARINTEK was awarded the contracts to perform full-scale tests measurements and to develop model test procedures, analysis standards and extrapolation methods.

The main performance factors of free-fall lifeboat systems in emergency conditions are structural strength, acceleration loads as imposed on passengers on water impact, boat forward speed immediately after water entry, and manoeuvring away to a safe distance from the installation.

## Free-fall lifeboat performance in up to 100-years storm condition

As part of the 2005-2009 OLF project, MARINTEK has performed an extensive model test programme (over 20,000 tests) of 14 different types of free-fall lifeboats. Systematic tests to document pressure loads, acceleration loads, and forward speed were performed in three regular wave heights, in four points of incidence to the waves, and in selected wave headings. Calm-water model test results were compared to full-scale test results (250 full-scale tests were performed). In order to extend prognosis of lifeboat performance up to 100-year storm conditions (Hs=15.7 m), special extrapolation methods were developed for studying the three basic performance areas, augmented by computer simulations of higher sea states. For each type of lifeboat the extrapolation methods were vali-dated by comparing extrapolated results with statistical results from up to 100 random tests in irregular sea conditions up to significant wave height Hs=7.1 m. "Forward distance" model tests were performed in combined wave and wind conditions.

## Pressure loads and accelerations

During the first part of the OLF project, pressure loads on free-fall lifeboat superstructures and acceleration loads in seat positions were studied and documented.

The main conclusion from the pressure load tests was that the highest pressure load on the roof was generally measured in head seas at certain hit-points in the waves. In order to document slamming loads, several boats were tested in following, beam, and oblique seas. The basic method for extrapolation of model test results from systematic tests in regular waves to irregular sea states was developed during the first part of the project. The purpose of this analysis was to evaluate the probability distribution of the maximum pressure on the roof and the "characteristic load", which also embraced acceleration loads, defined from a given probability of being exceeded in any irregular sea condition.

In order to assess the likelihood of an occupant of a lifeboat being injured by accelerations, the IMO International Life-Saving Appliances code provides criteria based on the Combined Acceleration Ratio (CAR) index, which is a measure of the acceleration exposure on persons on board a free-fall lifeboat directly computed from filtered acceleration time-series. Following a square-root-sum-of-the-squares approach, accelerations are regarded as acceptable as long as the CAR index remains equal to or smaller than one. It needs to be remembered that the CAR index method does not take the protective qualities of specific seat and seatbelt systems into account, but is a suitable indicator for screening purposes. Model test results confirmed that the worst possible acceleration levels, and thus the highest CAR values, are highly dependent on both the point of incidence in waves and wave heading. Depending on the type and design of boat, launches in headings between stern-quarter and following seas might give the highest combined acceleration loads, particularly when significant lateral loads (Y-accelerations) are generated in oblique seas.

In collaboration with NTNU, MARINTEK developed a theoretical method of predicting three-dimensional accelerations of a lifeboat impacting an irregular wave surface (see Figure 3). Body motions are described in terms of six degrees of freedom and wave

*Photo 1: "Forward Distance" model tests in bow oblique seas (Regular Wave H=11.3 m and wind 35 m/s).*

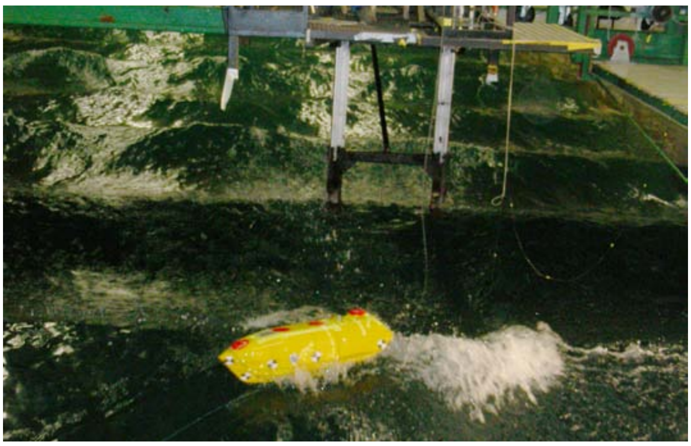

*Photo 2: Model track during tests in regular waves was recorded using a digital video camera located under the roof of the wave tank. To enable the large amount of photos (about 100000 per tested lifeboat) to be processed, automatic tracking software was developed and implemented in Matlab.*

kinematics is described in three dimensions. This allows any type of impact in waves to be studied. This theoretical model has been implemented and validated by comparing predicted accelerations on impact to experimental data. About 300 cases with different types of lifeboats in various wave conditions were used in the validation phase. The tool allowed reliable statistical estimates of accelerations in extreme sea states to be established, and boat-specific operational limits to be set.

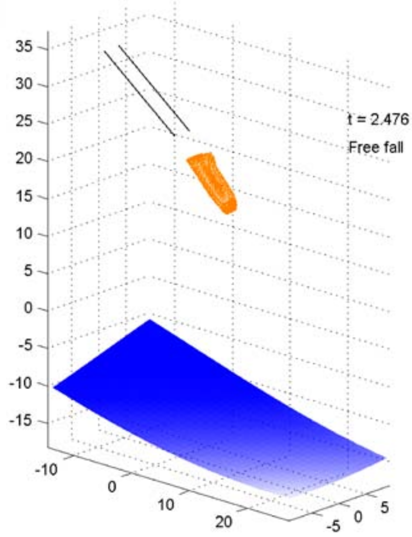


*Figure 3.*

Selected acceleration pulses produced by the simulator were also provided to TNO-Science and Industry in the Netherlands, which performed the vital and comprehensive assessment of the quality of existing free-fall lifeboat seat and seatbelt systems, tested new systems by laboratory sled tests, developed injury criteria and acceptance levels related to dummy tests and the use of numerical human models. Based on the selected acceleration pulses provided to TNO, the risk of injury was finally predicted for boat-specific seat and seatbelt systems and, if relevant, restrictions in the use of specific seats can now be issued.

## Forward distance performance

A lifeboat needs to be capable of escaping to a safe position away from, and without risk of collision with, the installation or other obstacles. By spring 2009, the OLF project had documented forward speed performance for conditions up to 100-year sea states for 16 types of free-fall lifeboats.

A series of initial model tests that aimed to evaluate lifeboat performances after water entry were performed with and without active propulsion and steering. The test results and experience from these tests were further utilized to developed forward distance test procedures, statistical extrapolation methods, and comprehensive computer simulations of lifeboat steering and seakeeping performance in heavy weather.

A special approach was proposed in which free-fall lifeboat performance after launch is divided into two distinct phases. The objective of this approach is to give an intuitive presentation of the vessel's headway. This is done by first extracting information on the position, direction and velocity of the vessel from model launch tests in regular waves and then adapting it to irregular seas (Phase 1). This is subsequently combined with numerical simulations of the vessel's path in VeSim (Phase 2). The final products are plots showing various probability levels for boat passage.

Figure 4 provides an overview of the two phase approach in order to evaluate the forward distance performance of free-fall lifeboats after water entry in required irregular sea conditions.

## Outline combined use of model tests and VeSim simulation results

First, the position of the lifeboat (x and y position, yaw angle and speed) in different irregular sea conditions before engagement of gear must be defined by extrapolating the model test results from model tests in regular waves.

On the basis of extrapolated model test results, 1000 simultaneous start positions, yaw and speed were randomly selected and applied as starting conditions for VeSim simulation (gear engaged). For every start condition 1 of 100 simulated tracks was selected at random. The autopilot was set to gain distance against the weather at full power. The mathematical model employed in the VeSim computer programme was validated by comparing the results of the full-scale tests with the computer simulations. Several manoeuvring tests in calm water and manoeuvring and seakeeping tests in rough seas (significant wave height up to Hs=7.5 m) were therefore carried out.

The final "Forward Distance" data are shown as contour plots showing the cumulative probability distribution of the boat tracks in the "out of platform" direction.


### *Acknowledgement*

MARINTEK appreciate the permission given by OLF and StatoilHydro to publish the results of this research and development programme.



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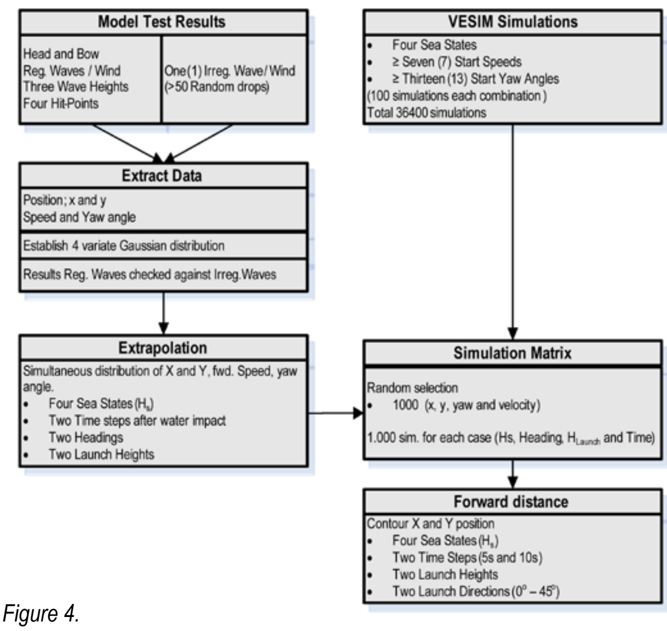


*Figure 4.*

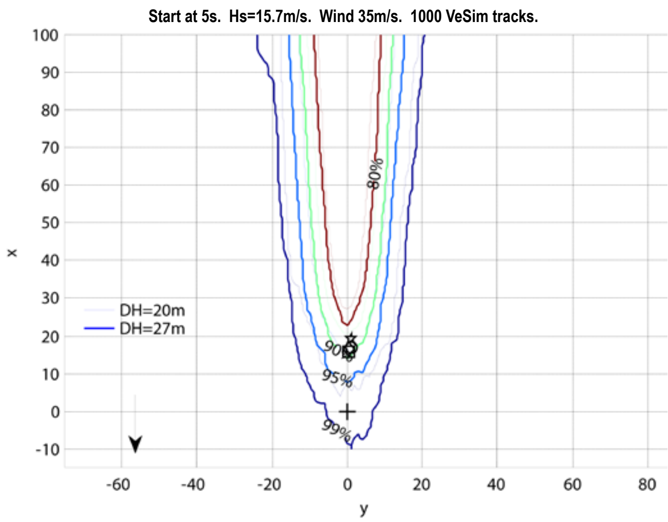


*Figure 5. Example forward distance contour plot. Engagement of gear (thrust) 5s after water impact. Zero position (cross) refers to boat stern at launch position. The mark at about x=18 m shows stern position at water impact.*

# Wave-induced ship vibrations

**Wave-induced hull girder vibrations are normally described using the terms "springing" and "whipping". Whipping is the transient vibration response excited by wave-impact loads, such as those that arise from bottom slamming or bow-flare slamming. Springing is associated with resonant vibrations; i.e. when there are excitation forces whose frequency coincides with the natural frequency of one of the hull girder vibration modes.**

Normally, this will be the 2-node vertical vibration mode, since this mode has the lowest natural frequency. Recently, there has also been concern about vibrations in the 1-node torsion mode and the 2-node lateral mode, particularly for ships with open cross-sections. A typical example is large container ships moving at relatively high speed.

In order to study wave-induced hull girder vibrations in general and combined lateral-torsional responses in particular, a flexible backbone model was designed and constructed in a joint project with the Centre for Ships and Ocean Structures (CeSOS) at NTNU.

The model consists of 15 box-shaped segments, in addition to bow and stern segments that can easily be replaced with alternative shapes. The segments are made of coated plastic foam and connected by an aluminium beam on top. The beam has a square thin-walled cross-section, whose dimensions are carefully selected to give the appropriate natural frequencies in bending and torsion. Cut-outs in the top flange were required to obtain the desired flexural and torsional dynamic features. Strain gauges are located at seven stations along the beam. At each station there are gauges measuring longitudinal and shear strains on the top, bottom and both sides of the beam. Static tests with known loads were used to determine the coefficients that correlated the measured strains with the shear forces, bending moments and torsional moments at each station.

The model has been tested extensively in the Towing Tank and the Ocean Basin. A wide range of speeds, headings and sea-states has been tested, and tests have also been performed in regular waves, as well as in extreme waves to study slam-induced torsional vibrations. The model is shown in Figure 1.

Nonlinear effects mean that the forces from the waves can oscillate at a frequency which is an integer multiple of the encounter frequency. Relatively long and energetic waves can thus cause springing. In the experiments, this nonlinear springing phenomenon was observed in vertical bending vibrations in head seas and in torsional vibrations in oblique seas. Torsional springing is illustrated in Figure 2, which shows the power spectrum of the torsional moment at one longitudinal position in the backbone beam during tests in irregular oblique seas. The low peak at around 2 Hz corresponds to the wave encounter frequency, while the high peak at 5.4 Hz corresponds to the natural frequency in torsion. A sample time-series of the torsional moment in the same condition is shown in Figure 3 together with the relative wave elevation. Once again, the difference in oscillation frequency between the waves and the torsional vibrations is evident, illustrating the importance of nonlinear effects.

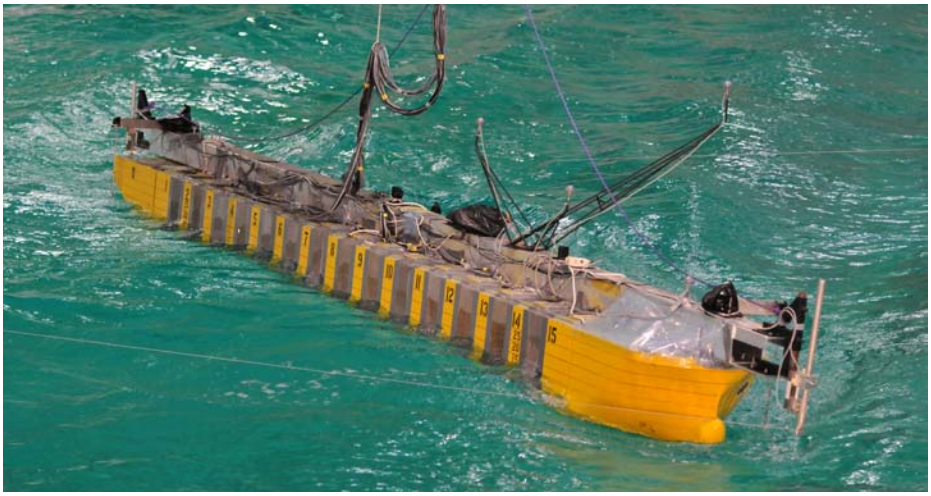

*Figure 1. Flexible backbone model during tests in oblique seas in the Ocean Basin.*

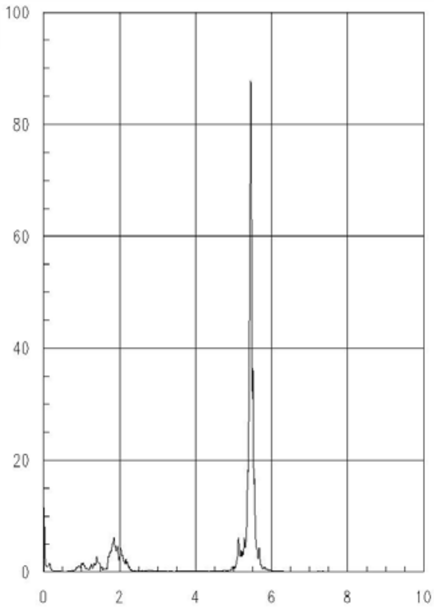


*Figure 2. Power spectrum of measured torsional moment in the backbone during tests in irregular oblique seas.*

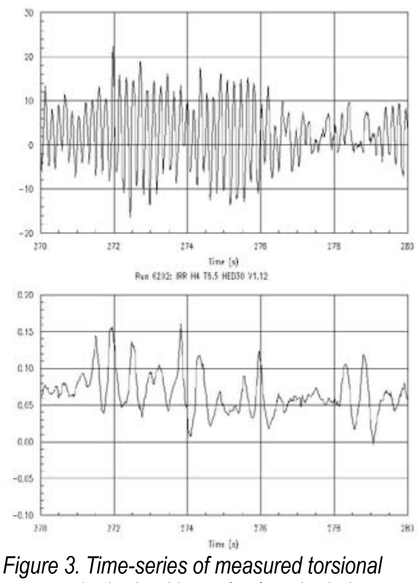

*Figure 3. Time-series of measured torsional moment in the backbone (top) and relative wave elevation at the bow (bottom) during tests in irregular oblique seas.*

Further analyses of the test results and comparisons with numerical calculations are currently under way at CeSOS and MARINTEK.

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# STX Europe: Development of tomorrow's offshore vessels

# Environmentally friendly, cost-effective and safe – A TOTAL DESIGN

**STX Europe is working on the development of more energy-efficient hulls. The company aims to reduce fuel consumption by up to 20% compared to today's offshore vessels. The design process needs to provide both good calm-water and seakeeping performance. The parameters studied were LCB, L/B, B/T and CB. Better understanding of how individual parameter variations influence ship performance is taken into account by developing an early-stage design tool that enables designers to vary the parametera and instantly see the effect upon calm-water and seakeeping performance.**

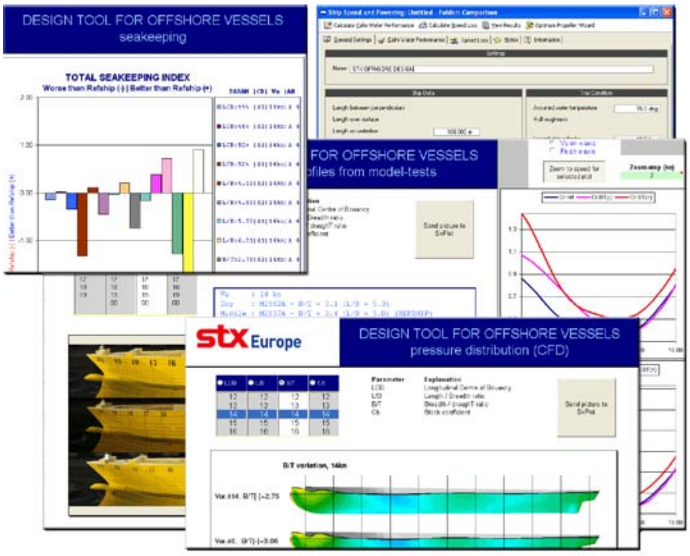


*Figure 2. Overview of tools for designing customised offshore vessels. A complete software tool that combines all the findings for better understanding of early design for client (consultant) and client's customers (final users of the design). The software tool offers an overview of CFD findings, model-test results from calm water and extensive seakeeping/operability calculations using MARINTEK's in-house seakeeping code VERES. In addition, a customized calm-water performance regression tool will be prepared for the client, using MARINTEK's Ship Speed and Powering program, a ShipX plug-in. This regression tool will also be used in the above-mentioned design tool.*

Performance in calm water is documented by model-tests at design draft in the speed range of 9-19 knots, while seakeeping operability is being studied for four different cases; transit, on hold, crane operation, ROV launch, in three regions; the North Sea, the Norwegian Sea and the East coast of Brazil.

## Solutions by doing systematic research

A development project for STX Europe, the aim of which was to design offshore vessels that will be both cost-effective and environmentally friendly, has been completed. The aim is to reduce fuel consumption and determine how the main characteristics of the ship will influence its seakeeping characteristics, by systematically varying the principal dimensions of offshore vessels approximately 100 metres in length.

Both CFD calculations and model tests have been performed for a calm-water performance study. The CFD report concluded that the resistance values cannot be calculated satisfactorily to study the effect of the parameter variations. However, wave patterns from model tests have been compared with calculated values, good agreement has been found. The latter can be exploited by comparing coloured pressure images for a given speed with a single parameter change, for instance in the blockcoefficient. This can be helpful as a way of studying how wavepatterns develop following a parameter change in the early design phase.

## Environmental optimization by using a "complete design tool"

Optimizing calm-water performance by changing main parameters will also influence a ship's seakeeping characteristics. This is important to remember in the early-stage design process, in particular that it is the main parameters of the ship that determine the seakeeping characteristics and that these parameters are difficult to change at later stages of the design process. The final design will thus be optimised with respect to calm water performance when the seakeeping characteristics have already been taken into account.

A software tool that provides an overview of both calm water performance and seakeeping characteristics is the final delivery and will function as a design tool for the client which he can use as a guide to understanding how the parametric changes will influence both types of performance. This of course will be helpful in reaching agreement on the optimum final design.

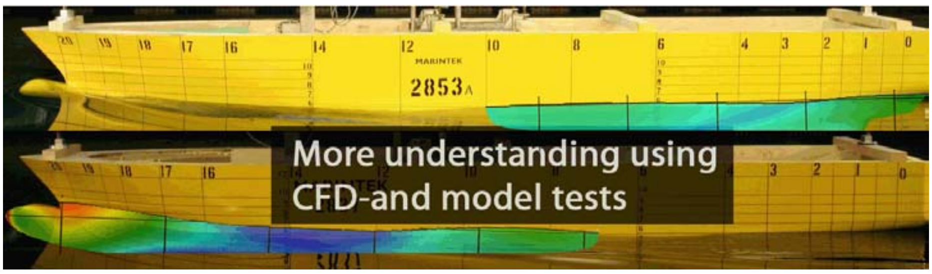


*Figure 1. Model tests of two variations at the same speed merged with CFD calculations. During the model tests photos are taken to show the wave profile along the hull. CFD calculations provide useful information about the pressure field below the water surface that creates the wave pattern along the hull. Details of bow/bulb-design are critical and can be better understood using a combination of CFD and model tests.*

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# The Shipping KPI Standard

## "…a joint initiative on performance measurements in shipping improving the competitive edge of quality players …"


**In collaboration with more than 20 shipping-related companies and interest organizations, Intermanager and MARINTEK have developed a Performance Hierarchy comprising Shipping Performance Indexes, Key Performance Indicators and their measurement.**
**The project was funded by the participating companies with additional funding from the Research Council of Norway (RCN). A steering committee headed by Wilh. Wilhelmsen ASA supervised the project work while MARINTEK was project manager and the main R&D partner.**
**More information can be found at:** *www.shipping-kpi.com.*

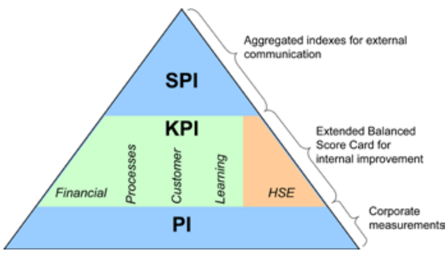
The Shipping KPI standard has been developed over the past few years and was released towards the end of 2008. Intermanager (*http://www.intermanager.org/*) is the caretaker of the standard and is hosting the governing body of the standard. It is not an international standard in the sense of being hosted by an international standardization body, but it aims to become a de facto industry standard.

The objective of the Shipping KPI project was to create a KPI standard suitable for:

- Internal improvement processes
- External communication about performance

In order to be able to serve both internal improvement and external communication, aggregation is used as the principle for creating the KPI and the higher-level indexes. Data are collected once and re-used for two different purposes, thus reducing the amount of data needed. At the lowest level are the Performance Indicators, which are measurements or counters that can be found directly in the shipping company, i.e. number of technical failures of critical equipment, LTIF etc. The PIs are information that is needed to calculate the KPI and SPI.

The Key Performance Indicators are designed to measure performance in a particular area, such as "Flawless port state control performance", "Condition of class" and "Environmental deficiencies". At KPI level a form of normalisation takes place; for example, the "port state control deficiency rate" is defined as the number of port state control deficiencies divided by the total number of port state controls. This makes it possible to compare vessels with different numbers of controls. To make the KPIs even more intuitive they are scaled into a normalised range from 0-100, where zero indicates unacceptable performance and 100 is outstanding. The KPI's are grouped into four slightly modified Balanced Scorecard perspectives in order to secure adequate coverage for internal improvement (omitting the financial perspective, as this is well covered elsewhere).




*The Shipping KPI hierarchy.*

On the next level the KPIs are combined into the Shipping Performance Indexes in order to express performance in the following seven main areas:

- Environmental
- Human relations
- Safety
- Security
- Technical
- Navigation
- Operational.

The seven areas are the result of identifying the external stakeholders' area of interest and which roles they are likely to play. An analysis of information requirements associated with the roles leads to the seven areas that become the SPIs.

The level of detail to which the standard is defined leaves little room for interpretation at KPI level. There is a defined mathematical relation between all PIs, KPIs and SPIs. The level of uncertainty is related to data capture at PI level. However, the standard has based data capture on official reporting, in order to reduce ambiguity and uncertainty. A total of more than 30 KPIs and around 60 PIs have been defined.

### Development method

The KPI model was developed in the course of several iterations with industry stakeholders. A three-phased approach was taken:

- first, known KPIs in use in the industry today were collected
- the KPIs were then collated, cleaned and mapped into the extended Balanced Score Card perspectives
- finally, a stakeholder information analysis was performed in order to elicit a wider set of KPIs and the requirements for forming the SPI.

This process resulted in a set of KPIs and subordinate PIs that were used to express performance information that would be relevant to external stakeholders (owner, class, flag/port state etc.) as SPIs.

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# Novel maritime communication systems - Broadband at sea and in the High North

**Current maritime systems are largely based on legacy analogue VHF radio for ship-to-shore communication in coastal waters, and relatively low bandwidth digital satellite communications (SatCom) for long-range ship-to-ship and ship-to-shore communications. The cost of bandwidth for SatCom networks is expected to remain high due to the cost of launching satellites into orbit and also due to the stabilizers required for currently available on-board antennas. On the other hand, the legacy VHF system comprises low-bandwidth radios that are not capable of supporting applications requiring high data rates. Consequently advances in maritime networks are severely lagging behind their land counterparts.**

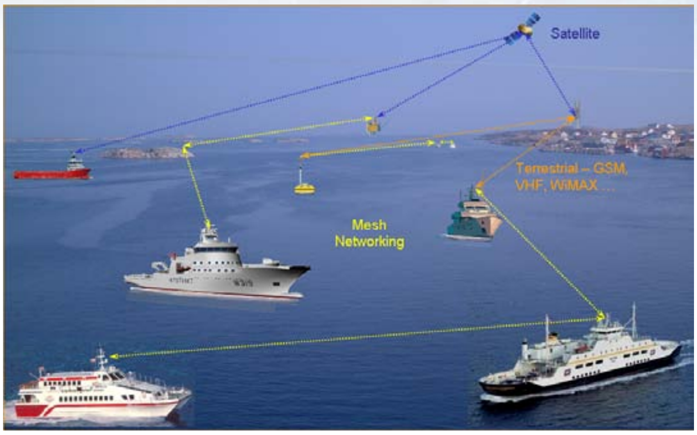


*Figure 1. Illustration of MARINTEK's WiCAN concept.*

MARINTEK is the project manager and principal technical investigator of the projects MarCom ("Maritime Communications – broadband at sea") and MarSafe North ("Maritime Safety Management in the High North"), both of which joint initiatives involving several national and international R&D institutions, universities and colleges, public authorities and industry, funded by the industry itself and the Research Council of Norway's MAROFF programme. Both initiatives aim to develop a novel digital communication system platform that will ensure the proliferation of innovative mobile network applications that are currently being widely implemented in land-based wireless systems.

MARINTEK's approach to MarCom is characterized by its combination of thorough investigations of present and future user needs (through nine user cases) with the identification of pertinent cost-effective communication technologies in order to enable the requirements to be met.

Aiming at a bearer-independent solution that will permit communication over various transmission media and protocols, we have identified three major challenges:

- Extending the coverage and range at sea for current and novel land-based (terrestrial) systems; cellular, wireless broadband and wireless narrowband.
- Finding appropriate SatCom solutions to

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## The Shipping KPI ...

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The iterative development model relies on the R&D partners to facilitate the process and exploit the joint knowledge of the industrial partners so that the results reflect the total of industry knowledge. In order to achieve this goal, a series of thematic workshops were organised, at which the guiding principle for decision-making was consensus. This indicates that to some extent the KPIs are the result of compromise, which in turn makes the KPIs more generally applicable.

### Application of results

There are several potential applications of the results from standardising performance measurements within an industry:

**Internal improvement** is one obvious application and the industry is already applying KPIs in management, so the effect of standardising it is questionable as this might drive changes in data collection methods which could lead to additional work. If a company also relies on specialised KPIs these might not be covered by the standard.

**Benchmarking** is another obvious application, and for this purpose standardisation acts as an enabler to achieve an industry benchmark. To develop an industry benchmark, several roads can be pursued, either through third-party data collection and anonymous presentation of results or through bi-lateral data exchange between contract parties. Either way the question of data validity will arise and must be tackled, but the KPI Standard is a prerequisite for succeeding in benchmarking.

**Performance-based contracting** is a very interesting aspect of applying standardised performance measures. The incentivizion built into a KPI-based contract payment method offers substantial advantages. This can act as booster for the industry towards better performance. Some side effects need to be taken into account; these include marked segregation and competition shifting (which could be an EU issue).

**Building public awareness** through the use of standardised KPIs is an objective tool for keeping public opinion informed about absolute performance levels, as well as to illustrate trends and the effects of measures employed to achieve particular industrial or political objectives.

### Making the results available

The Shipping KPI standard has been defined, and the results are available through a web-based interface; a Depository, www.shipping-kpi.com. The definitions and calculation formulae are available for download. What is most important, however, is that as far as possible, relevant background information and the evaluations performed while defining the KPI are available in addition to calculation examples for the KPIs.

A simple Q&A session that acts as a moderated forum is included in the Depository.

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## Novel maritime communication ...

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complement/supplement land-based ones, mainly beyond their coverage.
- Obtaining seamless and continuous handover and roaming within and between systems, in addition to satisfactory reliability, security and integrity.

The concept of a Wireless Coastal Area Network (WiCAN), as illustrated in Figure 1, has therefore been introduced for further exploration.

The potential coverage obtainable by land-based technologies is exemplified by the 1st generation of Digital VHF systems devised by Telenor Maritime Radio (TMR), which covers the whole Norwegian coastline of 2400 km and parts of the North Sea and the Norwegian Sea via 74 base stations, each providing communications up to a range of about 72 nm (130 km), although offering relatively narrow-band services (Figure 2).

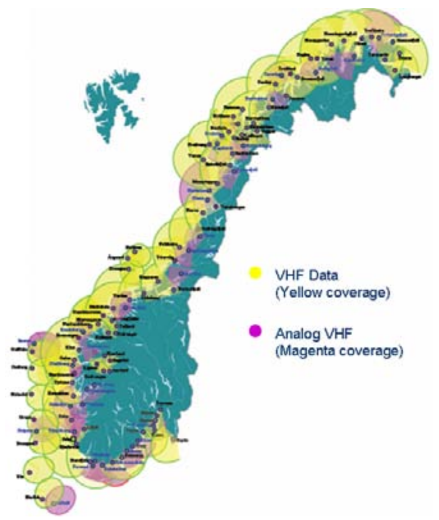


*Figure 2. Coverage map of TMRs Digital VHF system ('VHF Data').*

However, by developing the WiCAN concept, which utilises novel wireless broadband technologies (e.g. WiMAX) similar coverage can be obtained at data rates of several tens of Mbps, thus providing user-requested bandwidth-intensive services (e.g. Internet) at sea and in the High North.

The fragile environment of the High North is decidedly dependent on a sustainable ecosystem balance. Safeguarding this balance calls for a highly developed communication infrastructure and sophisticated surveillance systems, which are currently unavailable. Reliable broadband radio communications in the Northern and Arctic Region is vital for fast reporting of the status and evolution of the environment, and

*Figure 3. RV Akademik Fedorov and the nuclear-powered icebreaker Rossia near the North Pole in September 2007.* Photo: Aleksey Marchenko, UNIS.

early warning of pollution threats. Furthermore, these technologies are decisive for efficient handling of hazards and accidents that threaten people and/or the environment.

People all over the world are deeply engaged in discussions and research on the challenges that Mother Earth is facing today, as a result of climate change. The amount of ice covering the Northern hemispheres is rapidly decreasing, and several researchers believe that in the course this century much of the Arctic will be ice-free in larger periods of the year.

This will definitely affect the maritime transport community, for example by facilitating the use of new transport routes through the Northeast and Northwest passages for much of the year (Figure 4).Traffic directly across the Arctic Ocean will also rise significantly. As a result, the Arctic meltdown could lead to huge cost reductions in terms of shorter voyages and avoidance of the pirates who are now operating at southern latitudes. In addition to these considerable benefits to the maritime transport sector, other maritime actors will most certainly be attracted to the area due to the vast amount of valuable resources that are believed to lie under the present polar ice cap.

Increased maritime traffic and activity in the Arctic will bring forth demands for a maritime communication infrastructure comprising satellites, terrestrial communication systems and ad

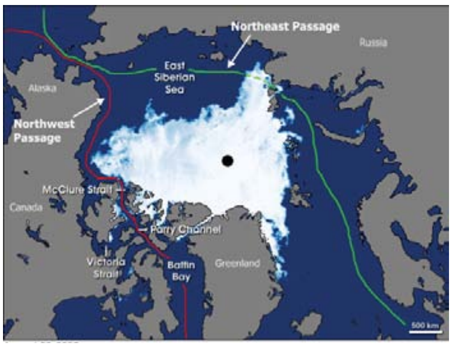


*Figure 4. Potential new transport routes in the High North.*
Image Credit: modified from NASA's Earth Observatory and NSIDC.

hoc communication systems that do not exist as yet. Ad hoc systems can provide, for example, crucial support during demanding marine operations such as emergency manoeuvres, transport and management of offshore installations. A demand for greater availability of real-time information pertaining to weather and ice conditions and traffic information will also emerge. The current infrastructure for maritime communications in the Arctic is decidedly inadequate for these purposes, as it lacks sufficient capacity, availability and integrity to contribute satisfactorily to safe navigation and operations. Geostationary satellites (GEO), has virtually no coverage in areas beyond 76° North, and is therefore not trustable as communication channel for moving targets in the Arctic. Low Earth Orbit (LEO) satellite systems provide allegedly 'true' global coverage, but has limited capacity. For some operations the services offered by LEO satellites may be adequate, but for more challenging operations it is certainly not enough available capacity. This situation should also be evaluated in terms of the increasing requirements for capacity and availability due to the desire to be able to perform more highly automated and to support remotely controlled operations at sea.

MARINTEK's preliminary findings indicate that the coastal areas (including the Northeast and Northwest Passage) are adequately covered by extended novel terrestrial systems, but in order to cover the passages to the north of Russia or Canada, or the area near Spitsbergen, a "chain" of base stations with an appropriate backhaul infrastructure would be required. The cost and complexity of such a system would necessitate a detailed study of the area's topography.

However, even if such systems could be deployed, vast areas would still be left uncovered, and other solutions to complement these coastal area systems (ref. the WiCAN concept) would still be required. The crucial limitations of traditional SatCom systems mentioned above obviously require new technologies, and our preliminary studies indicate that High Elliptical Orbit satellites (HEO) might be a preferred solution to provide a technically viable alternative for adequate SatComs in the northern areas - in fact to the northern hemisphere on the whole (which also applies to the southern hemisphere if the orbits are 'reversed'). However, in-depth studies are required to reveal the cost/performance figures of relevant systems, along with their success and risk factors.

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# Studies of particulate matter (PM) from ship engines

**Particulate matter from exhausts is arousing more attention because of its negative effects on health, and PM is now on the IMO list of harmful emissions. MARINTEK has taken the initiative to establish a competence project (KMB) with the objective of generating better knowledge of level and size distribution of PM in ship exhausts from different kind of fuels. The project will also look at how different exhaust cleaning technologies affect PM level and size distribution.**

## Particles and health

Most of the particulate matter from diesel engines is created during combustion in regions where the fuel-air mixture is rich. These particles consist mainly of carbonaceous material and are often referred to as the accumulation mode. The mean diameter of the accumulation mode matter is around 60 to 80 nm. Depending on the fuel quality, particularly sulphur content, and the amount of accumulation mode particles, there may also exist a nucleation mode. The nucleation mode consists of volatile components and is created when the exhaust cools and the volatile components become supersaturated, forming particles with a mean size in the range of 30 to 50 nm. The nucleation mode makes up most of the particles in terms of numbers, but contributes little mass. Recent studies have shown that ultra-fine particles, i.e. smaller than 100 nm, pose a health risk to human, and the health risk is more related to the number of particles than to their mass.

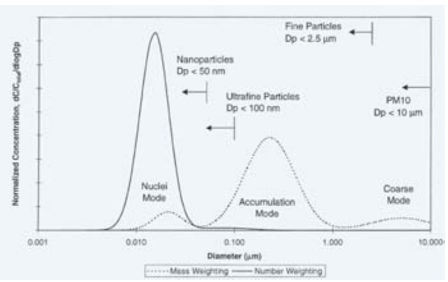


*Figure 1. Typical particle size distribution in diesel engine exhaust (high-speed heavy-duty diesel engine).*

## Research tasks

The KMB study will be a combination of theoretical studies and analysis and experimental laboratory work and on board ships in operation. The main tasks in the programme are:

- Adapt existing methodology for advanced measurements of PM level and size distribution. Develop methods for on-board PM measurements.
- Perform tests to determine PM level and size distribution as affected by fuel quality, and the effects of exhaust scrubbing technologies and $NO_x$ reduction techniques, on PM.
- Improve our understanding of the formation and growth of particulate matter and the mechanisms that influence PM formation.

The experimental tests will be performed in MARINTEKs engine laboratory and on board ships in operation.

## PM measurement

To investigate PM in the nanometre size range requires sophisticated instruments, and MARINTEK has invested in two particle sizers, for laboratory and field use respectively.

- ELPI particle sizer makes use of the impactor principle for separation and measurement of particle sizes, with an option to collect the different particle groups for further analysis of particle compositions.
- SMPS sizer utilises the electrostatic mobility of particles for separation and scanning of the size distribution.

Advanced exhaust diluter systems are also in place.

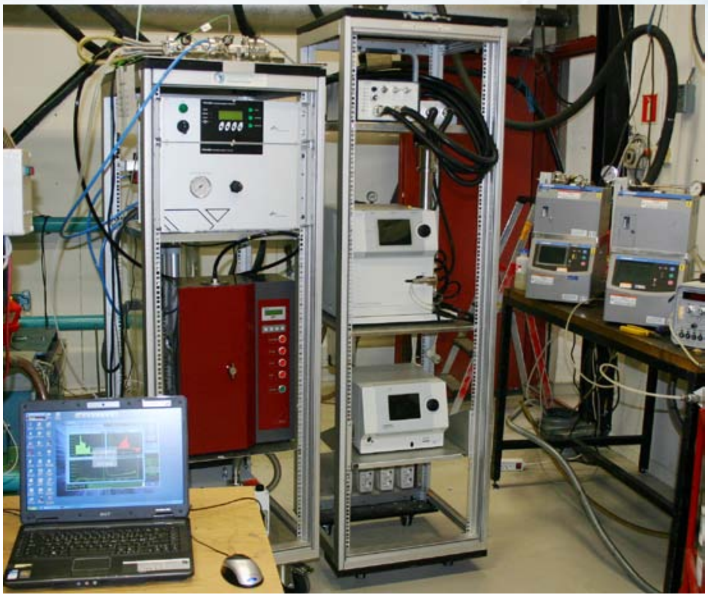

*Figure 2. ELPI (left) and SMPS (right) particle sizers.*

Figure 3 gives an example of particle size distribution from tests recently run at MARINTEK on heavy fuel oil samples.

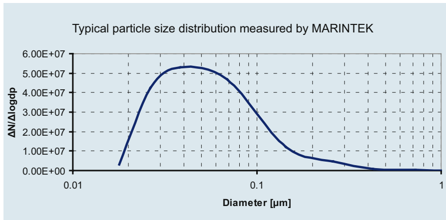


*Figure 3. Example of particle size distribution from heavy fuel combustion (ELPI instrument).*

In the course of 2009 a complete $NO_x$ reduction system (selective catalyst reaction, SCR) will be installed in MARINTEK's energy laboratory. PM measurements will be made during testing of the new system, as well as on board ships that have various types of emission reduction technology in operation.

## Project partners

The KMB project is funded by the Research Council of Norway's MarOff program and co-funded by TeeKay, Yarwil, StatoilHydro, DNV and Fueltech Solutions. NTNU is running the PhD study, and MARINTEK is heading the project.


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# Vessel simulator VeSim combining manoeuvring and seakeeping

**The MARINTEK Vessel Simulator (VeSim) is a time-domain simulation tool for the simulation of ships in a seaway with variable heading and speed. The simulator has been developed in the course of several research projects during the past five years and is still under continuous improvement. All of its hydrodynamic modules are based on years of experience in numerical modelling at MARINTEK.**

*Snapshot from SimVis showing a VeSim simulation of a supply vessel in a seaway. The arrows can show various forces and moments acting on the vessel and offers the end users and developers an excellent way of checking and understanding the physics in the numerical models as well as being a tool for communicating complex results to people from other disciplines.*

*View at the main propulsion units. Arrows denote forward thrust.*

One of the principal challenges in the development of the simulator has been to combine manoeuvring and seakeeping into one common simulation. Traditionally, these two fields have been treated separately. Manoeuvring has been simulated in calm water only, and seakeeping has been studied at constant forward speed and heading. Creating a unified formulation of the hydrodynamics that link these two disciplines has been a key aim in the development of VeSim, as it should be able to handle not only a vessel in DP operations or calm water manoeuvring, but actual manoeuvres at sea in rough conditions.

The external forces from waves, wind and current are modelled, including effects such as short-crested irregular waves and the effects of wind gusts. Propulsion units such as propeller and rudder, tunnel thrusters, etc. including loss effects due to ventilation, hull interaction and interaction between thrusters are also modelled, as this has been one of the areas of focus during the past few years. Typical sensors onboard a ship, such as GPS, MRU and gyrocompass are also modelled, enabling hardware-in-the-loop testing of control systems, where the hardware can receive sensor signals as if it were on board a real ship and pass control signals back to the simulation software.

The simulator can be configured using MARINTEK's hydrodynamic workbench ShipX, in which the numerical model of the ship can be computed and propulsion units, sensors etc. can be defined and the simulation scenario set up. A simple scripting language has developed that enables the end-user to set up customized simulation scenarios with events happening at specified time instances.

The simulation infrastructure allows other software or hardware to be connected to the simulation. The simulation can also be divided among several computers if necessary. This "black box" thinking creates an arena for different parties to interact within a simulation without having to disclose any company-sensitive information. This kind of coupling has been performed for example against MATLAB code and other third-party code as well as against control hardware and laboratory equipment.

VeSim includes full 3D visualization using MARINTEK's SimVis visualisation package. All input for the visualization can be set up automatically in ShipX, including hull geometry and propulsion units (propellers, rudders, pod housing etc.).

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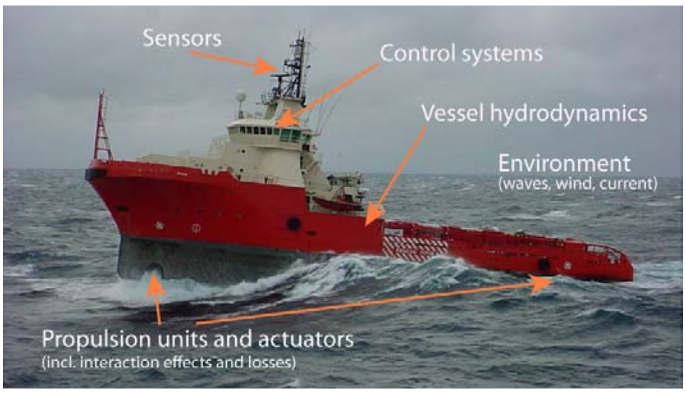


*The illustration above shows the topics covered by VeSim in order to capture the behaviour of a ship in a seaway.* (Photo: Courtesy of I Wall)


*A web browser gives easy access to viewing simulation values and changing input parameters online.*

# Optimisation in the maritime business

**MARINTEK's history started with the towing tank, which enabled researchers to perform model tests. Those tests were used to develop the theory of water-hull interaction and led to the design of hulls with minimal drag and wave resistance.**

**Ever since those early days, shipowners and future shipowners have been coming to MARINTEK to find out which hulls to build. MARINTEK subsequently extended its range of expertise to cover almost all aspects of the maritime transport, fishery and offshore industries. Nowadays, shipowners and managers can obtain support from MARINTEK throughout the life-cycle of their vessels, from the initial concept of building a new ship to scrapping one after a long and successful service life.**

*Specialized cargo ship (LNG), source: BW Gas.*

## Strategic decision-making

### Investment planning

Investing in new ships is a major decision. First of all, each individual segment of the maritime transport market presents a different challenge to investors. Some segments are easy accessible, and an investor needs only to buy a ship and start taking transport orders. However, the profit margin is normally rather moderate in those segments over time. Other segments including the transport of specialized cargoes such as liquefied natural gas (LNG) offer greater margins, but also require higher investments and are more exposed to market fluctuations and risks. And then there are markets that require political decisions in order to obtain access to them; these include local ferry services.

In some cases time chartering of an additional ship means that the fleet can operate at lower speed; such slow steaming may save more in fuel costs than the cost of the additional time charter. Another reason to build a new ship is to keep the shipyard occupied so that competitors cannot increase their market shares.

Questions of what type of ship to build, how to finance it and how manage it, lead to the field of investment analysis and risk management. MARINTEK has developed tools tailor-made for analysing profitability of alternative fleet mix and ships for a given transport need.

### Options and flexibility

In market situations such as the current one, several decisions need to be considered in order to survive. We may choose to continue with "business as usual", since fuel costs may drop due to reduced demand. This also has the advantage of keeping customer relations alive. Laying up or scrapping reduces operational costs. Laying up also offers potential flexibility – since there are different levels of lay-up, all of which have different reactivation times. On this area MARINTEK has developed tools for analysing cost and transport capacity effects of alternative lay-up scenarios.

The different options involved in owning, leasing or chartering ships, and the different financing schemes available, are all tools of risk management.

## Tactical and operational decisions

MARINTEK's department of Strategy and Logistics has developed tools that support the optimal assignment of cargos to ships and route planning. Good route planning can save costs by avoiding transports with half-filled ships or empty return trips, or increase income by servicing more cargoes.

### TurboRouter

This program aims at route optimization and cargo assignment to ships. Its inputs are:

- the heterogeneous fleet of ships, each ship with its own set of data, like fuel costs, draught, size, cargo capacity, berth requirements and other limitations
- the list of harbours with berth constraints, opening hours and costs, tidal restrictions
- the list of committed and optional spot cargos with their requirements: loading and discharging time windows, stowage requirements and contractual bindings
- the initial position of ships
- geographical information about seas, straits, channels and their limitations to shipping.

TurboRouter aims to find feasible assignments of cargos to ships and sailing plans for ships, with the objective of maximising profits. Ongoing research is attempting to identify even

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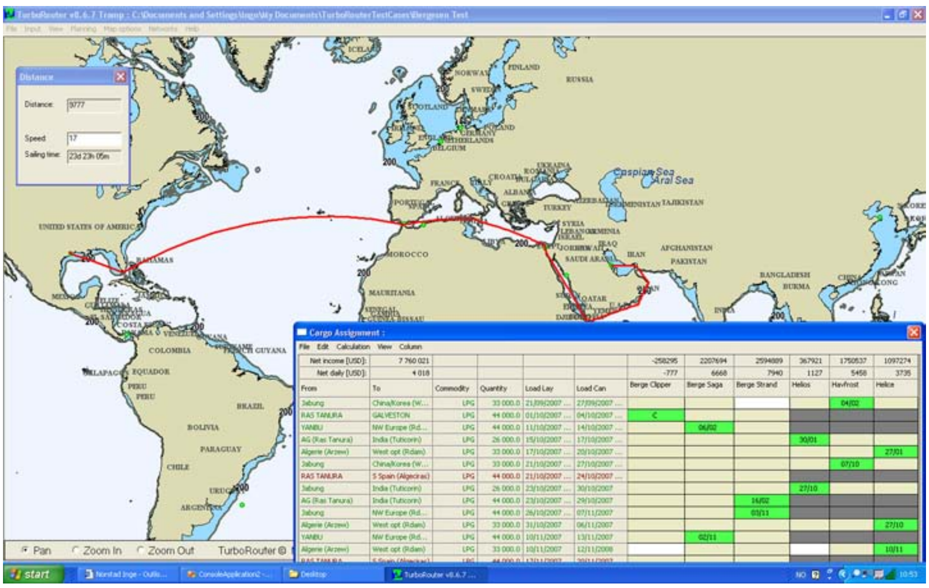


*Figure 1. TurboRouter showing a cargo assignment.*

## Optimisation in ...

*Cont. from page 11*

better solutions with shorter computation times and to take into account more realistic details, such as lower fuel costs when slow steaming (figure 3). Today, versions exist both for tramp and liner shipping.

### Invent

This tool is similar to TurboRouter but instead of assigning cargos to ships, it solves the task of keeping inventory levels at both ends of a maritime transport leg within certain limits.

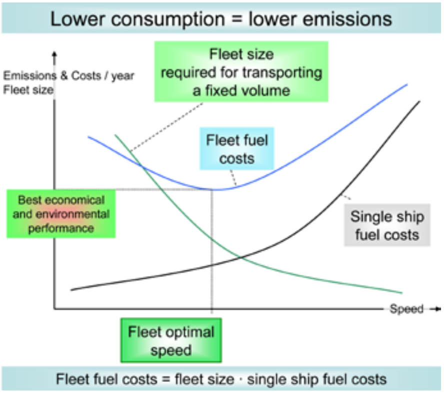


*Figure 3. Costs and emissions of slow steaming.*

This means that it also finds the optimal frequency and cargo size for the transports. In such cases, the contract between the cargo owner and the shipper will not specify how often or exactly when there will be a shipment; instead, the ship operator/logistics provider is responsible for keeping the inventory level between given levels.

### LoadManager

The offshore industry requires specialised vessels for the transport of equipment and commodities to and from platforms and similar. However, there are safety requirements that put limits on feasible loading patterns. Dangerous goods can be placed into several zones onboard the vessel but a certain minimum distance must be kept between them. Since supply vessels visit several platforms during one trip, this turns out to be a rather complicated puzzle.

### Benchmarking tool

New regulations require manufacturers to account for the environmental impact of the production and transport of a commercial item, while internal benchmarking is used in the continuous improvement cycle. Current best practice is identified and the factors that have been contributing to the success are analysed. The same factors are then applied to other areas in order to improve efficiency. Benchmarking comes in several forms:

- Checklist of items that have been identified as successful factors.
- Rating approach: Scores are given according to certain threshold levels for unacceptable and current best performance. Those ratings can be aggregated in order to provide a hierarchical view. This aggregation approach is also used in monitoring technical and operational conditions.
- Data envelope analysis. This approach includes optimization and determines how far current operation is from the best practice.

In the DESIMAL project, MARINTEK is developing a benchmarking tool that models the logistics network including the maritime legs and tries to find the best possible solution in terms of financial, environmental and other aspects.

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## LNG as fuel for ships ...

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two RoRo cargo vessels for delivery in 2011. The concept is a single pure gas engine installation that will meet the new IMO Interim Guidelines for gas-fuelled ships. The solution is an inherently safe engine room which will be implemented by employing double walled gas supply pipework. Back-up power will be supplied by a diesel generator and a PTI (power take in) arrangement.

Another concept is a coastal freighter for bulk transport of stone products or fish feed. The propulsion arrangement is similar to the RoRo concept. This concept is a result of the R&D project “NyFrakt”, which is supported by the Research Council of Norway.

The primary challenge is to find sufficient space for storing LNG. For this type of vessel, vacuum-insulated pressure-storage tanks have been the preferred solution. This systems offers high reliability (no moving parts for pressure buildup) and provides a high level of safety. The negative aspects are the level of costs and storage space requirements. Because of the cylindrical form of the pressure tank the space requirement is three or four times that required for diesel oil with equivalent energy content.

LNG-fuelled ships have an added building cost mainly due to the bunkering and storage system of LNG. In percentage terms this is higher for small than for large ships. MARINTEK has performed several financial calculations and finds the additional cost to be in the range of 8-20%.

To justify the increased investment, operating costs need to be lower than in diesel oil operation. The main parameter is the actual cost of fuel, and calculations suggest a reasonable payback time for the increased investment when the price of oil is 80 USD or higher. In such a situation, LNG seems to have a favourable cost margin compared to distillate fuels. With the prospect of limited sources of oil in the future, and hence higher fuel prices, and given the stringent new emission limits, we believe that LNG will be the dominant fuel for ships in short sea operation.

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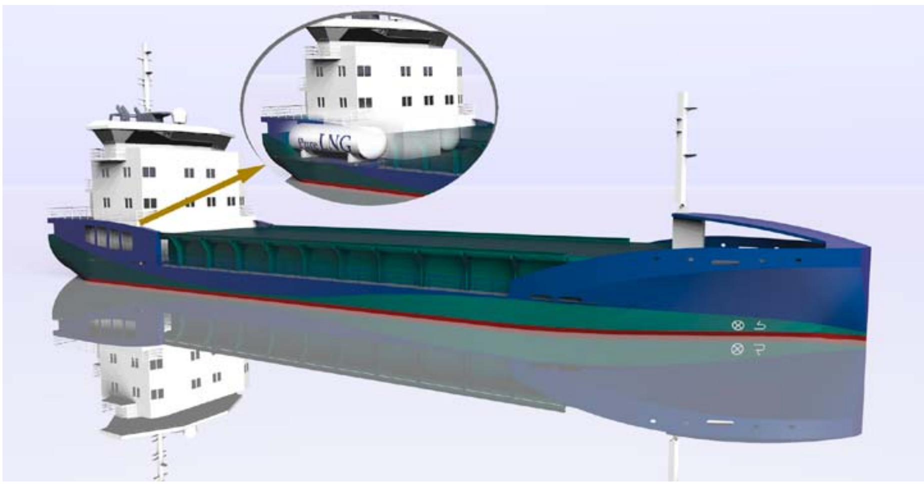

*Coastal bulk carrier for gas only operation. Location of LNG storage tanks, one on each side of the superstructure. (Rolls-Royce Marine design).*