Development of an Innovative Autonomous & Intelligent Tool for 'Least-Fuel-Voyage' Management within the Shipping Industry (IShip)

Concept and approach

A review of recent publications (Lloyd's Register, Life Matters, June 2012) and the IMO's own reports (Marine Environmental Protection Committee (MEPC), 64 session, Agenda item 4, 29th June 2012) and similar reports by learnt societies and classification societies and maritime organisations, for instance, German Lloyd Academy (GL, EEDI in practice, 2012) which give a clear view of the roadmap for reducing the marine engine emissions in particular in the near future. The whole of Central and North America coastal areas are now almost an ECA (Emission Control Area) and it is expected that coasts of Mexico, Alaska and the Great lakes, Singapore, Hong Kong, Korea, Australia, Black Sea, Mediterranean Sea and Tokyo bay are currently considering becoming ECAs. What is significant is that these constitute 90% of shipping routes so the implications are serious. The Lloyd's report (Life Matters, June 2012) contains a set of guidance notes to provide advice to owners, operators and shipyards who are perhaps looking to adopt the EEDI early on a voluntary basis, or prepare themselves for its future mandatory implementation. The guidance reflects the current status of the IMO regulations as well as providing information on what options are currently available for ensuring compliance. It is stated that the purpose of the EEDI is to provide a design index, primarily applicable to new ships, that has been developed by the International Maritime Organisation (IMO) and is to be used as a tool for control of CO2 emissions from ships. The IMO aims to improve the energy efficiency of ships via (future) mandatory implementation of the EEDI. IMO has developed a number of technical and operational measures that include: i) The Energy Efficiency Design Index (EEDI); ii) The Energy Efficiency Operational Index (EEOI) and iii) The Ship Energy Efficiency Management Plan (SEEMP). The IMO has also been working on a number of Market-Based Measures (MBMs) for the marine industry. The MBMs' development is still ongoing. It should be noted that the EEDI represents one of the major technical regulations for marine CO2 reduction. Each ship will require its own EEDI which will be verified by a recognised organisation (RO) as described further on in this document. Following verification, an International Energy Efficiency Certificate (IEEC) covering both EEDI and SEEMP will be issued by the RO on behalf of the Flag State and will be required to be maintained onboard the ship throughout its life. The certificate is valid for the life of the ship unless the ship undergoes major conversion, is withdrawn from service or transfers flag.

The ultimate aim of this project is to develop an intelligent ship management system (engine, navigation and transducers) – Figures 1 and 2 - which helps to reduce energy consumption and engine emissions to a minimum, whilst simultaneously considering the hydrodynamic characteristics and above all safety of the ship and its crew. It is also intended to develop a means of monitoring the emissions at ports by novel means as demonstrated by Figure 3 below. One of the partners (TRANSAS) has well-known knowledge of on-board navigation, simulation and Vessel Traffic Management Systems in marine sector (see for instance https://www.youtube.com/watch?v=95rrRtGPmXw)- TRANSAS shall provide some navigation tools for the ships for optimisation of fuel consumption.

Figure 1. Proposed Ship AutoSet System Is Based on New Knowledge – Innovation Is New Knowledge and in Integration

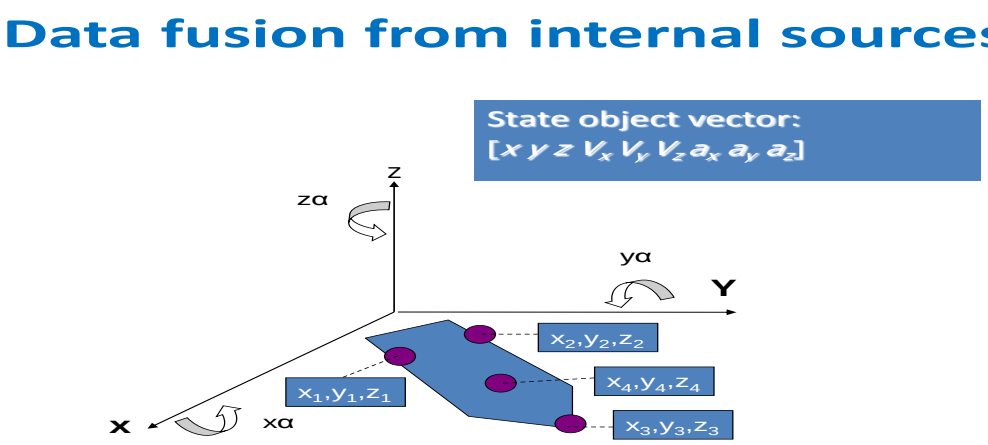


Figure 2. Navigation Automation – Novel Means of Change Course

Example: Technology

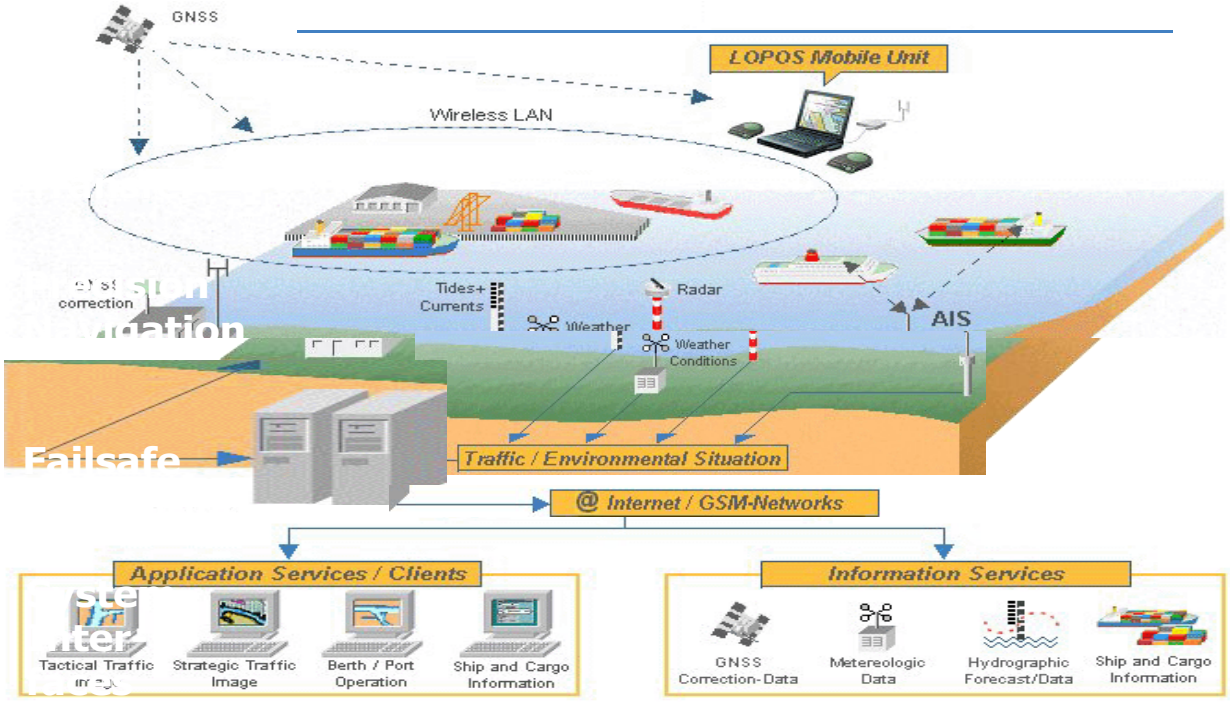


Figure 3. Ports as Controlled Zones Monitoring Arrival of EEDI and Non-EEDI Vessels

It is assumed that ship designers/builders will have to abide by the EEDI requirements and hence, as part of this project, the EEDI will be used as one of the core equations for integration and fusion of data from various navigation and engine controls. It is also acknowledged that the project will also use slow steaming when considered beneficial for saving fuel or reducing emissions such as CO2. The advantages of slow steaming is documented in a report by Maersk Group, showing a reduction of bunker fuel use in 2007, dropping from 13.8 million tonnes to 10.7 million in 2010, which is reported to have saved 2 million tomes of CO2 and brought about a significant reduction of NOX and SOX levels. Slow steaming has already proven its merits worldwide, so much so that COSCO, K-Line, Yang Ming and Hanjin are already applying slow steaming throughout their fleets with the result of considerable energy savings and reduced emissions. The latest report from Maersk is that emissions reduced by 36.44% in 2007, 38% in 2008 and 42.67% in 2009 as a result of applying slow steaming, although the details of what these figures really mean and where the base lines lie are not yet clear as there is no mention of losses due to slowing down the engines and increasing journey times.

However, considering a surplus of ships, due to the current economic crisis, the decision to slow down the ships may not be a major issue now but will be an issue in the future when business is expected to pick up. It is also true that slow steaming can mean a drive to cutting energy consumption through optimal hull designs, waste heat recovery systems, use of wind power wherever and whenever feasible or solar power. Recent research by Ziarati (2010) using high pressure fuel injection systems, reduced engine heat losses and shown that lighter engines and engine components can considerably reduce CO2. Ziarati (2002) also argues that better management of energy on board vessels is an important consideration in reducing fuel consumptions with lower engine emissions. One significant area is an improved matching of

turbochargers with the engines. While his engine designs are used worldwide, and his laboratory in Bath University is reported to have been supported by almost all oil majors and engine and engine component manufacturers, he believes there is a long way to go to make diesel engines consume less oil and produce reduced amount of pollutants. He is also of the view that fuel types make a difference and that lower Sulphur fuels often produce lesser CO2, NOX and of course, SOX. The emergence of novel catalysts has shown that some harmful diesel particulates also be effectively removed.

As a result of a project with Lloyd's Register, funded through an EU non-nuclear initiative, Ziarati (1994) produced the UK's first revolutionary hybrid engine for cars and trucks using dual power systems. The work led to development of engine 'finger printing' that would be an easier means of monitoring a ship's engine efficiency and exhaust emissions. The findings from these pieces of research will be built into the intended set of tools, which are expected to be developed as result of this proposed programme of research and development. The two papers by Ziarati (1992 and 2009) will be sent if requested.

This is a near market project. The intention is to test and evaluate a set of tools and validate a new knowledge in the form of new ship management system. This project comprises several key tasks:

Technological

1. To test a tool for monitoring sea surface condition.
2. To test and refine a tool for ship hull stress concentration and possible navigational movements to relieve pressure.
3. To test and refine a tool to estimate ship hull resistance, specifically wave-making resistance in order to support the work done by IACS for IMO regarding minimum power requirements.
4. To test a tool for engine management and control.
5. To test a tool for coordinated navigation guidance and control.
6. To develop a new tool, hereafter referred to as the AutoSet, to introduce new knowledge for engine management and take the output from tools 1 to 5 above and provides decision support for consideration by the crew. The new knowledge includes the latest and sophisticated neural network (Ziarati, 2013).

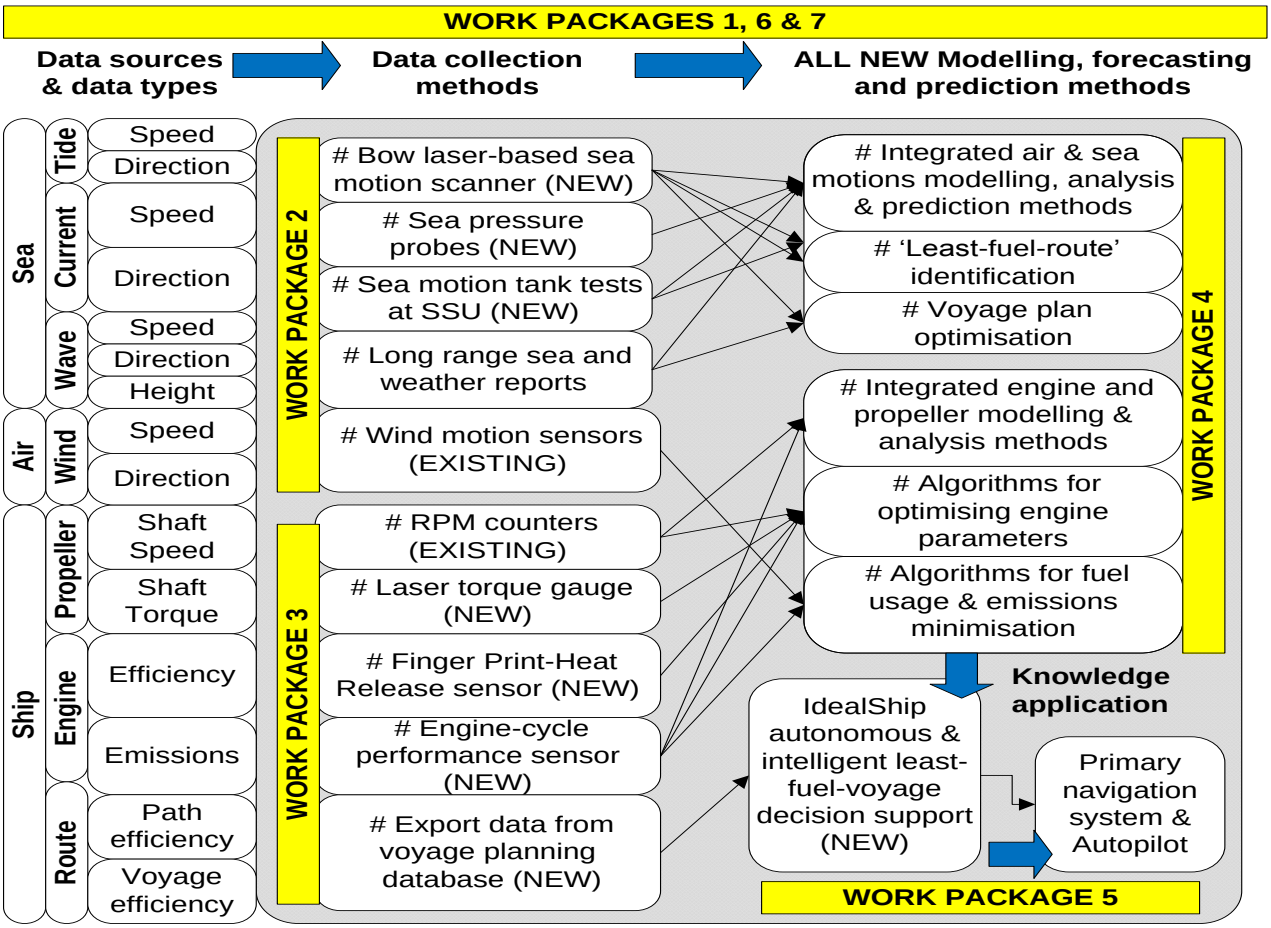
Business

The business tasks to reduce the cost of operating ships (test results leading to a saving of 150,000 EUR per ship per year for 50 KTon tanker) by reducing fuel consumption (275 MTon of Fuel per ship per year) and emissions (220 Ton per ship per year) and ensuring no compromise with power requirements (EEDI, etc) for safe shipping.

The Socio-Economical and Environmental

The tasks is to substantially reduce marine engine exhaust emissions (by around 275 MTon/per year for a 50 KTon Tanker), which is expected to revolutionise shipping as did the Clean Diesel project (Ziarati, 2009), developed by two of the partners, which revolutionised the use of diesel engines worldwide in all transportation sectors.

Work Package Diagrams followed by Description of Work Package Tasks, Milestones & Deliverable



Technical Innovation

Technical innovation is also significant and pushes the boundaries over and beyond current leading-edge fuel and emissions reduction technology by its first time use of A&I systems to provide autonomous control of novel sensors, modelling and analysis functionality and intelligent decision-support systems.In this respect the autonomous processes to be developed within this project makes use of the work of Schlitt and Brazma, (Schlitt, T. and Brazma, A., 2007, "Current approaches to gene regulatory network modelling", BMC Bioinformatics B (Supplement 6):59, pp 1 to 22). Through experience, gained by the C4FF team through 2 previous UK Government TSB CRD projects, that involved use of autonomous control techniques within operations planning, this biological modelling approach was adapted for use in fuel and emissions reduction through improved navigation and engine control. In this respect the innovative sensor data-collection, autonomous control and artificial intelligence modelling and analysis technologies to be developed will be able to identify alternative direction changes and from these select those that contribute most to minimising the amount of fuel used during a vessel's entire voyage, i.e. selected paths when accumulated will achieve least-fuel-voyages (L-F-V). Autonomous control systems will enable fast responses to the high levels of sea and air condition variability that can be expected and enable synchronisation of engine management with such changes. Innovative Artificial Neural Network (ANN) based advanced modelling and analysis functionality will be used involves adapting existing ANN network structures, and using data collected from sensing devices to directly train ANNs and test their accuracy and reliability with which least-fuel-voyages can be identified and followed. There are no existing systems capable of this level of technical innovation and it represents a significant

step in the management of fuel usage in the maritime sector but also with potential in other transport sectors particularly rail. The following are some related EU funded projects.

Ambition

There is no dispute that an intelligent integration of ship navigation and engine controls for accurate and efficient analysis of safety and performance sensitive hydrodynamic problems in normal and extreme sea and air operational conditions, including intact stability performance would help realise the ultimate aim of **improving the efficiency of waterborne transports** by the reduction of ship emissions through energy systems' integration. The intention is continuous assessment and minimisation of the risks. Risk awareness and management will play a major role in developing the intended tools and system measurements and their integration. The project will further strengthen the competitiveness by focusing on innovative vessel designs and automatic manufacturing techniques. The research will also contribute to cross-thematic marine and maritime research ("The Ocean of Tomorrow 2013") and the Commission's 'Marine Knowledge 2020.' The results of the project will contribute to enhancing the safety of vessels in compromised situations, while respecting regulatory environmental constraints. The results will also contribute to the strengthening of technical knowledge as inputs to negotiations at IMO committee meetings.

Safety is a critical success factor for shipping companies that want to survive; this means that, whatever benefits a new tool brings, safety should not be compromised. The second factor is the IMO and its requirements. These have to be respected, even if some requirements have not been fully tested. The IMO's recently introduced new standards related to energy efficiency in particular the EEDI is not as clearly understood as it first appears. A careful review of the EEDI clearly shows that the formula used to arrive at the Index is more rigid than first appears. The formula itself has not been fully tested, but EEDI signals the introduction of emission controls at sea and there are more regulations to come. The mid-eighties brought the beginning of the end for many engine designers as the EU started discussing future emissions levels for several pollutants such as CO2, NOX and so forth, yet failed to limit the unacceptable levels of particulates from combustion of diesel fuels responsible for many cancer cases. Nevertheless, the imposition of emission levels brought new ways of designing and producing cars and this process is continuing. The same is expected for the shipping industry. If the shipping industry fails to regulate itself, EU or USA and some others will take the lead. This is already happening with the introduction of the North America Emission control Area (NCA).