

Energy-efficient Ship Operation – Training Requirements and Challenges

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ABSTRACT: The International Maritime Organization (IMO), through its Maritime Environmental Protection Committee (MEPC), has been carrying out substantive work on the reduction and limitation of greenhouse gas emissions from international shipping since 1997, following the adoption of the Kyoto Protocol and the 1997 MARPOL Conference. While to date no mandatory GHG instrument for international shipping has been adopted, IMO has given significant consideration of the matter and has been working in accordance with an ambitious work plan with a view to adopting a package of technical provisions. Beside the efforts undertaken by IMO, it is assumed that e.g. optimized manoeuvring regimes have potential to contribute to a reduction of GHG emissions. Such procedures and supporting technologies can decrease the negative effects to the environment and also may reduce fuel consumption. However, related training has to be developed and to be integrated into existing course schemes accordingly. IMO intends to develop a Model Course aiming at promoting the energy-efficient operation of ships. This Course will contribute to the IMO's environmental protection goals as set out in resolutions A.947(23) and A.998(25) by promulgating industry "best practices", which reduce greenhouse gas emissions and the negative impact of global shipping on climate change. In this paper the outline of the research work will be introduced and the fundamental ideas and concepts are described. A concept for the overall structure and the development of suggested detailed content of the draft Model course will be exemplarily explained. Also, a developed draft module for the model course with samples of the suggested integrated practical exercises will be introduced and discussed. The materials and data in this publication have been obtained partly through capacity building research project of IAMU kindly supported by the International Association of Maritime Universities (IAMU) and The Nippon Foundation in Japan.

1 INTRODUCTION

It is globally very well recognised, that best results regarding maritime safety bases on well-trained crews. The same is valid for environmentally-friendly operation of ships. Only mariners and crews who have background knowledge and who know how they can contribute in the best way to energy efficient and emission reduced ship operation will be able to contribute to the ambitious aims.

Numerous technological developments in other transport modes has made shipping to become one of the main contributors to air pollution especially in coastal zones and harbour areas sensitive to inhabitants living there. Beside the efforts undertaken by IMO, it is assumed that e.g. optimized manoeuvring regimes have potential to contribute to a reduction of GHG emissions. Such procedures and supporting technologies can decrease the negative effects to the environment and also may reduce fuel consumption. However, related training has to be

developed and to be integrated into existing course schemes accordingly.

The International Maritime Organization (IMO), through its Maritime Environmental Protection Committee (MEPC), has been carrying out substantial work to provide the fundamental conditions for the reduction and stepwise limitation of greenhouse gas emissions from international shipping since 1997, following the adoption of the Kyoto Protocol and the 1997 MARPOL Conference. While to date no mandatory GHG instrument for international shipping has been adopted, IMO has given significant consideration of the matter and has been working in accordance with an ambitious work plan with a view to adopting a package of technical provisions (i.a. see Roche, 2009).

Further to those and other efforts IMO initiated the development of training framework supporting the introduction of ship energy efficiency management plans (SEEMP) but also to promote adequate operations of ships.

In this paper the outline of the research work to develop training frameworks will be introduced and the fundamental ideas and concepts are described. The overall structure and the development of detailed content of a draft Model course will be exemplarily explained. Also, the developed draft modules for the model course and samples of the suggested integrated practical exercises will be introduced and discussed. One example and test results for an integrated simulation-based training module of the course are presented.

Some parts of the conceptual analysis behind the presented materials build on earlier work (as e.g. Magnusson, Fridell & Ingelsten, 2012; Winnes & Fridell, 2010 and Baldauf, Pourzanji, Brooks, de Melo and Benedict (2012)), which was performed to analyse ship emissions and to investigate potential counter measures by ship crews.

2 BACKGROUND AND PRESENT SITUATION

2.1 *The work of IMO and the Protection of the Marine Environment*

The IMO as the main international body is the driving force that has taken the responsibility for developing and adopting globally binding rules, regulations and guidance not only on safety and efficiency of ships but also on the protection of the marine and atmospheric environment from shipping operations. The work of the organisation's subjects related to the protection of the marine environment ranges from pollution prevention (including e.g. MARPOL) over pollution preparedness and response (e.g. OPRC 90), ballast water management and anti-fouling systems up to ship recycling and also covers special programmes and initiatives (like e.g. the 'GloBallast' initiative or the 'Marine Electronic Highway' demonstration project). All the initiatives and developed and adopted conventions and guidance are subject to training of the personnel involved in maritime transportation. Seafarers should be made aware of the conventions and their objectives. Without the participation of the frontline operators of

the shipping industry, the implementation of the Conventions cannot be achieved properly. The integration of the environmental standards in the daily work practices onboard should ensure the implementation of the requirements.

The backbone of maritime training and education is IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (the STCW Convention), and its associated Code which were firstly adopted 7 July 1978 and set into force on 28 April 1986. There were numerous reviews and amendments. The latest and most important amendment of the convention and the code were adopted in June 2010 with substantial revisions and important changes of the training content and standards. These amendments were set into force by 1st January 2012. Among the significant number of changed subjects by the Manila amendments also new requirements for marine environment awareness training is mentioned (Bai, Jun, Zhang, Bin, Yu Jiajia, (2012).

New requirements about enhancing the protection of the marine environment are proposed and are addressed in "Chapter II Master and deck department" and "Chapter III Engine department". Consequently training and education for all mariners are concerned. Education and training courses should introduce knowledge of protection of the marine environment in order to enhance seafarers' consciousness. This requirement is accompanied by general requirements regarding the adjustment of existing MET management systems, teaching equipment and content as well as promoting teaching levels.

Beside the general requirements regarding the standards of training to be implemented into the course schemes for captains, engineers, deck and engine officers there are several model courses covering aspects of the protection of the marine environment. In the following chapters the Model course on energy efficient ship operation will be considered in more detail.

2.2 *Development of a Draft Model course for Ship Energy Efficient Management Planning*

With the specific focus on the reduction or limitation of greenhouse gas emissions from international shipping, IMO has given significant consideration of the matter and has been working in accordance with an ambitious work plan with a view to adopting a package of technical provisions to include among others:

- an energy efficiency design index (EEDI) for new ships;
- an energy efficiency operational indicator (EEOI), which will enable operators to measure the fuel efficiency of an existing ship and, therefore, gauge the effectiveness of any measure adopted to reduce energy consumption; and
- a Ship Energy Management Plan (SEMP) that incorporates guidance on best practices, to develop onboard their specific vessel, which include improved voyage planning, speed and power optimization, optimized ship handling, improved

fleet management and cargo handling, as well as energy management.

It is in continuation of such efforts that it is intended to develop a Model Course aiming at promoting the energy-efficient operation of ships. The Course will contribute to the IMO's environmental protection goals as set out in resolutions A.947(23) and A.998(25) by promulgating industry "best practices", which reduce greenhouse gas emissions and the negative impact of global shipping on climate change.

Consequently the IMO Secretariat at its 60th session of the Marine Environment Protection Committee has commissioned World Maritime University to develop a draft model course for energy efficient operation of ships.

Based on literature and database reviews, questionnaires, interviews with stakeholders and further data collection a draft model course has been developed and submitted to IMO MEPC. This draft contains additionally and some kind unique a set of examples for practical activities by which both theoretical knowledge and practical skills can be easily obtained by participants to the course.

The initial course development was mainly be based on the introduced management tool of a Ship Energy Efficiency Management Plan (SEEMP) as agreed and circulated by MEPC 59/24 (Annex 19) as well as on the Guidance for the development of a SEEMP as agreed and distributed in MEPC.1/Circ.683.

Performed survey studies have shown that there have already been many courses or materials in terms of the energy-efficient operation of ships mainly developed by classification societies and shipping companies in the world. Though each of them is well developed and recognised as a good reference for the model course, the final draft model course submitted to IMO doesn't contain contents of those materials developed by them in order to avoid the issues on the copyright protection as well as confidentiality.

On the basis of the draft model course associated materials should be updated from time to time to introduce the latest development and situations in the shipping industry as well as the requirement of the related IMO instrument in terms of energy efficient operation of ships. Therefore, the final draft of the model course contains only the core part for the energy efficient operation of ships.

The developed draft outline of the model course suggested to MEPC for further discussion is given in Table 1.

The draft course outline, submitted to MEPC, clearly states that its main purpose is to assist Maritime Education and Training institutions as well as their teaching staff in organising and introducing new training courses, or in enhancing, updating or supplementing existing training material, so that the quality and effectiveness of the training courses and materials may thereby be improved.

2.3 Development of a Train-the-trainer course

Beside the detailed development of a first draft outline for a training course on energy-efficient ship operation, which especially focuses on the onboard implementation of practical measures to ensure energy efficiency and reduced emissions of greenhouse gases.

The draft model course was developed mainly on the basis of the introduced management tool of a Ship Energy Efficiency Management Plan (SEEMP) as agreed and circulated by MEPC 59/24 (Annex 19) as well as on the Guidance for the development of a SEEMP as agreed and distributed in MEPC.1/Circ.683.

The draft serves as a starting point and should be further developed with experience gained by shipping companies and to support the distribution of good and innovative practices to implement sustainable energy efficient operation of ships and shipping companies.

As a continuation and accompanying measure the IMO also supported and drove forth the development of a train-the-trainer course on greenhouse gas emissions. Among others, this initiative was to accelerate the process of distribution of knowledge and good practices to all IMO member states.

The course development aimed at a training package to promote energy efficiency operations in shipping and is performed to provide a trainer's as well as a trainees manual, samples of presentations for use in lectures and seminars and a generic delivery guidelines. The course development also included a phase for testing the package in order to ensure a common understanding of the issue and moreover to develop basic capacity among the developing regions.

One of the main goals of the development work was to provide a ready-to-use training package and its accompanying presentations which focus on GHG issues in shipping.

The five modules of the package are designed to be adaptable and focus on the operational issues relevant on board as well as ashore. The course comprises the following five modules:

- Module 1: The climate change and the international response;
- Module 2: From Management to Operation;
- Module 3: Port stay and its Impacts
- Module 4: En Route
- Module 5: Energy Efficiency Management Systems

These modules contains lectures and workshop seminars, including presentations, discussions and group works and are embedded by discussions to explain IMO's intentions, provision of pedagogical guidance to experts as well as feedback sessions.

Table 1. Outline of the draft IMO model course for "Energy Efficient Operation of Ships"

Module & Task Activity	Course hours	Lecture	Practical
1 Background	4 hours		
1.1 Climate Change	4	2.0	-
1.2 IMO related work		2.0	-
2 Guidance on best practices for fuel-efficient operation of ships	18 hours	14 hours	4 hours
Section I: Fuel efficient operations			
2.1 Improved voyage planning		2.0	2.0
2.2 Weather routing			
2.3 Just in time			
2.4 Speed optimization			
2.5 Optimized shaft power			
Section II: Optimized ship handling			
2.6 Optimum trim		2.0	2.0
2.7 Optimum ballast			
2.8 Optimum propeller and propeller inflow considerations			
2.9 Optimum use of rudder and heading control system (autopilots)			
Section III: Hull and propulsion system			
2.10 Hull maintenance		2.0	2.0
2.11 Propulsion system			
2.12 Propulsion system maintenance			
2.13 Waste heat recovery			
Section IV: Management			
2.14 Improved fleet management		2.0	2.0
2.15 Improved cargo handling			
2.16 Energy management			
2.17 Fuel type			
2.18 Other measures			
Section V: Other Issues			
2.19 Compatibility of measures		1.0	1.0
2.20 Age and operational service life of a ship			
2.21 Trade and sailing area			
3 Application	6 hours		
3.1 Planning	6	4.0	2.0
3.2 Ship-specific measures			
3.3 Company-specific measures			
3.4 Human resource development			
3.5 Self-evaluation and improvement			
3.6 Voluntary reporting/review			
4 Implementation and Monitoring	2 hours		
4.1 Implementation	2	1.0	1.0
4.2 Monitoring			
Total Course hours	30 hours	18 hours	12

The submitted draft clearly states that its main purpose is to assist training providers and their teaching staff in organising and introducing new training courses, or in enhancing, updating or supplementing existing training material, so that the quality and effectiveness of the training courses may thereby be improved.

3 PRACTICAL EXERCISES – ENHANCED SHIPHANDLING SIMULATION TRAINING FOR ENERGY EFFICIENT SHIP OPERATION

Five main subject areas for training have been defined in the draft model course on energy efficient ship operation and for each section practical activities are suggested. For instance "Fuel efficient operations" addresses the fields of voyage planning, weather routing as well as "Just-in-time" operations and can preferably be trained in ship handling simulation exercises.

The subject "Improved voyage planning" is foremost dedicated to the appropriate implementation of procedures according to IMO resolution A.893(21) (25 November 1999) – (and Chapter VIII of STCW Code) on voyage planning as this resolution provides essential guidance for the ship's crew and voyage planners. It is mentioned that the optimum route and improved efficiency can be achieved through careful planning and execution of voyages. Thorough voyage planning needs time, but a number of different software tools are available for planning purposes.

With respect to potential measures for green ship operation related to nautical departments, voyage planning and weather routing are seen as the "macro (planning) level" for rather strategic decisions whereas manoeuvring planning is seen as the micro (planning) level belonging to tactical decisions of the ship navigation process.

"Just-in-time" practices are described with emphasize to good early communication with the

next port. This should be an aim in order to give maximum notice of berth availability and facilitate the use of optimum speed where port operational procedures support this approach. Optimized port operation could involve a change in procedures involving different handling arrangements in ports. Port authorities should be encouraged to maximize efficiency, minimize delay, and produce reliable work schedule.

A sample should be given here for the section entitled "Optimized ship handling" where, among others, optimum trim and ballasting but also optimum propeller and propeller inflow considerations and optimal use of rudder and heading control systems are addressed. These items have impact on manoeuvring performance on both the macro (voyage planning in open sea areas) and the micro (manoeuvre planning in coastal areas and harbour basins) planning level and therefore are also relevant for the development of simulation-based training modules of such a training course.



Figure 1. Recorded tracks of real harbour manoeuvres of a ferry

From research studies into the application of advanced tools for enhanced manoeuvre planning in coastal areas, approaches to ports and even in harbour basins - specifically using Fast-Time-Simulation technologies for planning and monitoring purposes (Benedict, K.; Baldauf, M.; Fischer, S., Gluch, M. Kirchhoff, M.; 2009) - it is known that detailed pre-planning of manoeuvres can significantly contribute to more energy-efficient ship operation in the harbour areas. Furthermore, as demonstrated in the simulations studies, there is clear potential for time as well as fuel savings and consequently also for the reduction of GHG emissions. Figure 1 depicts one section of a harbour area considered in a field study and additionally shows exemplarily the tracks of a ferry recorded onboard and ashore (synchronized VDR and AIS data) when manoeuvring in the harbour basin.

WINNES and FRIDELL (2010) have proven by direct measurements the emissions of both the main greenhouse gases NO_x and CO_2 of vessels are significantly higher especially when they are manoeuvring in coastal areas and harbour basins.

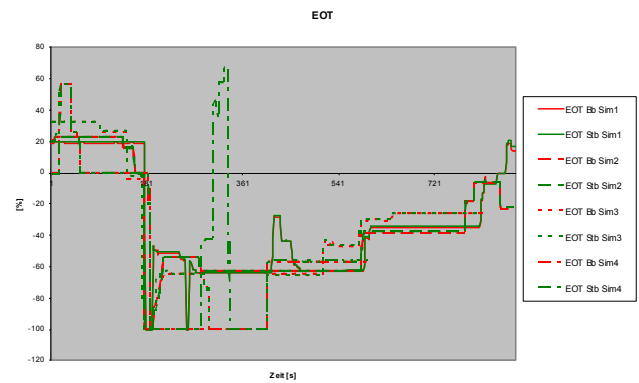


Figure 2. Analysis of elementary manoeuvres of a ferry operating in a harbour basin (sample use of engines)

In the frame of the measurements of the combined field studies and simulation-based experiments of the IAMU project "ProGreenShip" (Baldauf et al (2012)) it was analysed that the number of elementary manoeuvres (defined as each given command for rudder, thrusters, engine etc. to manoeuvre the ship) is very high. Also the intensity (in terms of the used energy) of the used steering equipment is on a high level. An example is shown in Figure 2: different graphs are shown representing times and the intensity of engine manoeuvres and illustrating that they were used relatively often and a high power rate.

4 INTEGRATION OF IMO COMPETENCE-BASED TRAINING OBJECTIVES INTO SIMULATION SCENARIOS

As identified above, careful and thorough planning on macro (route optimisation including weather routing) and micro level (optimisation of manoeuvring regimes in port approaches and harbour basins) are key elements for energy-efficient ship operation. Good planning needs experience and associated training.

Modern comprehensive improved voyage planning nowadays can be performed by using a dedicated software system providing processed information regarding e.g. currents, tidal streams, and impact of shallow water as well as weather and sea state). However systems depend on reasonable and intelligent use of the provided functions taking into account the actual and forecasted prevailing circumstances.

On the other hand experienced navigators are also using manuals containing graphs indicating the performance parameter information as e.g. about pitch handling, power, speed and fuel consumption under different loading conditions and for the two main types of fairways: deep and shallow water (Williamson, 2001).

A practical exercise on fuel efficient operation integrated into a course framework should make use of simulators or otherwise suitable equipped laboratories providing specific assistance systems as standalone version or integrated into a complex ship-handling simulator preferably connected to ship engine simulator.

In addition, there are also game-based simulators available enabling demonstrating relationships between power, speed, fuel consumption and CO2 emissions and furthermore allows savings that can be made when the power is adjusted to ETA, instead of sailing 100% to the destination and anchoring to avoid arriving too early. However, we have to consider that this practice is very often dictated by the ship's schedule and lack of reliable data concerning berth availability.

By applying the described methodology the principle framework of a practical simulation-based exercise on fuel efficient ship operation is structured as exemplarily described below. The exercise framework allows for flexible integration of the suggested and other appropriate exercises into an applied IMO model course.

For a simulation-based exercise dedicated to the micro level planning, it is suggested to integrate practical activities on the one hand to support optimized ship handling and to demonstrate effects of such actions regarding fuel saving, reduction of GHG emissions etc. and on the other hand to perform actions/tasks in simulation environment.

Practical activities on this subject can range from performing manual or desktop calculation exercises of specific case studies up to full-mission simulation exercises.

As a sample exercise the ship operation when approaching a berth in a harbour is suggested. A potential frame for the sequence of events and tasks of such an exercise is given in Table 2.

The emphasis of the simulation exercise is laid on planning of energy efficient manoeuvring taking into account optimized use of engine, propeller, thrusters etc. and by using available sources of information and taking into account different trim and ballast conditions.

The learning objectives of the training unit including the practical activity should focus on the application of good practices for manoeuvre planning, the use of the available appropriate means, and consideration of different trim options and potential impact of wind on the manoeuvre performance. The paramount planning process must be completed with an updated manoeuvre plan available and appropriate for monitoring during the real conduction of the harbour manoeuvres.

Figure 3 below gives an example for such a detailed manoeuvre plan developed with the sophisticated SAMMON tool (Benedict, K.; Baldauf, M.; Fischer, S.; Gluch, M.; Kirchhoff, M.; Schaub, M.; M.; Klaes, S. 2012) for planning, designing and monitoring ship manoeuvres. The picture shows the

approach to the berthing place in the harbour basin of the port investigated in the above mentioned study for the manoeuvring regime of a RoRoPax ferry. The ship shapes in the chart represent the manoeuvring points (MP x) where a planned elementary manoeuvre is to be executed.

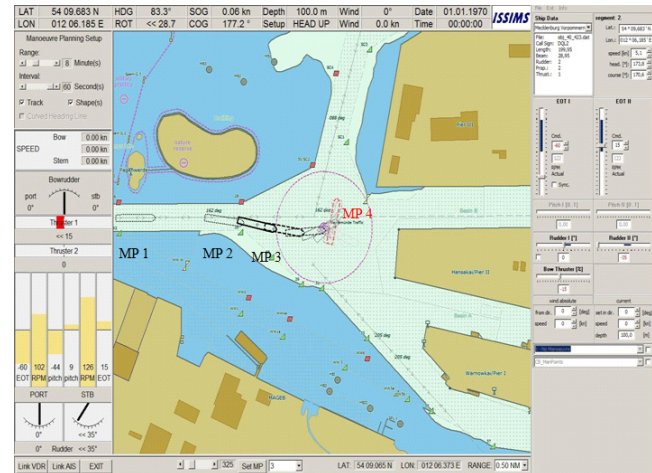


Figure 3. Planning of elementary manoeuvres using an ECDIS based planning station with integrated Fast-Time Simulation functionality to approach the berthing place

One of the fundamental ideas of the SAMMON tool for the planning of complex manoeuvring regimes in a harbour basin is the dynamic prediction of the ship movement in response to any steering command and simultaneously taking into account the actual ship status as well as the environmental conditions (Källström, CG., Ottosson, P., Raggl, KJ., 1999).

During tests trainees planned manoeuvring plans with just only less than ten elementary manoeuvres compared to more than 20 of the analysed real manoeuvring regimes. Moreover the conduction of the manoeuvres to approach the berthing were also faster and up to six minutes were saved in the simulation environment compared to the real manoeuvre regimes.

Such an exercise can be implemented to full-mission ship handling simulators and, preferably, directly connected to a ship engine room simulator to cover the onboard regime of ship operation more completely.

The sample exercises introduced here are suggested for integration into the final draft of the IMO model course and were forwarded accordingly.

Table 2. Outline of the draft IMO model course for "Energy Efficient Operation of Ships"

Draft sample exercise scenario "energy-efficient ship operation in harbour areas"	
Identifier	Optimized ship handling I Manoeuvre planning for harbour basin and berthing operation
Training objective	i.a. / e.g. <ul style="list-style-type: none"> • Manoeuvring in shallow water areas of harbour basin • Optimum use of steering and control systems • Use of tools for planning and monitoring ship operation considering different trim / ballast conditions
Simulator tool	Full mission ship handling simulator
Standard of competence	Master, chief mate (management level) and navigating officers
Configuration	e.g. RoRo Ferry ($L_{oa} = 200$ m; draught = 6,0 m; service speed = 24 kn)
Traffic situation	Moderate (about 3 ships per 10 min)
Time of day	Daylight
Current	Realistic (regarding area)
Environment	Wind: moderate, < 4 BF Sea state: low to moderate, average high of wave ~ 2,5 m
Duration	Long, > 45 min
Visibility	More than 8 nm
Area	Harbour area
Event-description	<ul style="list-style-type: none"> • Ferry/Passenger vessel (i.a. equipped with two propellers, bow thrusters) is approaching a harbour area for berthing operation, • Communication with shore-based VTS station • Passage to berth includes several rudder/engine manoeuvre, also use of thrusters is necessary • Passage planning to berth including pre-planning of manoeuvring up to berthing • Combined rudder/engine manoeuvres possible to save time while simultaneously keeping safety limits • Effects of "squat" on under keel clearance power, speed and fuel consumption in shallow water • Situation assessment (including trim operation and speed adaptation)

5 SUMMARY AND CONCLUSION

Within this paper general IMO activities to reduce pollution of the marine and atmospheric environment have been mentioned and some selected training requirements and needs resulting from latest STCW amendments and developments of model courses are described.

Focus was laid on the development of the model course on energy efficient ship operation.

Moreover, investigations into potential contributions of ships to reduce greenhouse gas emissions that were performed in the frame of the development of the model course and a train-the-trainer training package, are described.

One of the main objectives of the course development is to distribute knowledge and good practices. That is why a good balance of theoretical and practical activities should be provided by the course framework and simulation exercises should be integrated to highlight some key principles.

The main objective of the exemplarily described investigations into the integration of practical activities was to develop the basics for a simulation based training module that supports optimized ship operation by means of enhanced integrated manoeuvring planning and monitoring to assist captains, pilots and navigating officers when entering port entrances and manoeuvring in harbour areas. For this purpose a prototyped manoeuvring assistance system was integrated into a full-mission simulation environment and tested with respect to potentials for

energy and time savings. It was demonstrated that by means of enhanced simulation-based technologies time savings are possible and allow for a reduction of fuel consumption while simultaneously keeping the economic constraints of the voyage's time schedule and consequently reduce emission of greenhouse gases.

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