Study of Greenhouse Gas emissions from Ships

APPENDICES

CONTENT

A1. MARINE EMISSION INVENTORY

A1.1. Method for Calculating the marine emissions based on installed engine power

A breakdown of the world fleet according to ship type, ship size and engine type is made on three levels (Figure 1-1). Level three consists of the fraction of vessels with engine type *s* for a ship type *i* and of size x (*k*). Knowing the fuel (F) consumption and the emissions factors, the emissions rate for NO_x, SO_2, CO_2, CO and NMVOC may be calculated on four levels, using the equations below.

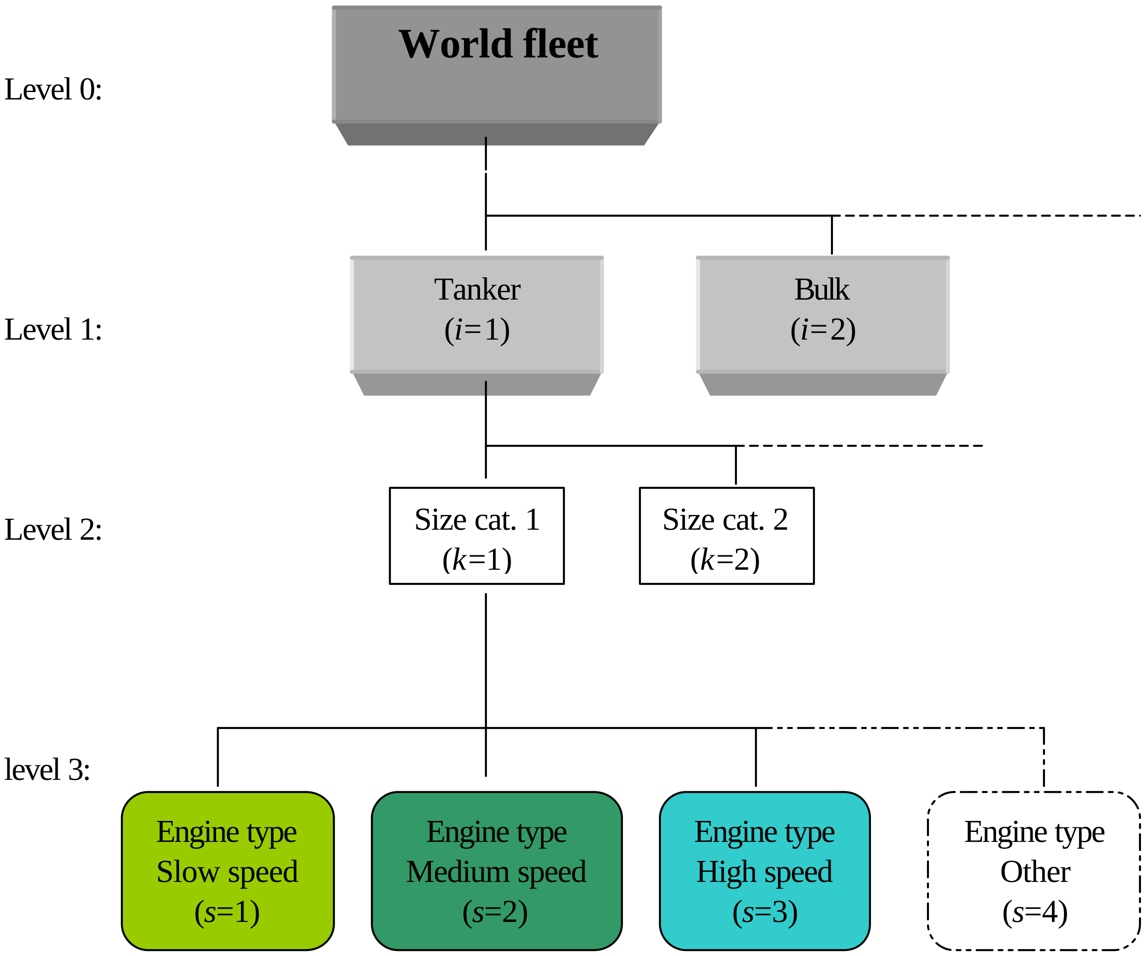

Figure 1-1 - A breakdown of the World fleet

- The calculating methods described below are based on information from:
- The World Fleet Statistic (Lloyd's, 1996), Table 1-2.
- Distribution of engine types (Table 1-3) and relations between installed engine power and DWT (DNV, 1998 (2)).
- Marine emission factors. The emissions factor for slow and medium speed is given in the main report. Emission factors for high-speed engines were assumed equal medium speed engines. Steam turbine emission factors assumed equal medium speed engines, except for NO_x: 7 kg/tonne fuel; CO: 0.4 kg/tonne fuel and NMVOC: 0.1 kg/tonne fuel [EMEP/CORINAIR, 1999].
- Specific fuel consumption (Table 1-3) and activity profile (Table 1-4).

Emission level 3: The emission from vessels using engine type *s* in ship category *i* and size category *k* is:

$$M_{(g)iks} = C_{(g)s} \cdot F_{iks} \qquad (1)$$

Level 2: The emission from vessels in ship category *i* and size category *k*:

$$M_{(g)ik} = C_{(g)1} \cdot F_{ik1} + C_{(g)2} \cdot F_{ik2} + C_{(g)3} \cdot F_{ik3} = \sum_{s=1}^{S} C_{(g)s} \cdot F_{iks} \qquad (2)$$

Level 1: The emission from vessels using engine type *s* in ship category *i*:

$$M_{(g)is} = \sum_{k=1}^{K} C_{(g)s} \cdot F_{iks} \qquad (3)$$

And the emission from vessel in ship category *i*:

$$M_{(g)i} = \sum_{s=1}^{S} M_{(g)is} \qquad (4)$$

Level 0: The total emission:

$$M_{(g)} = \sum_{i=1}^{I} M_{(g)i} \qquad (5)$$

Table 1-1 Input parameter

Parameter	Description	Unit
g	Individual exhaust gas component (NO_x, SO_2, CO_2, CO and NMVOC)	-
i	Individual ship type, Table 1-2	-
s	Size category (DWT) each ship type *i*, according to the World Fleet Statistics (Lloyd's, 1996)	-
k	Engine type, i.e. slow, medium, high speed and other	
F_{iks}	The total fuel consumption during a year world wide for a ship type category *i* and size category *k* and engine type *s*	kg
$C_{(g)s}$	Emission factor (pollution per kg fuel) the individual exhaust gas component *g* and engine type *s*	kg pollution/ kg fuel
$M_{(g)}$	Total emission for the individual exhaust gas component	
$M_{(g)i}$	Total emission for the individual exhaust gas component in a ship type category *i*	kg
$M_{(g)ik}$	Total emission for the individual exhaust gas component in a ship type category *i* and size category *k*	kg
$M_{(g)iks}$	Total emission for the individual exhaust gas component in a ship type category *i* and size category *k* and engine type category *s*	kg
$M_{(g)is}$	Total emission for the individual exhaust gas component in a ship type category *i* and engine type category *s*	kg

Table 1-2 Breakdown of the world fleet (Lloyd's, 1996).

Abbreviation	Vessel types	Number of DWT size categories
LGT	Liquid gas tanker	14
CT	Chemical tanker	14
OT	Oil tanker	21
B	Bulk	21
GC	General cargo	11
RO	RO-RO cargo	11
C	Container	14
RC	Refrigerated cargo	4
P	Passenger	4[1)]

[1)] Number of Gross tonnage size categories

Table 1-3 Specific fuel consumption (average).

Engine type	Specific fuel consumption (g/kWh)	Publication/reference
Slow speed	195	Harrington, 1992[1)] & Appendix ??? & Klokk, 1994 & DNV, 1998 (1)[2)]
Medium speed	215	
High speed	230	
Turbine machinery	290	

[1)] Supported by J. J. Corbett, 1999.

2) Based on testbed measurement and DNV ship onboard measurement (medium speed)

Table 1-4 Activity profile.

Ship size	Hours/year	Publication/reference	Average main engine load* % MCR
< 4999 DWT	4000	Isensee, 1994 & Oftedal, 1996	0.7
> 4999 and < 99999 DWT	5000		0.7
0ver 99999 DWT	6000		0.7

MCR- maximum continues rating

* Average main engine load, estimated based on the NO_x weight factors, duty cycle (ref: ISO 8178). Lloyd's in a previous study assumed 0.85 % MCR (1995)

A1.2. EMISSION FACTORS FROM SHIP OPERATION

A1.2.1. Introduction

The methodology used in the ship emissions inventory calculations as presented in the main report, use fuel based emission factor's to establish the aggregated emission figures. Fuel based emission factor's are conversion values from consumed fuel to derived emission from a combustion process.

This annex present an assessment of the most important fuel based emission factors established by use of different sources. Although different emission factors are available through literature, limited information is found describing the limitations when applying factors in emission inventory calculations.

Based on available information, emission factors for marine diesel engines have been considered in this annex.

The main objective of the assessment as presented in this annex was to quantify the statistical power of the fuel based emission factors used, and to indicate the level of uncertainty these factors impose on the calculated emission inventory.

A1.2.2. Sources

Manufacturer data
One obvious source of information regarding emission factors is data as provided by engine manufacturers. In connection with engine research work and test bed measurements, the engine manufacturer posses the complete set of data related to emissions from the combustion process.

The availability of data from the various engine manufacturers varies. Complete data sets for emission assessment include both primary emission measurement data as well as associated test data (effect, consumption, fuel analysis, test equipment and procedures).

In this annex, only available data at MARINTEK from various manufacturers were used, as it was outside the scope and resources for this assessment to collect new material at the time of this study.

A total of 22 data sets were considered, where 11 represent slow speed engines and 11 represent medium speed engines.

Lloyds exhaust emissions research programme

The two reports from Lloyd's Register marine exhaust emissions research programme [Lloyd's, 1990 and Lloyds 1991], provides a well-documented source for emission factors for slow and medium speed marine diesel engines. This study covers emission measurements from a total of fifty engines. Emission measurements were performed on six different ship types, selecting different sizes and age when selecting ships to be included in the study.

In addition to presenting fuel based emission factors for NO_x, SO_x, CO_2, CO and HC, the reports draw a clear picture of the large uncertainties involved when trying to establish emission factors.

An extract of the raw data from the Lloyd's study was used as input in a conversion routine, where results according to ISO 8178 were prepared. As this study focus on international shipping, some measurement data were discarded (tug, dredger type of vessels). Where values from relevant ISO defined test modes were not available, these were established by interpolation between given values.

A total of 28 data sets were considered, where 9 represent slow speed engines and 19 represent medium speed engines.

MARINTEK series of measurements

MARINTEK has performed emission measurements both in connection with laboratory research and onboard various ships. A large number of measurement series have a background in engine development, where emission measurements including all components were not scope of work. In this annex, complete results from only seven measurement series have been included, as they are complete with regards to requirements as given below. A total of 7 data sets were considered, where all represent medium speed engines.

In a MARINTEK report from 1990 [MARINTEK, 1990], results from measurements from 15 ships were presented. These measurements only focused on NO_x emissions, and are only included in the assessed in this annex with reference to results established.

Germanischer Lloyd measurement series

Germanischer Lloyd made results from 35 measurement series available to MARINTEK for the comparison and verification of findings in this report. These data sets for NO_x, HC, CO and fuel oil consumption were compared to other results, however they were not statistically assessed to the same extent as the other sources of information for this report.

A1.2.3. Methodology applied

Requirements to data
Data referred to in this assessment are complete set of data with regards to:

- Engine specification
- Test cycles and procedures, including defined test conditions (rpm/effect)
- Emission data set (ppm or %) including NO_x, CO_2, HC and O_2.
- Fuel consumption and fuel composition

A significant amount of additional data was available, but was discarded as one of the above components was missing.

Equipment for measurements
For all data used in the assessment, measuring equipment for emissions were in line with the ISO standard. In the Lloyd's research programme, fuel consumption was measured with onboard ship measuring equipment or established from manufacturer and trial data.

Test procedures and mass emission calculations
All data sets were compared based on the guidelines given in [ISO 8178]. Where data sets were not originally based on these guidelines, the data sets were converted to this format as far as applicable for the data at hand.

A1.2.4. Summary and conclusions

Emission factors
Based on the emission measurement data, descriptive statistical values were obtained.
In Table 1-5, the mean values for emission components are presented, based on the three sets of data.

Table 1-5– Emission factors in kg emission per tonne fuel

Mean Values (kg/tonne)	Manufacturer data		Lloyd's Register		MARINTEK	
	Slow speed	Medium speed	Slow Speed	Medium speed	Slow speed	Medium speed
NO_x,	105.4	61.2	80.4	57.5	-	63.8
CO	3.3	2.8	8.7	7,9	-	6.1
HC	7.7	1.8	7.0	6.6	-	2.1
CO_2	-	-	3153	3165	-	3171

NO_x

All NO_x emission factors are based on emission measurements of NO. For medium speed engines, the three data sources provide similar results. The major source for variation between the three sources may be related to the fuel consumption. Mean values for specific emissions (g/kWh) from medium speed engines were almost identical for the Lloyd's and MARINTEK data sets (13.8 and 14.2 respectively), while the manufacturer based data set gave a lower value (11.2 g/kWh). Similar, the mean values for specific emission for slow speed engines were 18.2 g/kWh and 17.9 g/kWh for the Lloyd's data and manufacturer data respectively.

MARINTEK performed emission measurements on 15 vessels in 1989-1990 [MARINTEK, 1990], and an emission factor for NO_x was established in conjunction with the project. The emission factor for NO_x was from this work found to be 63 kg/tonne (mean value from the measurement series).

Germanischer Lloyd data gave a mean value for specific emissions of 12.6 g/kWh for medium speed engines (based on 17 data sets for main engines). This value falls between mean values for manufacturer data and MARINTEK data (14.2 g/kWh)

CO and HC

Both CO and HC represent small values for emissions per unit fuel used. For all three data sets, the mean specific emission level for both HC and CO was found to be below 2.0 g/kWh. As seen from Table 1-5, the emission factors derived from the data sets are not consistent, and this is likely to be due to the level of uncertainty and low values measured related with these emission components.

Data from Germanischer Lloyd confirm the large spread in measurement results for CO and HC.

CO_2

Emission factors for CO_2 were established based on mass flow calculations combined with measurements of CO_2 or O_2. As seen from table 1, the emission factors for CO_2 are consistent for the two data sets where results are given.

Uncertainties

The results from the assessment indicate significant uncertainties involved when applying a set of standard emission factors based on a limited number of measurements.

Table 1-6– Standard deviation for associated mean values as given in table 1

Standard Deviation	Manufacturer data		Lloyd's Register		MARINTEK	
	Slow Speed	Medium Speed	Slow Speed	Medium Speed	Slow speed	Medium Speed
NO_x,	10.0	12.5	17.7	10.5	-	12.0
CO	0.7	2.0	7.6	3.2	-	4.4
HC	1.0	1.5	5.8	2.8	-	1.6
CO_2	-	-	29.5	18.9	-	30.8

Table 1-7– 95% Confidence interval for mean values as given in table 1. Values in parentheses are percent of mean value.

95 % Conf. Interval	Manufacturer data		Lloyd's Register		MARINTEK	
	Slow Speed	Medium Speed	Slow Speed	Medium Speed	Slow speed	Medium Speed
NO_x,	11.8(11%)	14.7(24%)	23.2(29%)	9.4(16.3%)	-	6.7(10.5%)
CO	0.9(27%)	2.4(86%)	9.9(114%)	2.9(37%)	-	2.4(39%)
HC	1.2(16%)	1.8(100%)	7.6(109%)	2.5(38%)	-	0.9(43%)
CO_2	-	-	38.6(1.2%)	17.0(0.5%)	-	17.2(0.5%)

Uncertainties related to the presented results may be considered as either uncertainties with regards to the measurement series or related to the statistical power of the results.

With regards to uncertainties from the measurement series, the data with largest systematic variation was found to be the specific fuel consumption for various data sets.
The three data sets considered show small variation of fuel consumption for each data set, while the fuel consumption from one data set to the other was considerable, see also Table 1-8. As the fuel consumption is one factor included when establishing the emission factor, any uncertainty related to the fuel consumption will apply also for the derived emission factor.

Table 1-8– Mean value and standard deviation for fuel consumption data

Fuel Consump. g/kWh	Manufacturer data		Lloyd's Register		MARINTEK	
	Slow Speed	Medium Speed	Slow Speed	Medium Speed	Slow speed	Medium speed
Mean	170	184	230	243	-	222
SDEV	2.1	7.6	15.9	15.1	-	4.3

Data from Germanischer Lloyd confirm the significant variation related to the determination of fuel consumption. The mean value for the fuel consumption from the Germanischer Lloyd data for medium speed engines was 207 g/kWh. This value falls between mean value from manufacturer data and MARINTEK data. The standard deviation for the series of measurements is also here significant.

Where as measured emissions of NO_x might vary significantly, this was found to be the case for all data sets in a similar way.

Figure 1-2 indicates the variation in measured NO_x emissions from the data involved in the assessment. The MARPOL Annex VI limit curve and the trend curve for the data set is shown in the same figure as the source data used in this annex.

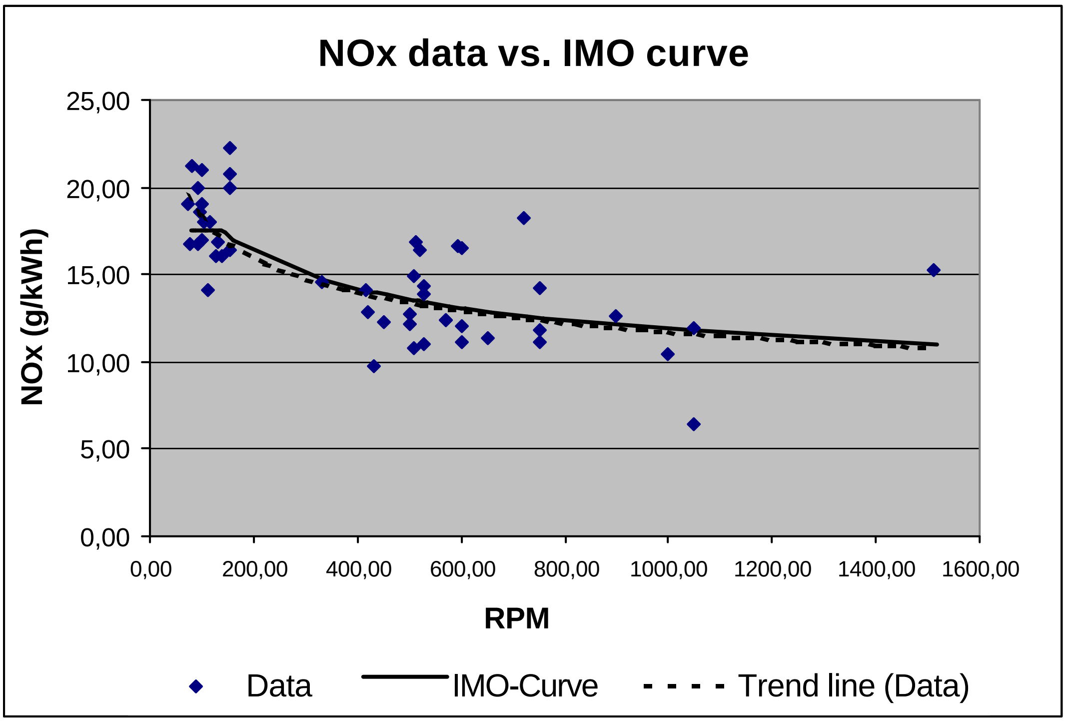

Figure 1-2 – NOx measurement data set considered.

Conclusion

Based on the assessment, the following conclusions are made:

- Fuel based emission factors are encumber with significant uncertainties
- Emission factor for CO_2 is considered to be the best estimate of the emission components considered

- The determination of the fuel consumption is a source for error when establishing the emission factor based on fraction of fuel consumed rather than per kWh.
- Fuel based NO_x emission estimates may be based on the IMO curve combined with fuel consumption estimates with similar accuracy as specific emission factors established from measurements. A procedure for fuel consumption estimates should however be established if this approach is to be considered.
- Fuel based emission factors for HC and CO are uncertain due to the low level of emissions measured

Based on the assessment, a range for some of the emission factors have been proposed as an addition to previously proposed estimated values. This will provide an improved basis for understanding the source of uncertainty related to the emission inventory results. In order to perform the basic emission inventory in line with recognised standards, the emission factors recommended in [EMEP/CORINAIR, 1999] was proposed applied in this study. Emission factors recommended in both [IPPC,1996] and [EMEP/CORINAIR, 1999] have been based on findings in Lloyds Marine Exhaust Emissions research Programme.

Table 1-9 – Emission factors for medium and slow speed diesel engines

Component	CORINAIR	95% conf. Interv.
CO_2	3170	3159-3175
SO_2	20*S	
CO	7.4	5.0-8.0
NO_x - slow speed - medium speed	 87 57	 85-96 56-63
NmVOC	2.4	-
CH_4	0.3	-
N_2O	0.08	-

A1.2.5. REFERENCES

EMEP Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe, CORINAIR (The Core Inventory of Air Emissions in Europe), ATMOSPHERIC EMISSION INVENTORY GUIDEBOOK, Second Edition, 1999.

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A2. EFFECT OF SHIP EMISSIONS ON AMBIENT CONCENTRATIONS OF NITROGEN OXIDES AND OZONE IN THE MARINE BOUNDARY LAYER

A2.1. Introduction

The effects of ship emissions on the concentrations of nitrogen oxides (NO_x) and ozone (O_3) in the marine boundary layer (MBL) in open oceanic regions was assessed using a global chemical transport model (GCTM). The GCTM used in this study was the 11-level Geophysical Fluid Dynamics Laboratory model. The analysis was conducted using a two-step process. In the first step of the analysis, the effect of ship emissions on MBL NO_x was studied using the model configuration described in Levy et al. (1999). In this configuration, the model explicitly simulates three reactive nitrogen (NOy) species, namely NO_x, nitric acid, and peroxyacetyl nitrate. Interconversions between these species are calculated using prescribed rates as described in Levy et al. (1999). While the NOy chemical scheme used is highly parameterized, this configuration of the model has been shown to successfully simulate key features of the global NO_x and NOy distributions (Levy et al., 1999). In the second step of the analysis, the effect of ship emissions of NO_x on MBL O_3 was investigated using the same GCTM, but with a parameterized representation of the O_3 chemistry and the NO_x results from the first part of the analysis. Again, the O_3 chemistry is highly parameterized, but nevertheless this configuration of the model has been shown to reproduce key features of the global O_3 distribution reasonably well (Levy et al., 1997). We discuss below the results from our analysis in detail.

A2.2. Modeled Effects of Ship Emissions on MBL NO_x and O_3

In the first stage of the project two simulations, one excluding and one including ship emissions (hereafter referred to as the NO_x-NOSHIP and NO_x-SHIP simulation, respectively), were performed to delineate the relative impact of these emissions on the NO_x distribution. The following sources of NO_x are considered in these simulations: (i) land-based fossil fuel combustion (22.4 Tg N/yr), (ii) biomass burning (7.8 Tg N/yr), (iii) biogenic processes (5.0 Tg N/yr), (iv) lightning discharges (4.0 Tg N/yr), (v) aircraft fossil fuel combustion (0.45 Tg/yr), and (vi) stratospheric injection (0.64 Tg N/yr). The NO_x-NOSHIP simulation does not include NO_x emissions from ships. The NO_x-SHIP run includes seasonally-varying emissions of NO_x from ships (Corbett et al., 1997; 1999). The annual, global magnitude of this source is 3 Tg N/yr, with the annual-average global distribution as shown in Figure 1.

Figure 2 shows the simulated monthly-mean NO_x mixing ratios from the NO_x-NOSHIP and the NO_x-SHIP simulations for January and July. Considering first the results from the NO_x-

NOSHIP simulation, we see that modelled NO_x mixing ratios are highest over the United States, Europe, China, and India which are the regions of largest NO_x emissions from fossil-fuel combustion. Seasonal maxima associated with biomass burning are also seen in tropical North Africa during January and in South America and southern Africa during July. Owing to the short lifetime of NO_x in the lower troposphere, simulated NO_x mixing ratios are generally low over most remote oceanic regions. From the perspective of this study, the seasonal contrast over the midlatitude Northern Hemisphere oceans is striking. In July, model simulated NO_x mixing ratios are less than 10 pptv in contrast to the mixing ratios during January which range from 50 to 200 pptv over parts of the North Atlantic and North Pacific. This contrast is due to a combination of longer NO_x lifetimes and faster transport from continental regions during winter.

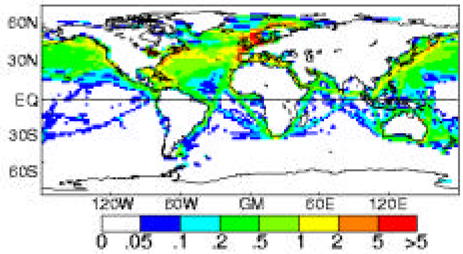

Figure 3. Annual-average emissions of NO_x from ships (10^{-12} kg N m^{-2} s^{-1}).

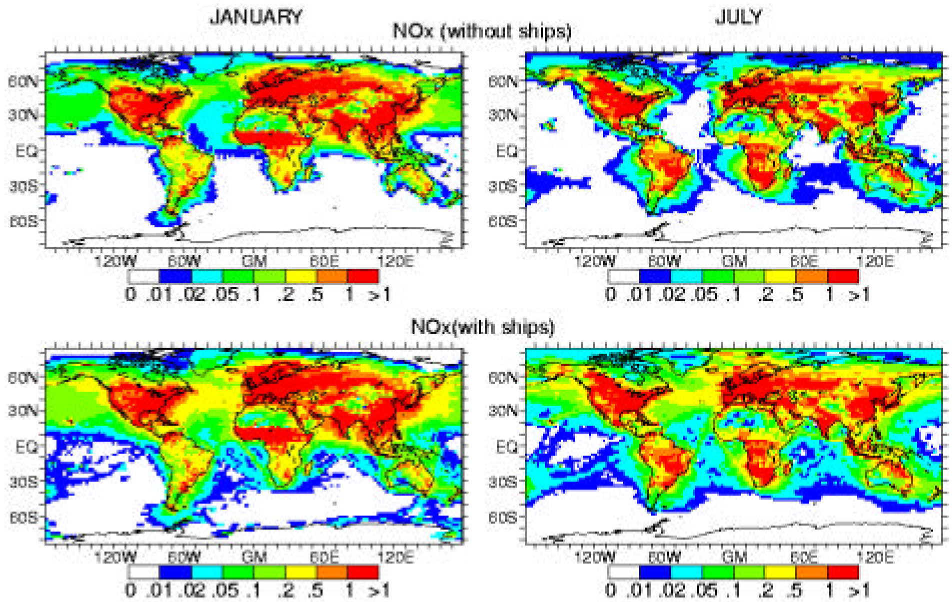

Figure 4. January- and July-mean surface NO_x mixing ratios (ppbv) from the NOSHIP-NO_x and SHIP-NO_x simulations.

Turning now to the results from the NO_x-SHIP simulation, we see that there is a significant enhancement in modelled MBL NO_x mixing ratios over certain oceanic regions. Peak NO_x mixing ratios as high as 200-500 pptv are now simulated over parts of the North Pacific and North Atlantic oceans in both January and July. A striking example of the large simulated impact of ships is the extratropical North Atlantic during July, where simulated NO_x mixing ratios are 100-500 pptv in the NO_x-SHIP simulation compared to the very low values (<10 pptv) in the NO_x-NOSHIP simulation. The large simulated effect of ships is clearly illustrated in Figure 3, which shows differences and ratios between simulated MBL NO_x levels from the NO_x-SHIP and NO_x-NOSHIP simulations. The difference maps roughly reflect the distribution of NO_x emissions from ships. Our model study suggests that ship emissions can contribute as much as 200-500 pptv of NO_x at the surface of the Northern Hemisphere midlatitude oceans. On a relative basis, the modelled impact of emissions from ships is particularly large over the central North Atlantic ocean and over the midlatitude North Pacific ocean during July. As mentioned earlier, the combination of slower transport and shorter lifetime during summer results in a much weaker contribution from adjacent continental regions, leading to the relatively high contribution of the in-situ NO_x source from ships during this period.

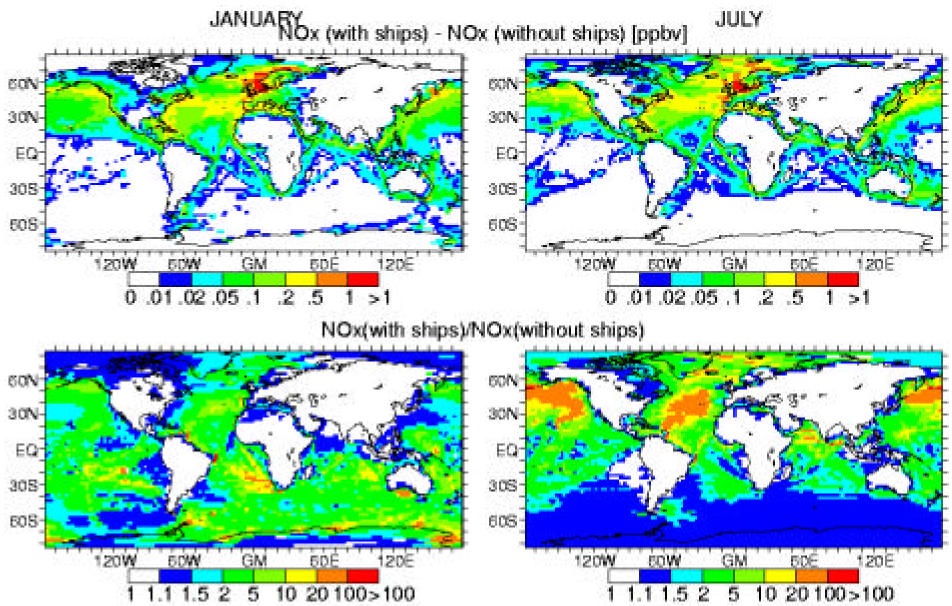

Figure 5. Enhancement of surface January-mean and July-mean NO_x due to ship emissions.

In the second stage of the analysis, the simulated NO_x mixing ratios from the previous runs were used to assess the impact of ship emissions on O_3. Figure 4 shows plots of modelled MBL O_3 with ship NO_x emissions included in the model ratioed to modelled MBL O_3 mixing ratios without ship emissions. With the exception of relatively small regions, the impact of ship emissions in January is relatively small. By contrast, the large enhancements of NO_x during July over the extratropical northern hemisphere oceans leads to large simulated increases in MBL O_3 in these regions. Between 30 and 60N, MBL O_3 increases by at least a factor of 1.5 when ship NO_x emissions are included, and in some regions the increase is about a factor of 2.

A2.3. Comparison with Measurements

An important issue that must be considered is whether or not the model predictions of a large impact of ship emissions on MBL NO_x and O_3 are realistic. The largest relative impact is on NO_x levels in the central North Atlantic, and we choose to focus in this issue in terms of our comparisons. Two datasets from recent field campaigns are particularly appropriate in this context. The first dataset consists of NOy measurements from a site in the Azores Islands (27.322W, 38.732N) from a field campaign during August 1993 (Peterson et al., 1998). MBL NO_x is converted to other longer-lived NOy species (such as nitric acid and peroxyacetyl nitrate) on a time-scale of 1-2 days during summer. Thus, the NOy measurements in this region serve not only as a point of reference for evaluating the modelled NOy mixing ratios, but also as an extreme upper bound of NO_x concentrations.

The Azores MBL NOy measurements used in this evaluation are believed to be minimally influenced by direct long-range transport (Peterson et al., 1998). In our climatological model, NOy mixing ratios at the Azores during the second half of August are influenced by transport from Europe. We have therefore used model results from only the first 14 days in August in an effort to provide as representative a comparison as possible. The second dataset consists of aircraft-based measurements in the MBL (bottom 1 km) from the NARE97 field campaign during September 1997 (Ryerson et al., 1999}. In this case, the comparisons with the measurements were limited to a latitude and longitude range of 37-50N and 35W-50W, respectively in order to avoid comparisons during periods of intense continental outflow.

The results of the comparisons are shown in Figure 5. At the Azores, while not perfect, the NOy predictions from the NOSHIP-NO_x simulation are in reasonable agreement but somewhat on the low end compared with the observations. The modeled NOy mixing ratios in the NOSHIP-NO_x simulation are also lower than the measurements taken during NARE97 by about 125 to 175 pptv. Figure 5 also shows that the NO_x mixing ratios from the NOSHIP-NO_x simulation are low in the NARE97 region, a feature that is more consistent with the observations than when the results from the SHIP-NO_x simulation are considered. The fact the NO_x mixing ratios from the SHIP-NO_x simulation are higher than even the measured NOy at the Azores is striking evidence that the SHIP-NO_x model significantly overestimates the impact of ship emissions on MBL NO_x in the North Atlantic. This also indicates that the modelled impact on O_3 emissions is a significant overestimate.

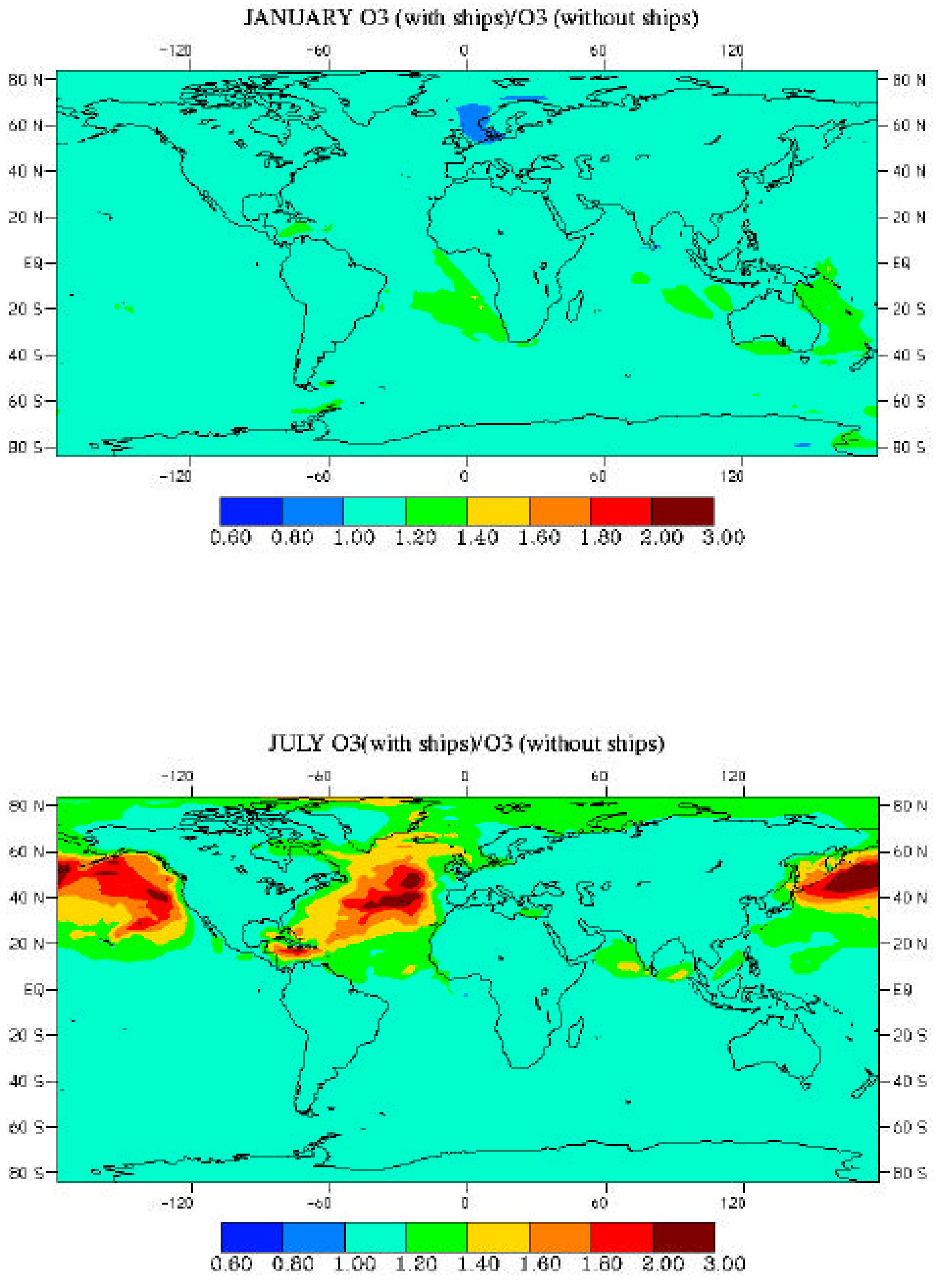

Figure 6. Enhancement of surface January-mean and July-mean O_3 due to ship emissions.

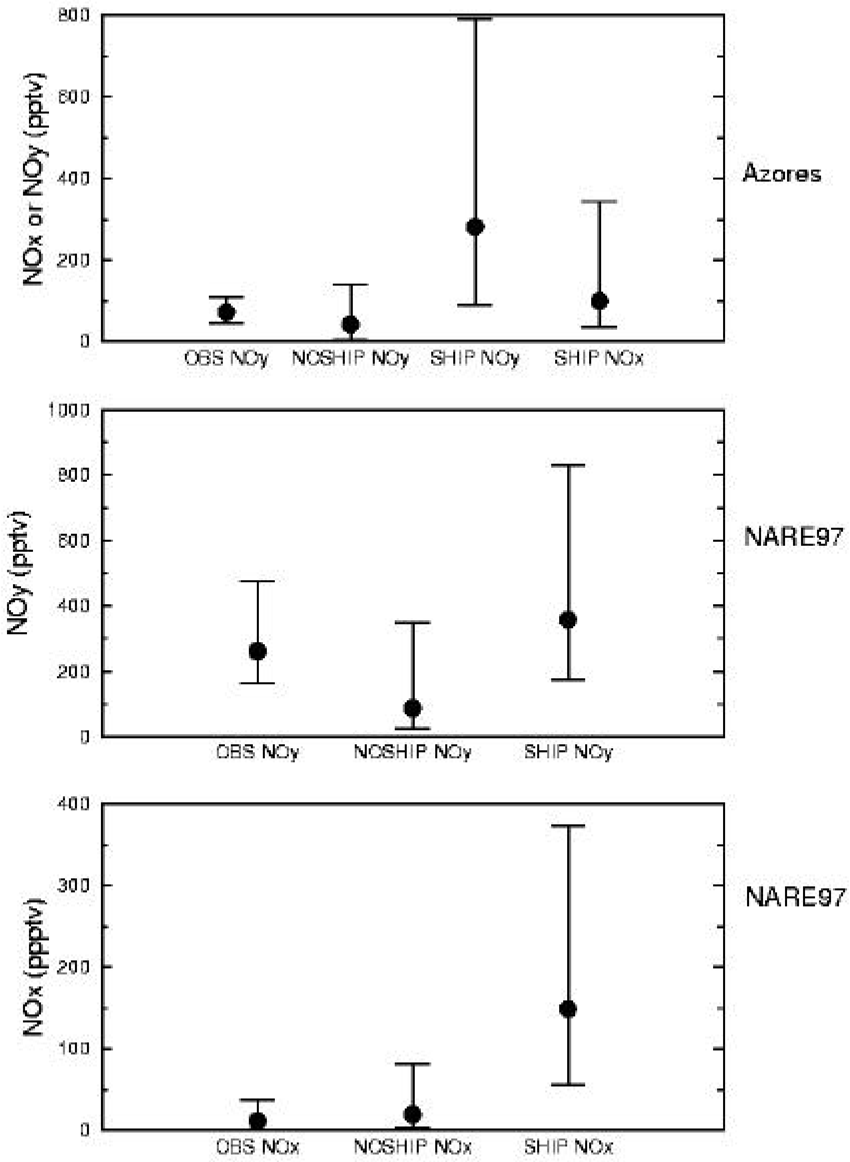

Figure 7. Comparisons of simulated NO_x and NOy mixing ratios over the central North Atlantic with measurements.

A2.3.1. Summary

We find that the simulated large-scale enhancements of NO_x predicted when ship emissions are included in the model are not supported by measurements of NO_x and NOy in the central North Atlantic MBL. One can speculate that this overprediction is related to an inadequate understanding of the chemical evolution of ship plumes as they disperse into the background

MBL. In this context, we recommend targeted field campaigns as well as longer-term monitoring at a few remote island locations to better understand the impact of ship emissions on the tropospheric chemistry of the MBL.

A2.4. References

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A3. MACHINERY MEASURES FOR REDUCTION OF EMISSIONS FROM SHIPS

This appendix provides supplementary information related to technical measures described in chapter 5 of the main report.

A3.1. Machinery measures applicable for new ships

A3.1.1. Measures - reduced fuel consumption/CO_2

Efficiency optimised (efficiency or economy rating):
Efficiency or economy rating implies a set of combined measures of which increased compression ratio and redesign of fuel injection is of main importance. The fuel injections rate and fuel atomisation has to be improved by both a higher fuel nozzle opening pressure and injection pressure. An overall engine optimisation also require some minor modifications and adoptions of:

- Combustion space: as the compression ratio is increased the combustion space has to be changed to make space for the fuel sprays.
- The piston, connection rod and cylinder head: designed for the higher peak combustion pressure (a modern engine normally has the strength capacity to take the increased peak pressure, approx. 10 bar).
- Turbocharger specifications and charge air temperature (reduced approx. $10^{O}C$).
- Inlet and exhaust valve lift to be increased

With efficiency rating utilising state of art techniques on new medium speed engines, a reduction of specific fuel consumption in the rage of 10-12 % can be obtained.

Efficiency rating measures by optimising turbo charging and injection system can also be adopted to slow speed two-stroke engines. There are however limitations, especially on peak pressure limit. The total gain in fuel consumption will be in the range of 2-4 %.

Machinery plant concepts:
When designing new ships today there are alternative options for configuration of the machinery plant. For some type of ships the traditional drive train with main engine connected to a fixed propeller has got a competitor in diesel-electric propulsion solutions. These multi-engine concepts offer a great deal of flexibility and possibilities to run with more optimal fuel consumption at the different operational conditions for a ship [Stenersen et al., 1996]. Diesel electric solutions will in principal represent an electrical power plant where loadsharing

onboard (both for propulsion and other consumer) can be handled to minimise fuel consumption. As an alternative to running one big engine at low or part load (low efficiency), one of a set of smaller engines can be run at full load (high efficiency). Exact figures on what fuel savings in real operation is difficult to obtain. Considerable fuel saving could be expected on ships or trades with significant part load operations.

On certain type of ships i.e. cruisers it is a growing interest of alternative machinery motivated by potential machinery space reduction (more cabins), increased operating flexibility (great deal of auxiliary power needed) and increased fuel economy and environmental friendliness.

A3.1.2. Measures on NO_X that affect CO_2

Retarded timing:
Retarding fuel injection timing is a commonly used method to reduce NO_x from a diesel engine, which does not require costly modification on the engine. By retarding timing the premixed burning phase is shortened, combustion temperature and pressure reduced and thus resulting in reduced formation of NO_x. However this will cause poorer fuel economy, mostly due to the reduced pressure. A delayed start of the injection of fuel will also lead to a delayed end of the injection unless the rate of injection is altered. Later stages of the combustion will as a consequence suffer from less optimal conditions, resulting in increased emissions of particulates and smoke.

The possible NO_x reduction by retarded timing may be limited by the maximum turbocharger speed, because lower engine efficiency caused by later fuel injection means more energy on turbine, causing the turbocharger to speed up.

This is the most common NO_x measure in existing ships, but for new ships better and more fuel-efficient methods will be applied.

A3.1.3. Measures on NO_X with minor or no affect on CO_2

Low NO_x combustion:
This option includes adjustments and adaptations to existing engine designs with the purpose of reducing NO_x emissions without suffering reduction in efficiency [Wärtsilä NSD, 1997]. Such measures are not only restricted to retarded fuel injection, but includes also adaptations of the fuel injection rate, change of nozzle specifications, improved fuel atomisation, compression ratio adaptations, turbocharger modifications and improved fuel/air mixing.

With a retarded injection start combined with a shorter injection period (increased injection rate) the combustion can take place at a point optimal from engine efficiency point of view. An increased injection rate allows a delay in the initiation of fuel injection, similar to retarded injection timing, causing lower peak combustion temperatures and reduced NO_x formation. Increasing the injection rate tends to reduce the particular emissions and fuel economy penalties of retarded injection timing, because the termination of fuel injection is not delayed.

To control NO_x formation it is also of great importance to reduce the ignition delay. Measures are increased compression ratio, using an extra pilot injection or a combination of both. Improved mixing by charge air movement and combustion chamber geometry is of great importance for optimal results.

Injection rate shaping is an additional strategy to reduce emission formation, described later on as long term measures as it implies quite much new techniques to be optimal

By introducing low NO_x combustion technique a positive effect is also obtained on efficiency and rate of CO_2 emissions [DNV, 1998].

The applicability for low NOx technique is high, illustrated by the fact that most new engines sold will have such.

Water injection:
Water may be injected into the cylinder through a combined diesel injector with a water nozzle included, or through a separate injection valve. Both solutions calls for additional water pump system as a high-pressure common rail pump.

A shut off has no implication on the engine as the diesel system is intact and the ship can be run of full power.

With the combined injector, the water injection is controlled electronically with full flexibility to control both water injection timing and amount of water. The water injected before the diesel fuel cools down the combustion chamber and cuts the peak temperatures, and thereby reducing the NO_x formation.

The water sprays injected (not interfering directly with the diesel spays) do not effect the ignition delay in the same manner as i.e. water-in fuel emulsion does.

Direct injection of water allow a water share up to 60-70 % of fuel to be applied [Wärtilä NSD, 1998], which is significantly more what is possible with i.e. water-in-fuel emulsion and a standard charge air humidification. NO_x reduction in the range of 50-60% is reported by use of direct water injection.

The system does not require extra space in the engine and does not add much extra cost to an engine. Water injection is available on a few types of medium speed marine engines. The installation cost is approximately 25 USD pr. kilowatt engine power. Operation and maintenance costs are approximately 4-5 % of fuel costs [Diesel & Gas Turbine, 1999].

It is expected a lot more engines installed in new ships with water injection or at least with such as an option.

Water emulsion:
By adding water to the fuel, NO_x and particulate emissions can be reduced. One way to produce emulsion is by first pressurising the fuel and water mixture and then choking the flow. Emulsion may also be produced by the use of a mechanical homogenizer, ultrasound or steam injection.

When adding water in the fuel, the capacity of the fuel pumps must be increased correspondingly in order to maintain 100 % load. In order to reduce the duration of the injection, a fuel system with greater capacity must be installed.

Water emulsion has a positive effect on the combustion process by the micro-vaporisation of the fuel drops. As a result, mixing of fuel and air is promoted, speeding up the combustion and increasing the constant volume combustion.

For the water to heat, vaporise and superheat, energy is required. Especially the energy required for vaporisation is significant, giving a positive effect on combustion temperatures. The energy used for vaporisation is lost, and can not be recovered in the later stages of the process. When water is added in the fuel, the cooling effects from the water are exploited in the flame front and not all over the combustion chamber where additional cooling has negative effects. This process leads to a reduction of the NO_x emissions.

NO_x in the exhaust gasses will decrease significantly when the water content of the fuel exceeds 10 %. Typically reductions of the NO_x emissions are 20 – 25 % at 20 – 25 % water content. Increasing the water content to 50% will lead to a reduction in
NO_x emission level of about 40% [Småvik at al.1994].

When it comes to the effects on the specific fuel consumption, the literature indicates a small reduction of the specific fuel consumption using emulsions with water contents up to approx. 20% and most effective at part load conditions. A higher water content is negative for fuel efficiency.
HAM:

The concept is called Humid Air Motor (HAM), and aims at increasing the specific heat capacity of the charge simultaneously as the oxygen concentration is reduced.

The basic idea [Muntes Europa, 1998] behind the HAM concept is to use charge air with 100% relative humidity at a higher than normal charge air temperature. As steam has twice the specific heat capacity of dry air, the specific heat capacity of the cylinder charge is increased. At the same time, the steam occupies space that would normally contain oxygen, and the concentration of oxygen in the cylinder charge is reduced.

In the HAM concept a humidification tower is added to the turbocharged engine. The tower replaces the air cooler between the compressor and engine air intake. In the tower, heated water is brought into contact with compressed air in a counterflow act, causing water to evaporate at a sliding temperature. As the relative humidity at the air outlet is nearly constant at around 99.5 %, the absolute humidity will change with the pressure and the air temperature at the tower outlet. Seawater can be used, even if freshwater is preferred at the moment.

Full scale tests with HAM have shown NOx reduction up to 70%.

The size of equipment to be added and especially the humification tower put restrictions on where the HAM can be put in use on existing ships. It is also necessary that the engine installation have the required excess energy for heating water available.

On new ships it is expected that the investment costs will be more or less the same as for a SCR installation. A retrofit on an existing ship is expected to be cheaper than an SCR retrofit. The running expenses in relation to a HAM installation is however far less than for a SCR installation [Bunes et al.,1998].

The HAM concept has still to prove its efficiency, cost effectiveness and reliability to go from prototype testing to more commercial use in ships.

EGR:
By EGR a small portion of the exhaust gas is routed back into the charge air, thus increasing its heat capacity and lowering the oxygen concentration. This results in lower peak temperatures, and thus a reduction of NO_x formation.

The exhaust is taken after the turbine outlet and cooled in a heat exchanger. Via a fan the exhaust gasses are lead in to a filter. The extensive use of residual fuel on ship diesel engines put a restriction on the use of EGR. These restrictions are mainly caused by particulates, which when deposing are influencing turbocharger operation and causing increased smoke emissions [DNV 1998].

Increased fuel consumption, partly due to poorer combustion properties in the combustion chamber and partly due to increased internal engine power consumption is experienced from EGR in service.

A catalyst or an electrostatic filter may remove the particulates from low sulphur fuel oil, but when HFO is used, the sulphur must also be removed from the exhaust gasses e.g. by a venturi washer. Remedial actions as high quality fuel or exhaust gas particulate removal, both significantly increasing operational costs. The latter even increase system complexity and reduce availability.

EGR is best suited for engines using natural gas or high quality MDO as a fuel. EGR is not used in marine installations due to the content of particulates and sulphur compounds.

Investment costs are in the magnitude of a water emulsion installation.

SCR:
In selective catalytic reduction (SCR) the NO_x in the exhaust gasses is reduced to nitrogen (N_2) and water by the use of a catalyst and a reducing agent. This is one of the most efficient means found in the marked for reducing NO_x content from exhaust gasses. At design load, 85–95% of the NO_x may be removed from the exhaust gasses when applying this alternative.

SCR requires an exhaust gas temperature of 250–450^{o}C. The lower temperature limit is determined by the formation of ammonia sulphate, a sticky and corrosive substance, giving fouling problems. The upper limit is set by the formation of undesired products, like N_2O. In addition to that, ammonia burns rather than react with NO and NO_2 at high temperatures.

Most suppliers of SCR installations use an ammonia based reduction agent. In all these installations, some ammonia will pass through the reactor without participating in any chemical reactions. This is called ammonia slip. By nature, SCR installations give slow response to systems controlling the injection of reducing agent, leading to ammonia slip.

The catalyst slowly deactivates with time, mainly due to thermal loading and physical blocking of the catalyst surface area by dust. When the performance is no longer adequate, the catalyst must be replaced.

To avoid e.g. catalyst poisoning, deposits and corrosion, special precautions are recommended by the manufacturers. This might comprise ultra low sulphur fuel, elevated process temperature or particulate removal from the exhaust gasses.

A large number of SCR units have been installed in power plants over the last 25 years. For marine diesel engine applications, the experience is significantly smaller. However, it is reported close to 70 SCR systems under construction or in pertain on ships [DNV 1998]. Experience from enduring continuos operation is still somewhat limited.

Even with today's technologies, SCR systems are relatively large installations, but may replace the silencer. The investment costs of such an installation lies in the area of 50 % of the diesel engine for a 7 MW medium speed diesel engine. Both investment and operating cost have been reduced over the past 4-5 years, but has to be lowered even more to make SCR more attractive for ship use.

A3.1.4. Other measures

Fuel specifications:
The majority of marine bunker delivered world wide today is HFO, and this has been the case for many years. The world major oil companies expect HFO to be the major fuel to be consumed for years to come. These fuels will be mixtures between oil refinery fractions with different properties. Residue oil from atmospheric distillation is becoming more frequent as input for secondary refinery processes. The residues from primary processes will be more rare so that the quality of future fuels must be expected to vary by time and differ by bunker stations in one and the same port [Hennie et al., 1998].

If the fuel has a low viscosity and a high density, the ignition property could be poor. This means the ignition delay in an engine operating on such fuel will be long, and result in a large cylinder pressure gradient during the initial part of the combustion. Despite this phenomenon the combustion could be good, but the production of NO_x would be rather high. However, most engine manufacturers can already satisfy the proposed IMO regulations on NO_x emission level even for slow and medium speed engines.

What is said about the expected varying quality of HFO will also be the case of MDO. Varying MDO quality must be expected to vary by time and differ by bunker stations in one and the same port. However, the variation of MDO quality may be more moderate than for the HFO since addition of chemicals, heavy distillate fractions, etc. into the MDO is fairly easy to detect at site by simple tests.

Combustion properties of MDO are good, and the production of NO_x is somewhat lower than that of the HFO. Less amounts of SO_x is produced because of the lower sulphuric content. A change over from using HFO to MDO will reduce NO_x formation [IMO 1989]. The CO_2 emissions will also be reduced in the range of 4-5 % by using MDO instead of HFO [The

Motor Ship, 1999]. The reason for lower CO_2 emissions is mainly because of the lower Carbon/Hydrogen ratio of MDO.

However, it is no driving force a change over as long as the difference in price between the two is at the current level (80-110$ difference between IFO380 and MDO in January 2000 [Telemarine, 2000]), and present emission requirements can be meet even with HFO [Hennie et al. 1998].

Machinery operation and strategies:
The success of operational strategies is dependent of the overriding and main governing parameters for the specific trade as: cargo owners time schedule, fuel bill payer, fuel oil prices etc.

When looking at operating strategies that favours fuel economy, multi-engine plants are in favour as they open for more flexibility in operation adapted speed requirements, manoeuvring, stand-by etc. [Stenersen et al.1996].

A set of new cruise ship will even have combined gas turbine and steam turbine integrated electric drive system (GOGES), which will offer a thermal efficiency as high as 50% [Diesel & Gas Turbine, 1999].

Machinery condition/efficiency monitoring
Efficiency monitoring could incorporate more regular use of systems for monitoring machinery efficiency and planning related maintenance and adjustments based on an optimum time interval. This could reduce the specific fuel oil consumption for the diesel engine and hence the emissions level for CO_2. For the main engine it is normally today good routines for controlling the efficiency. The deviation in the main engine efficiency is seldom increasing above a level of 1 – 2 % from the normal range. The control is mostly performed at a periodic manner. By using an on-line system, which could catch any deviation more quickly, a potential increase in the average efficiency could possible be obtained. A possible figure could be in the range from 0.5 – 1 % in improvements.

The deviation in efficiency is normally caused by offsets in injection time for the fuel pumps. This can be caused by machinery degradation, variation in fuel properties or set points getting offset by other matter. By adjusting the fuel pump set point the engine efficiency will increase and hence the CO_2 emission will decrease. However an improvement in the fuel pump set point could however increase the NO_X emission. Often a reduction of CO_2 by 1 % would often give an increase in NO_X by approx. 5 %, when adjusting fuel pump set points.

For auxiliary diesel engines the efficiency could have a larger deviation (2 – 5 %). But normally the auxiliary diesel consumption would only be in the range of 3 – 7 % of the main engine consumption and any improvements would have relative lower influence on the overall emission from the ship. By using more regular efficiency monitoring, a possible improvement in CO_2 emission could be in the range 0.5 – 2 %. This will an overall improvement for the ship in CO_2 emission in the range 0.02 – 0.14 %. A related increase in NO_X emission in the range 0.1 – 0.7 %.

Another possible improvement is to better control the efficiency for the electric power consumption equipment. It is difficult to set any figure for a possible improvement. A possible figure of 3 – 6 % could give an overall ship improvement on both CO_2 and NO_X by a value of 0.1 – 0.4 %.

For some ships exhaust boilers could produce the normal electrical consumption in sea or they will produce steam for other heating purposes. If the boilers is too much fouled, an auxiliary diesel engine must be started to produce the necessary power, and hence give an additional increase in CO_2 and NO_X by as much as 2 – 3 %. If mainly producing steam with an inefficient exhaust boiler, additional fuel must be burned to produce the necessary steam. This situation is mostly valid for ships in the range 10000–20000 DWT and where the exhaust energy only partly or almost can cover the steam requirement.

By having better routines for maintenance of the boiler this situation could be avoided. It is however only a percentage of the fleet which will experience this problem. An estimated figure could be 20 % of all ships (or of the total engine power). An estimate of the percentage time this situation could appear could be 20 %. Better boiler cleaning routines could reduce this figure to an estimated value of 15%. The improvements for these ships for CO_2 and NO_X emission would be in the range 0.1 – 0.15 %. This will give a contribution in overall average decrease for every ship for CO_2 and NO_X emission by a value in the range 0.02 – 0.03 %.

A3.2. Machinery measures applicable for existing ships

A3.2.1. Reduced fuel consumption/CO_2

Efficiency improvement of machinery on existing ships can be divided into different categories. Improvements may vary from minor modifications to the most extensive, reflecting both the magnitude of improvement and the costs.

Injection:
Fuel injection can be modified so that the amount of fuel is injected over a shorter period of time. This can be obtained either by modification on the pump (bore or stroke ratio) or by camshaft profile (faster lift). The injector with nozzles should also correspond with the new setting. Such a simple fuel rate-shaping can be applied on most engines from a strength point of view as the peak pressure is nearly unaffected. The cost involved by fuel injection modification is moderate.

Fuel consumption can be reduced in the range about 2-4 g/kWh by applying this measure on medium speed engines.

Turbo charging:
The new generation of turbo chargers has improved the overall efficiency. A replacement of an old turbo charger with a new modern normally requires some adaptations for the new one to fit in. The effect on the engine overall efficiency is in the same magnitude as for the simple rate shaping described above. Retrofit of a turbo charger installation represents a significant cost, and hence the payback should be quite clear before applying this measure.

Engine efficiency rating:
Engine efficiency rating implies quite extensive modifications, including an engine upgrade with a set of changes. The most important changes involved in efficiency rating are:

- Higher rate of fuel injection (shorter period) with improved atomisation and start/stop of injection. The consequences of this item are new camshaft, injection pump and injectors.
- Increased compression ratio either by new piston or extended camrod, new cylinder head (space for fuel spays at increased CR).
- Turbocharger re-specification.
- Higher inlet and exhaust valve lift, which implies change of camshaft.

For implementation of this measure, the mechanical strength of the engine has to allow for increased peak pressure (10-15 bar).

Of the measures discussed in this part this is the most extensive and thereby most expensive. Compared to the alternatives efficiency rating is found to be the measure that pays off with highest efficiency gain. A reduction in specific fuel consumption in the magnitude of 8-10 g/kWh may be achieved. A slight increase in NO_x has to be encountered [Wärtsilä NSD, 1997].

For slow speed engines the gain from efficiency rating measures cannot be established at the level of medium speed engines, mostly because of peak pressure limitations. The gain in fuel consumption is consequently lower, i.e. the range of 2-3 g/kWh. However, upgrading the injection system while at the same time accepting a trade-off with NO_x (slightly higher NO_x), yet another 4-5 g/kWh reduction at part-load can be obtained (at full load about 2 g/kWh) [Wärtsilä NSD, 2000].

Efficiency rating is in most cases easily applicable. However, it is always a question of cost/benefit for the shipowner. Such an engine upgrading should be combined with a engine major overhaul, planned anyway.

A3.2.2. Measures on NO_x - component and system retrofit/modifications

Timing retard:
Retarded fuel injection timing is the simplest way to reduce NO_x from a ship diesel engine. This measure can be implemented without hardware modification or extra cost. Retarded timing alone have a negative effect on fuel consumption (specific CO_2 increases). Reduction of the NO_x emission level in the range of 6-8 g/kWh is possible, but at a cost of an increased fuel consumption of 5-7 g/kWh.

When implementing the measures listed in section 4.2.2.1 above, the NO_x formation is also reduced, mainly because of the effects on ignition delay and peak temperature.

Most measures imply retrofit and engine modifications aiming for an improved combustion in order to reduce CO_2 and NO_x emissions. The possible measures descried in the following are all primarily for NO_x reduction and imply additional or modified equipment installed.

Low NO_x combustion:
Some engine manufacturer can offer retrofit/upgrading packages for ”low NO_x combustion” without increase of fuel consumption. A low NO_x combustion upgrade on an existing engine implies to some extent engine component retrofit. The reduction of NO_x emission is in the range of 4-6 g/kWh [Wärtsilä NSD, 1997].

Water injection:
Water injection to reduce NO_x emission is described in section 4.1.2.3. It is an effective measure (50-60% NO_x reduction) which can be retrofitted on existing engines. The main components are the combined injector, common rail water supply system and electronically control system. Retrofit cost figures are estimated to approximately 25 USD pr. kilowatt. The operating cost inclusive maintenance is about 4-5 % of fuel costs [Wärtsilä NSD, 1998, Diesel & Gas Turbine, 1999].

Today most water injection applications are found on new engines, either factory installed or delivered as an option. The technique is fairly new for commercial use, but there are examples on installations on existing engines, and more expected to come. Additional long-term experience is needed to confirm that water injection can be applied without harmful effects on cylinder liner/piston and cylinder head with valves.

Emulsion:
Fuel emulsion (adding water in fuel) is a NO_x reduction measure where the necessary equipment can be installed on existing engines. The reduction potential without penalty on fuel efficiency is in the range of 20-25%.

The additional equipment needed in the fuel supply system is a unit for dosing/ measuring of water and homogenisation. Several pilot projects are known which have served to gain operating experience and measure the effect on NO_x emissions from real operating conditions [EPA, 1998, Småvik et al. 1996, DNV, 1998].

For some installations the fuel oil pumps have to be modified or replaced for full load capacity reasons as a consequence of adding significant amount of water to the fuel.

Humid Air Motor (HAM):
Implementation of the HAM technique on existing engines can result in up to 60% reduction of NO_x emission level. The technique is however new and the long-term operational effect is not fully proven. In existing ship it is in most cases difficult to install the HAM equipment, mainly because of the rearrangement of the air supply system to the engine and the additional space required. Most engines have a turbo-charger and aftercooler system that is heavily integrated and matched for the specific engine. Engine manufacturers may be reluctant to modify this original integrated system solution [Bunes et .al, 1998, Munters Europa 1998].

The HAM concept has still to prove its efficiency, cost effectiveness and reliability to go from prototype testing to more commercial use in ships.

Miller Cycle:
By closing the inlet valves earlier, the temperature at BDC and during the hole combustion cycle can be reduced, and thereby also the level of NO_x emission. It requires an efficient turbocharger with higher pressure ratio to feed the engine with the required amount of air. However, care must be taken so that the ignition delay is not significantly prolonged, otherwise this will effect the NO_x formation in a negative way [CIMAC, 1998].

Adoption of the Miller Cycle requires a new camshaft and in most cases also a re-specification or a new turbocharger. The concept has not to any extent been taken into use.

Exhaust Gas Re-circulation (EGR):
Several problems need to be addressed and solved before EGR will be an applicable measure for existing or new ships. The main challenge is the re-entrance of particulates damaging for the engine, especially when running on HFO, and therefore very limited applicability is foreseen [EPA 1998, DNV, 1998].

SCR:
A properly operating SCR installation can remove up 95 % of NO_x components from the exhaust. It can be installed on existing machinery as retrofit packages, which includes the reactor, urea storage/dosing and control system. For installation on an existing ship there are some practical limitations due to the need for space. Although the reactor can replace the exhaust silencer it can be rather costly to install. In addition to the space for the reactor, there is also need for storage space for urea.

As for the water injection and emulsion techniques, the SCR installations on ships has been through a phase of testing to gain experience from transient operation. In addition to the efficiency on NO_x removal, the urea consumption and slip is of interest.

A significant number of new SCR installations in existing ships is not expected in the near future. The regulations addressing NO_x emission level today can be meet in more cost-effective ways. As the major part of the world feet uses heavy fuel oil, SCR as a NO_x reduction measure is excluded because fuels with very low content of sulphur is required when applying the technique [Bunes et al 1998, DNV 1998, EPA 1998].

A3.2.3. Effect of machinery measures - follow-up

Both the fuel reduction measures as i.e efficiency rating and the NO_x measures have to be implemented on quite an extensive number of ships in order to obtain any significance for the marine emission reductions. A close follow-up on improvements (particularly over time) and if they really are obtained on all ships are difficult or not realistic. This will also require establishing of an emission status for each individual ship, before implementing any measures.

Some follow-up (also “old” engine status) from engine manufacturer and equipment suppliers can be requested by the shipowner as a part of a purchasing contract. Onboard measurements have to be performed and will at least ensure a short-term poof on what is achieved. Some spot-test by a 3rd party can also bee foreseen. However, an extensive follow-up of a great number of ships will require significant resources.

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A4. CASE STUDY AND MODAL COMPARISON

A4.1. Case study

A4.1.1. Introduction

Table 4-1 - Description of case vessels

	Oil tanker	Bulk carrier	Container	General Cargo
DWT	275,000	70,000	36,500	12,700
Main engine type	Slow speed	Slow speed	Slow speed	Medium speed
Speed (knots)	14	14	20	15
Annual growth in % 1)	0.75	1.4	5	0.4
% of fleet, age > 10 years	58	61	38	80
% of fleet, age > 20 years	34	24	12	46
% of fleet using HFO	95	95	95	45

1) Figures representative for scenario with total growth of world fleet 1.5%. In the high-growth scenario (3.0%) these figures were multiplied by 2.

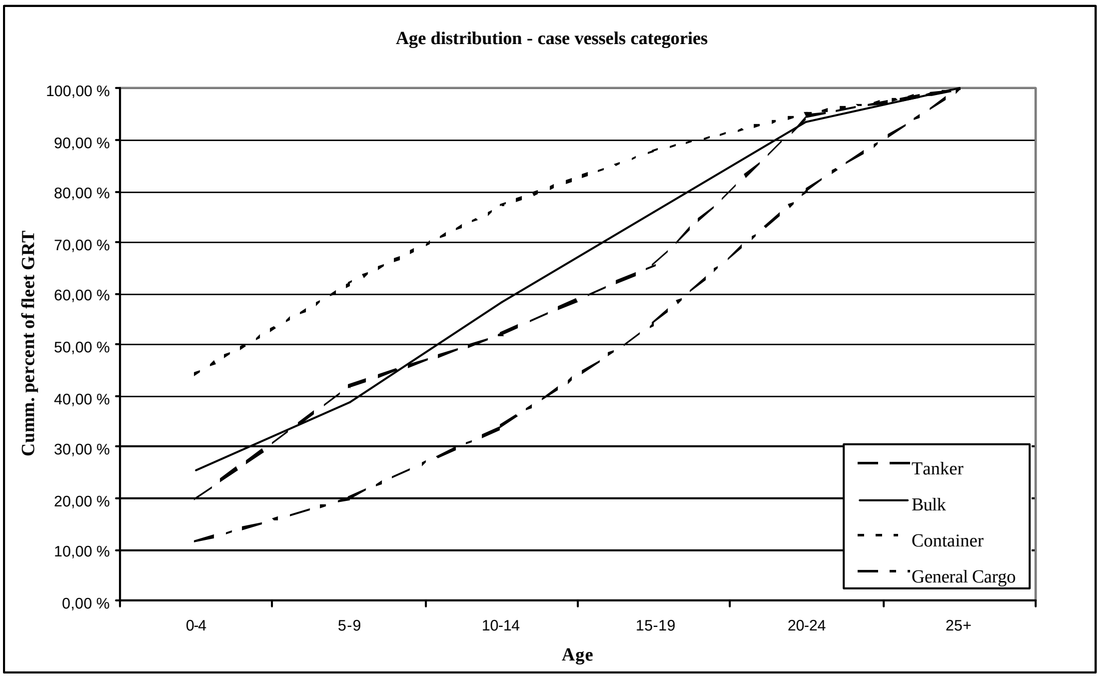

Figure 4-1 – Distribution of age of the case ships [Lloyds, 1998]

As seen from Figure 4-1, the age distribution for the various case ship fleet segments varies considerably. While the container vessel fleet has a low average age, the general cargo category has a high average age. This has to be taken into account when considering the potential for various options to obtain a reduced total emission level. For a fleet with very low average age, the most relevant option for short term consideration, will be related to measures for existing ships.

A4.1.2. Case study on tanker segment

Based on fleet data, the segment is dominated by vessels more than 100.000 DWT (66% of fleet above this size), with 58% of all vessels more than 10 years of age. Typical fuel in the tanker segment is HFO and engines are found in the area 15.000-30.000 kW. The case ship is defined at 275.000 DWT and powered by a two-stroke engine at approx. 23MW. Based on fleet data (ref. chapter 3 of the main report), the tanker fleet consists of approximately 6900 vessels of different DWT. The case ship of 275.000 DWT represents a size above the average for the entire fleet of tankers.

Machinery

For the case study, the most promising measures identified in chapter 5 were chosen, and it was focused on machinery measures that are foreseen as most applicable, both technical and operational. The reduction potentials indicated below are related to possible reduction in specific fuel oil consumption for a slow speed engine and used for estimating effect on CO_2 emissions 20 years from now. The percentages of reduction indicated are the improvements that can be achieved compared to the average of the ship engines in operation today.

The total effect would be best if focusing measures on existing ship engines during the period 2000-2020. Not all of these older engines can easily be upgraded. It will always be an assessment of what is technical and economical feasible for each ship, i.e. depending of age and type of engine. On existing ships efficiency rating is seen as the most promising measure in a 10 years timeframe. A gradually change from HFO to MDO was also used as case example with full effect in 2020.

It is foreseen a reduced specific fuel consumption relative to year 2000 consumption because of the change in age distribution and share of new engines in the period 2000-2020, i.e. a reduction relative to year 2000. This is illustrated by the measures related to efficiency rating of engines on both new and existing ships.

The measures considered in the case study were:

1) Efficiency rating of main engine on existing ships. Based on the above the effect of implementing efficiency rating on the share of the fleet more then 10 years old was considered.

2) Efficiency optimised main engines for all new ships.
3) Switching from HFO to MDO for all ships. The measure was considered based on an assumption that approximately 95% of the fuel for tankers are HFO. In 2010 this share was reduced to 45% and further down to zero in 2020.

The case study results on CO_2 reduction by machinery measures are summarised in Table 4-2.

Hull/propulsion

The effect of optimised hull and propeller designs versus conventional design and the effect of improved maintenance have been considered.

Based on the power-speed curve as shown in Figure 4-2 for the tanker case ship, a potential power reduction of 35% was identified at the speed of 14 knots (gap between typical case ship and lower limit represented by best hull shapes in data set). At lower speed the potential is even higher. However, to exploit this potential, one must be completely free to select the optimum main dimensions for the given tonnage. This is usually not possible, since entrance to harbours and canals sets restrictions for beam, draught and length.

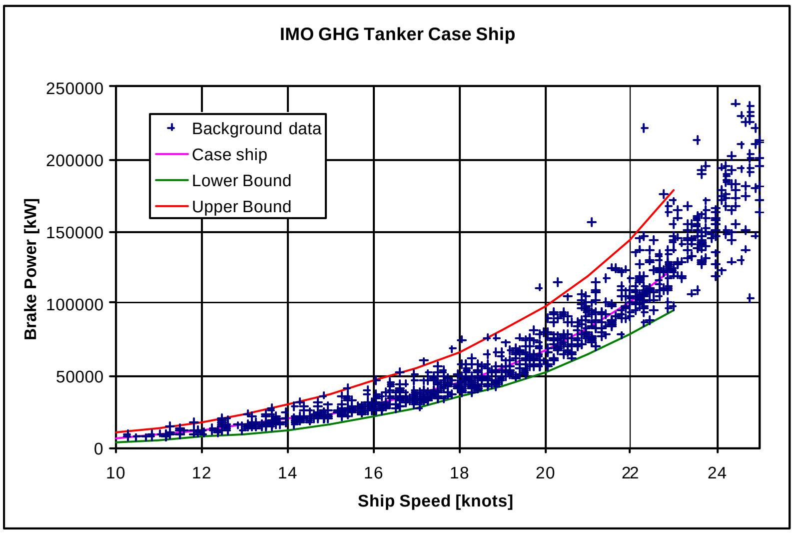

Figure 4-2 – Speed-power curve for tanker case ship, included predicted best power level

MARINTEK's experience from work in the towing tank and on hull design is that there is a potential for reducing the resistance up to 20% without a significant change of the main dimensions. A typical potential for a new but not optimised design is 10%. In this study we base comparisons with the average of existing ships, and the reduction potential used in the study was set to 15%. Reduced need for power will imply reduced fuel consumption for a new design.

In the case study, the reduction of fuel consumption for an optimal design was assumed proportional to the reduced need for propulsion power. In order to estimate the effect of all new tankers delivered with reduced need for power, the percentage reduction of 15% was applied to the forecast for fuel consumption by “new” ships at a future moment of time.

Based on the presentation given in chapter 5 of the main report, it could be expected to obtain savings in the order of 5% by proper selection of low RPM propeller, pre- and post-swirl devices or possibly a ducted propeller for a tank or a bulk ship.

Maintenance of the hull coating systems is important to avoid increased hull roughness and implicit increased fuel consumption. Although maintenance of hull coating normally is a standard operation in connection with docking, the effect of the maintenance should be appreciated in relation with the contribution to fuel savings. Application of modern antifouling systems will ensure that the general hull roughness of the underwater hull will not increase between dockings. Due to repairs, spot-blasting, touch-up work etc., the average hull roughness (AHR) tends to increase with increasing age of the vessel. For the tanker case ship, an increase of 30 microns AHR per docking will result in 4% increase in power demand in 10 years (2 dockings).

The measures considered in the case study were:
1) Optimised hull shape for all newbuildings, fuel reduction potential 15%.
2) Choise of optimal propeller on all newbuildings, fuel reduction potential of 5 %.
3) Improved hull and propeller maintenance, fuel reduction 4%, applicable for ships older that 10 years.

Operational aspects

As discussed in chapter 5 of the main report, operational control may provide significant reduction in fuel consumption and emissions. In this case study, the effect of fleet planning or improved efficiency by reduced time in port would require an entire study on its own.

As an illustration of the actual gain of being able to reduce speed at sea due to operational planning or other measures, the reduction in fuel consumption based on the reduction of speed by 10% was considered. The reduction in power needed by a 10% speed reduction is based on the power-speed curve above for the case ship.

In [Sowman, 1999], it is stated that a reduction in fuel consumption of up to 7 % can be achieved by use of weather routing. However, this will vary from trade to trade, and since a part of the fleet already applies weather routing, the potential reduction in fuel consumption for the fleet is less. In this case study a 3 % fuel reduction for half of the tanker fleet was considered. This assumption was only included to consider the impact of increased use of weather routing compared with other alternative measures.

The measures considered were:
1) The effect of a speed reduction of 10% for the entire case ship segment
2) Weather routing, assume 3% fuel reduction relevant for 50% of the tanker fleet

Results

Table 4-2 – Results from tanker case study

	% Reduction/increase	
Forecast of increased fuel consumption	**2000-2010**	**2000-2020**
Base line scenario 1, assuming 1.5% growth of fleet	7.3	14.2
Base line scenario 2, assuming 3.0% growth of fleet	14.1	28.3
Measure for reduction of emissions (CO_2)	**2010**	**2020**
Technical		
Machinery, efficiency rating existing ships	1.7	1.7
Machinery, optimised ME, new ships	1.7	2.6
Switch from HFO to MDO	2.0	3.8
Hull, optimal design	6.3	11.8
Hull, optimal propeller design	2.1	4.0
Improved hull and propeller maintenance	2.3	2.3
Operational		
Operational, reduce speed by 10%	18.4	18.4
Operational, increased weather routing	1.5	1.5

The theoretical maximum when implementing all technical measures considered is a 16.1% reduction of the emissions in 2010 and 26.2% in 2020. Compared to the two scenarios these values are above the values for the highest projected growth of fuel consumption and corresponding CO_2 emissions.

As seen from the results, operational measures show the largest potential as a measure to reduce emissions. The effect of improved hull design is also significant, especially in the 20-year scenario. The reason for growth in potential for reduction due to hull design improvement is that it is assumed that an increasing number of ships with improved hull lines enter service during the period 2000-2020. The effect of efficiency rating of engines are declining with time, as it is assumed that the standard will gradually improve over time, and giving less profit from this measure on existing ships in 10 years.

As an illustration of the actual gain of being able to reduce speed at sea due to operational planning, the reduction in fuel consumption based on the reduction of speed by 10 % has been considered. Based on the speed-power curve for the tanker case ship, a reduction in speed by 10 % will give a reduction in the power needed by approximately 28 %. However, due to the decrease in ship speed, the transport work performed by each ship will also decrease. In deep sea operation, we may assume that the time spent in ports are small compared with the sailing times. The transport work performed by each ship will then decrease by approximately 10 %. Therefore, for the world fleet to be able to carry the same volumes, the fleet size (and hence the emissions) must increase by 10 %. The total reduction in emissions by reducing the speed by 10 % will therefore in fact be only approximately 18 %. A further description of the potential of operational measures, substantiating these considerations, is described in part A4.2 below.

The reduction in emissions in short sea operation will be even more favourable than in the deep-sea case described. This is because the relative importance of sailing time compared with time in ports is less in short sea operation.

The applicability of speed reduction has not been considered in the above calculations. There are mainly two conditions that may influence a shipowner to reduce the ship speed: 1) High fuel prices and 2) Excess capacity of tonnage. If one chooses to increase the fuel prices, for instance by imposing environmental taxes, one can achieve the first condition. The consequence of high fuel prices must, however, be seen in comparison with the rate level. In a ‘high’ market, the relative importance of high fuel prices is less than in a ‘low’ market. The second condition is worse to control, as the market mechanism always tends to drive away from excess tonnage capacity.

Efficiency rating measures are complementary, as the two measures are considered for different segments of the fleet. Based on the reduction of emission due to engine modification the benefit is marginal compared to the fact that the result assumes that this measure is implemented on all ships (approximately 6900 ships).

A4.1.3. Case study on bulk carrier segment

The bulk carrier segment has large variation both in DWT and engine power. Main engines are typical in the range of 7.500-17.500 kW. The age distribution for bulk carriers shows that almost the same as for tankers with 60% of fleet being older than 10 years. The bulk fleet consists of approximately 5200 ships, and the case ship of 70.000 DWT represents a ship slightly below the average size of a ship in this fleet.

Machinery

The slow speed engines (average case ship power: 10.5MW) are also dominant for bulk carries and the same approach as described for tanker machinery above will be valid for the bulk carrier segment.

The measures considered in the case study were:
1) Efficiency rating of main engine on existing ships. Based on the above the effect of implementing efficiency rating on the share of the fleet more then 10 years old was considered.
2) Efficiency optimised main engines for all new ships.
3) Switching from HFO to MDO for all ships. The measure is considered based on an assumption that approximately 95% of the fuel for tankers are MDO. In 2010 this share was reduced to 45% and further down to zero in 2020.

Hull/Propeller

A somewhat lower potential for improvement due to optimised hull lines was identified for the bulk ship. Based on MARINTEK data, a potential for 28 % reduction of engine power at the defined speed on 14 knots is illustrated in the scatter plot. Referring to the discussion in the tanker case section, 15% potential for improvement was chosen as a realistic estimate to use in the calculation. For other measures, the background is equivalent to the tanker case.

The measures considered in the case study were:
1) Optimised hull shape for all newbuildings, fuel reduction potential 15%.
2) Choice of optimal propeller on all newbuildings, fuel reduction potential of 5 %.
3) Improved hull and propeller maintenance, fuel reduction 4%, applicable for ships older that 10 years.

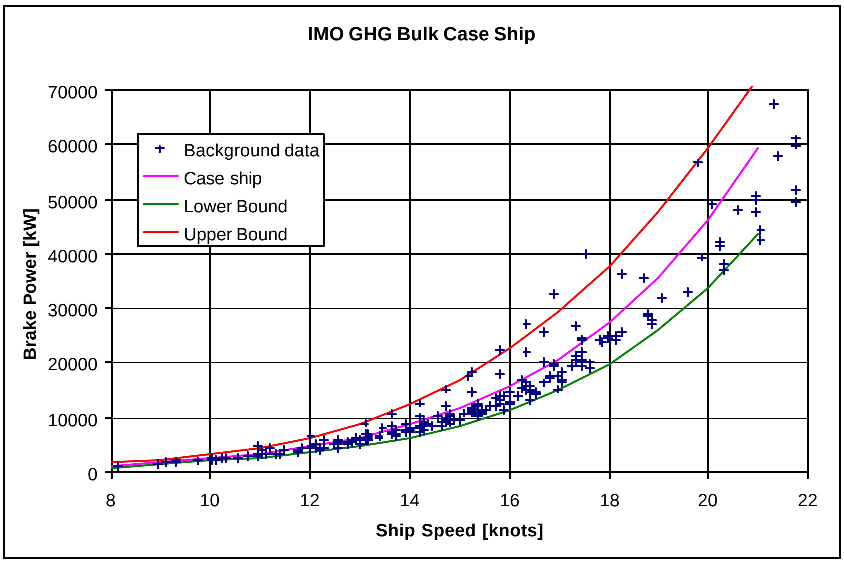

Figure 4-3 – Speed-power curve for bulk case ship, included predicted best power level

Operational aspects

The reductions in fuel consumption due to operational control will be approximately the same for the bulk fleet as for the tanker fleet.

The measures considered was:
1) The effect of a speed reduction of 10% for the entire case ship segment
2) Weather routing, assume 3% fuel reduction relevant for 50% of the bulk fleet

Results

The theoretical maximum when implementing all technical measures considered is a 15.7% reduction of the emissions in 2010 and 25.5% in 2020. Compared to the two scenarios these values are in the region of lower scenario of projected growth of emissions.

As the bulk segment was given a higher growth rate than the tanker segment, the increase in CO_2 emissions is also higher than for the tanker case study.

With tank and bulk having similar features (age distribution, speed, volume), the results are also similar for the two cases.

Table 4-3 – Results from case study for bulk

	% Reduction/increase	
Forecast of increased fuel consumption	**2000-2010**	**2000-2020**
Base line scenario 1, assuming 1.5% growth of fleet	13.3	26.5
Base line scenario 2, assuming 3.0% growth of fleet	25.2	50.4
Measure for reduction of emissions (CO_2)	**2010**	**2020**
Technical		
Machinery, efficiency rating existing ships	1.8	1.8
Machinery, optimised ME, new ships	1.6	3.0
Switch from HFO to MDO	2.0	3.8
Hull, optimal design	5.9	10.8
Hull, optimal propeller design	2.0	3.7
Improved hull and propeller maintenance	2.4	2.4
Operational		
Operational, reduce speed by 10%	23.7	23.7
Operational, increased weather routing	1.5	1.5

A4.1.4. Case study on container ship segment

The container ship segment is evenly distributed above and below 3.000 TEU of cargo capacity (approximately 40.000 DWT). For vessels below 3.000 TEU, engine size varies in the range 7.000-22.000 kW, while for the largest vessels engine size has reach 60.000 kW. The container ship fleet consists of approximately 1950 ships, and the case ship of 36.500 DWT represents the average size of the fleet.

The trend in the market has been towards increased size and speed, and also points to open hatch solutions and reduced time in port.

Machinery

The average case ship (36.500 DWT) is powered by slow speed or medium speed engine. Average power is approximately 22MW. Both slow speed and medium speed engines will be ordered in new ships. However, gas turbines could be a competitor to diesel engines in the time to come, depending on future power demands and fuel market. In the case study only diesel engines were assumed applicable.

For existing container ships engine upgrading/efficiency rating is considered as the most appropriate measure for reduced fuel consumption. The effect of a switch to MDO is also estimated for container ships.

The measures considered in the case study were:
1) Efficiency rating of main engine on existing ships. Based on the above the effect of implementing efficiency rating on the share of the fleet more then 10 years old was considered.
2) Efficiency optimised main engines for all new ships.
3) Switching from HFO to MDO for all ships. The measure is considered based on an assumption that approximately 95% of the fuel for container ships is HFO. In 2010 this share was reduced to 45% and further down to zero in 2020.

The case scenario results on CO_2 reduction by machinery measures are summarised in **Table 4-4**.

Hull/propulsion

Based on MARINTEK data, a potential for 30.7 % reduction of engine power at the defined speed on 20 knots is illustrated in the scatter plot. Referring to the discussion in the tanker case, 15% was applied as a realistic estimate to use in the calculation.

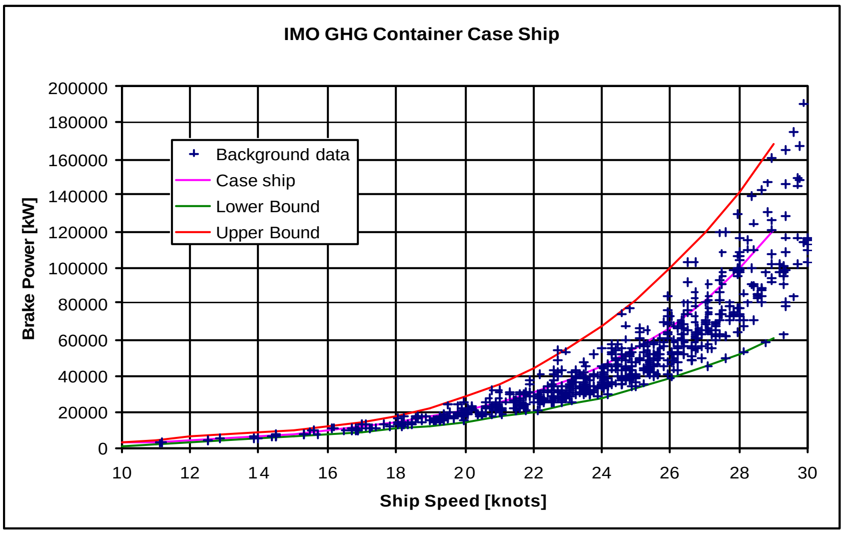

Figure 4-4 – Speed-power curve for container case ship, included predicted best power level

In addition to optimised hull lines, the choice of propulsor was also considered for the container case ship. For container vessels the savings potential was considered higher than tank and bulk and increased to 10%, mainly due to the possibility of using contra-rotating propellers and/or asymmetric sterns.

Operational aspects

The container fleet is the segment considered with the highest average speed. Fleet planning and operation according to a set schedule is common. It is assumed that the fleet utilises tools both for fleet and route planning.

Only speed reduction was selected as an operational measure to be considered.

The measures considered was:
1) The effect of a speed reduction of 10% for the entire case ship segment

Results

The theoretical maximum when implementing all technical measures considered is a 22.6% reduction of the emissions in 2010 and 35.5% in 2020. Compared to the two scenarios these values are below the projected growth of emissions.

The container segment has a different age distribution than the tank and bulk segment. As seen from results on efficiency rating, the potential is biggest for newbuildings, as the existing fleet is relatively new.

Table 4-4 – Results from case study on container

	% Reduction/increase	
Forecast of increased fuel consumption	**2000-2010**	**2000-2020**
Base line scenario 1, assuming 1.5% growth of fleet	41.7	83.3
Base line scenario 2, assuming 3.0% growth of fleet	71.4	143
Measure for reduction of emissions (CO_2)	**2010**	**2020**
Technical		
Machinery, efficiency rating existing ships	1.1	1.1
Machinery, optimised ME, new ships	2.5	3.5
Switch from HFO to MDO	2.0	3.8
Hull, optimal design	9.3	15.3
Hull, optimal propeller design	6.2	10.3
Improved hull and propeller maintenance	1.5	1.5
Operational		
Operational, reduce speed by 10%	22.0	22.0
Operational, increased weather routing	0	0

Based on the measures chosen in this case study, reductions based on technical measures alone are not capable of compensating the increased emissions due to the assumed growth.

A4.1.5. Case study on general cargo ship segment

Fleet data show that the general cargo fleet is the most complex ship segment of the four case ships. The general cargo fleet consists of approximately 18.000 ships of different size and capacity. For the purpose of this study, the case ship of 12.700 DWT represents an average size ship in the segment.

Machinery

General cargo ships are fitted with medium and slow speed engines. The average case ship has an engine of approx. 5.2MW.

As for the other type of ships, the fuel consumption can be reduced by machinery measures. The number of ships is huge with a great variety of engine type/manufacturer, not all worth extensive investments. However, engine upgrading for reduced fuel consumption (efficiency rating) can be technical and economical feasible on a significant part of existing ships.

A significant share of the general cargo ships is already running on MDO. For the case study only half of the consumption was considered to be HFO, with a gradually switch to MDO for the entire fleet.

The measures considered in the case study was:
1) Efficiency rating of main engine on existing ships. Based on the above the effect of implementing efficiency rating on the share of the fleet more then 10 years old was considered.
2) Efficiency optimised main engines for all new ships.
3) Switching from HFO to LFO for all ships. The measure is considered based on an assumption that approximately 45% of the fuel for general cargo ships is HFO. In 2010 this share was reduced to half of this and further down to zero in 2020.

Hull/Propulsion

Based on MARINTEK data, a potential for 42.6 % reduction of engine power at the defined speed on 15 knots is illustrated in the scatter plot. Referring to the discussion in the tanker case section, 20% was applied as a realistic estimate to use in the calculation, noting that especially among the smaller vessels there are potential for a significant improvement of hull lines.

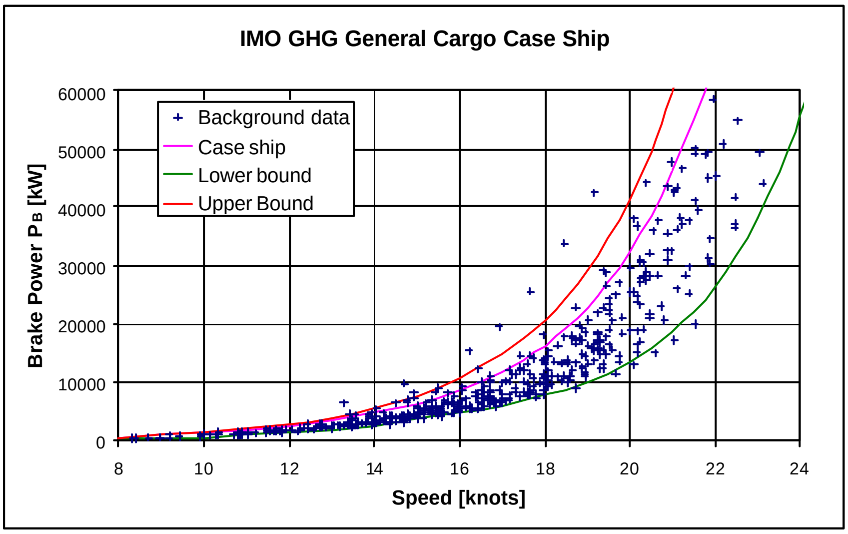

Figure 4-5 – Speed-power curve for general cargo case ship, included predicted best power level

Operational aspects

Weather routing is not considered to have the same potential for this segment as for the others considered above. As the general cargo segment represent smaller vessels trading in coastal regions with shorter hauls, the effect of weather routing will be less than for ocean-going vessels. However as the case study is very coarse with a large number of ships in this segment, it was considered relevant to assume that a fraction of the fleet may profit from weather routing.

Improved cargo handling operation or fleet planning is considered to have a significant potential for this segment. As above the effect is illustrated through speed reduction as the end effect of such measures.

The measures considered was:
1) The effect of a speed reduction of 10% for the entire case ship segment
2) Weather routing, assume 3% fuel reduction relevant for 10% of the general cargo fleet

Results

The theoretical maximum when implementing all technical measures considered is a 15.5% reduction of the emissions in 2010 and 24.1% in 2020. Compared to the two scenarios these values are above the projected growth of emissions.

Table 4-5 – Results from case study on general cargo

	% Reduction/increase	
Forecast of increased fuel consumption	**2000-2010**	**2000-2020**
Base line scenario 1, assuming 1.5% growth of fleet	3.9	7.9
Base line scenario 2, assuming 3.0% growth of fleet	7.7	15.5
Measure for reduction of emissions (CO_2)	**2010**	**2020**
Technical		
Machinery, efficiency rating existing ships	4.2	4.2
Machinery, optimised ME, new ships	1.2	3.3
Switch from HFO to MDO	0.9	1.8
Hull, optimal design	4.0	7.7
Hull, optimal propeller design	2.0	3.9
Improved hull and propeller maintenance	3.2	3.2
Operational		
Operational, reduce speed by 10%	25.4	25.4
Operational, increased weather routing	0.3	0.3

Based on an assumed low growth of this segment, measures on existing ships may compensate increase in emissions due to growth of the fleet. In fact for the general cargo segment, a reduction of the emissions is theoretically feasible.

The general cargo case segment is by far the biggest in number of ships. Due to this implementation of measures on existing ships will require significant effort. At the same time this segment has the highest average age of the fleet segments considered in the case study. Based on this, measures promoting replacement of the fleet is considered to be the most cost efficient way to reduce the greenhouse gas emissions.

A4.1.6. References

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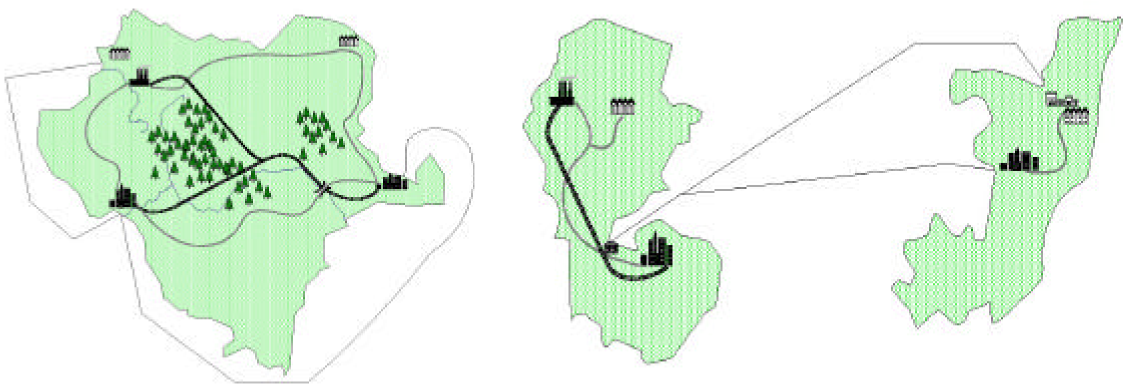
A4.2. Modal comparison

A4.2.1. Framework

International maritime shipping is a critical element in the global freight transportation system that includes ocean and coastal routes, inland waterways, railways and roads. In some cases, the freight transportation network connects locations by multiple modal routes, functioning as modal substitutes (see Figure 4.6a). In this case, the cargo shipper has some degree of choice how to move freight between locations. However, it is more common for international maritime transportation to function as a modal complement to other modes of transportation. International shipping connects roads, railways, and inland waterways through ocean and coastal routes (see Figure 4.6b).



(a) (b)

Figure 4.6. Interdependence of Mulit-modal Freight Transportation System as (a) Potential Substitute Modes and (b) Complementary Modes

Nonetheless, energy and environmental performance measures can be used to compare the separate freight transportation modes. Energy intensity by mode is commonly reported. The simplest way to make this calculation is to take the total energy used by a transportation sector (e.g., trucking) and divide by the total tonne-km that cargo is moved. Other measures can be used for environmental performance (e.g., emissions) or for movement of cargo (e.g., tonnes cargo, vehicle miles). Figure 4.7 presents published measures of this type.

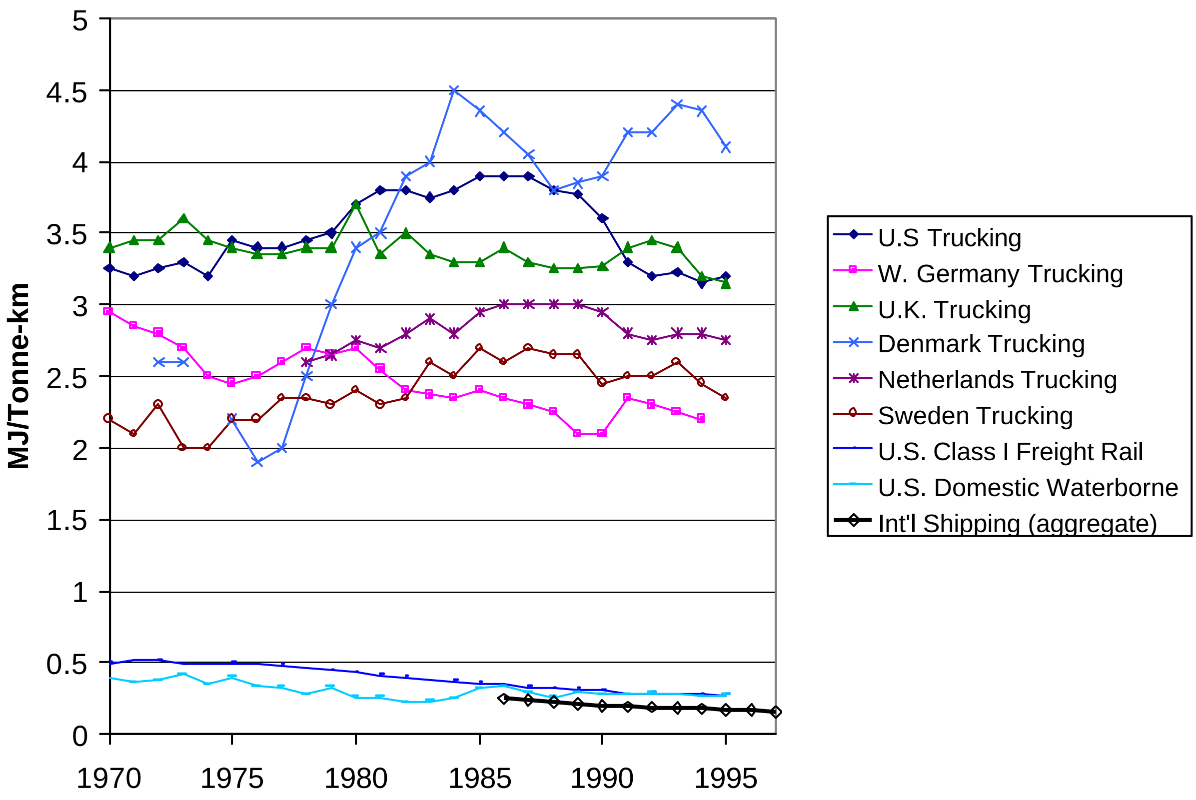


Figure 4.7. Energy Intensities Derived from Freight Transportation Activity Over Time (Trucking Data – includes light and heavy duty – from Shipper and Marie-Lilliu, 1999; Rail and Domestic Waterborne from TEBD 18, 1998; Int'l Shipping derived in this work)

One difficulty with this approach is that only qualitative insights can be offered to explain differences or trends. For example, it is clear in Figure 4.7 that trucking appears to use significantly more energy per tonne-km than rail or water modes. However, freight movements by trucks vary widely from one country to another. The following qualitative explanation for this variability has been made:

> "Since the trucks are produced by large, international firms, difference between the figures shown cannot be very much attributed to actual differences in the energy efficiency of trucks. Instead the differences arise largely because of differences in fleet mix (between large, medium, and light trucks), differences in traffic, and above all differences in the capacity utilisation of each kind of truck [*Schipper et al*., 1997]. Heavy trucks, when fully loaded (say with 40 tonnes) use about one-eighth the fuel per tonne-km as a light delivery truck carrying 200 kg. In Germany, regulations limit empty hauling, while in Denmark or the Netherlands more than 40 percent of all truck km are empty. … Again it is changes in the loading and utilisation of trucks that affect the overall evolution of each country's freight modal intensity the most. These changes have explanations in the need for just-in-

> time deliveries, the rising value (as opposed to tonnage) of freight, and above all the importance of other costs besides those of fuel in determining the optimal use of trucks." [*Schipper and Marie-Lilliu*, 1999]

In general, light-duty trucking is significantly more energy intensive than heavy-duty trucking. This is supported by data presented in Table 4.6 that shows heavy-duty trucking to have energy intensities within the same range as rail. Variation in load and utilisation (capacity factor) and patterns of use will change the energy intensities of all modes of freight transportation, including international maritime shipping.

As shown in Table 4.6, marine-freight capacity factors vary significantly between about 50-75% on average. This represents either a market with full ships transiting in one direction and less-full ships returning (e.g., tramp shipping), or a market with predictable cargo volumes in both directions (e.g., liner shipping). When average ship cargo capacities begin to exceed 75% in a given market, freight rates begin to rise sharply and/or shipping traffic in that region increases [*Abrams*, 1997; *Corbett*, 1999; *Fairplay*, 1997; *Wilde Mathews*, 1998].

Figure 4.7 indicates that energy intensities for marine freight are the lowest of all modes of transportation (0.1 to 0.4 MJ/tonne-km). According to these statistics, only rail approaches these levels with 0.4 MJ/tonne-km.

In terms of environmental performance measures, the air emissions can also be calculated on a per-tonne-km basis in the same way as energy intensity is calculated. However, the energy content of a given fuel is generally more constant than emissions, which vary by engine type, fuel content, and most importantly imposed emissions controls. Table 4.7 presents a summary of emission factors from a number of sources, developed in several different countries. "Because of the variation in the initial test procedures in the algorithms used to develop overall emission factors, … it is not possible to determine whether the differences among these factors reflect actual differences among countries, or variations in the estimation method" [*OECD and Hecht*, 1997].

Air emissions vary substantially between mode and across air pollutants. For example, Table 4.7 suggests that marine transportation has the lowest CO_2 emissions, but that rail may have equal or better environmental performance for many other pollutants, including NOx. Moreover, it appears that the previous analyses summarised in Table 4.7 may have assumed that the marine sector is using a lower sulphur fuel than is typical in international shipping. The point is simply that one cannot tell from these summaries.

Table 4.6. Freight Data Excerpted from UNFCCC Working Paper No. 1, Appendix A. Table 21 [*OECD and Michaelis*, 1997][a]. (Actual energy intensities depend strongly on vehicle load factors and patterns of use.)

Mode	National Average Load Factors (tonne load per tonne capacity)	National Averages of Energy Intensity (MJ/tonne-km)
Average Road Freight	0.2 - 0.4	1.8 - 4.5
Heavy Trucks	0.6 - 1.1 [b]	0.6 - 1.0
Freight Trains	0.5 - 0.8	0.4 - 1.0
Marine Freight	0.5 - 0.75[c]	0.1 - 0.4
Air Freight	n.a.	7 - 15

a. Sources and notes cited in [*Michaelis*, 1996; *OECD and Michaelis*, 1997].

b. Load factors exceeding 1.0 indicate overloading.

c. Capacity factors for Marine Freight from [*Abrams*, 1997; *Corbett*, 1999; *Fairplay*, 1997; *Wilde Mathews*, 1998].

Table 4.7. Published Air Emission Factor Ranges for Truck, Rail, and Marine, in grams/tonne-km [*OECD and Hecht*, 1997]

Pollutant	Truck	Rail	Marine
CO	0.25 - 2.40	0.02 - 0.15	0.018 - 0.20
CO_2	127 - 451	41 - 102	30 - 40
HC	0.30 - 1.57	0.01 - 0.07	0.04 - 0.08
NO x	1.85 - 5.65	0.20 - 1.01	0.26 - 0.58
SO_2	0.10 - 0.43	0.07 - 0.18	0.02 - 0.05
Particulate	0.04 - 0.90	0.01 - 0.08	0.02 - 0.04
VOC	1.1	0.08	0.04 - 0.11

While generally useful, these comparisons do not provide a picture with sufficient resolution for water modes. For example, these comparisons do not identify how energy intensity or emissions differ between oil tankers and container ships. To identify explicitly the most important energy and environmental performance factors for international shipping, a Freight Transportation Model was developed. The conceptual framework is shown in Figure 4.8.

This idealised Freight Transportation Model defines an equal amount of cargo to be moved by each mode (ship, rail, and truck) across the same distance. It does not specify one type of cargo, but rather an equal tonnage of cargo that could be carried by each mode. By defining an equal tonnage of cargo and an equal distance, the tonne-km in the denominator are identical for all modes and all modes of freight transportation can be compared directly.

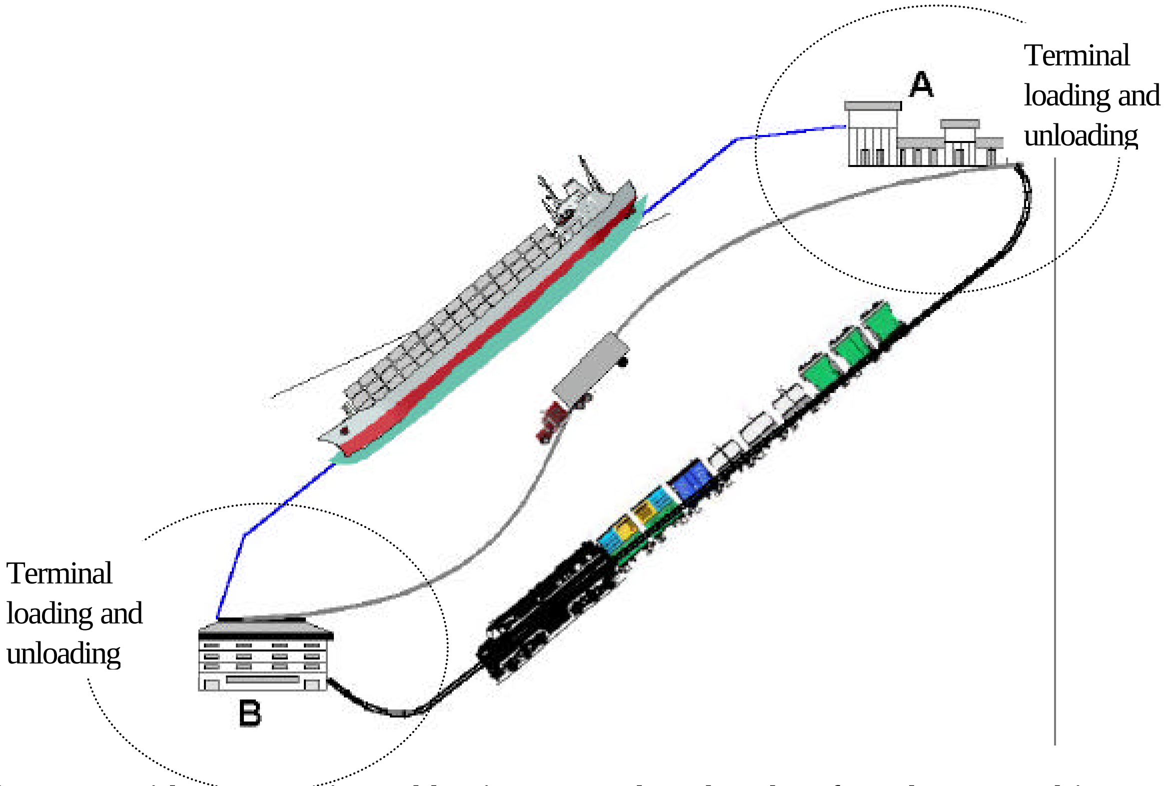


Figure 4.8. Freight Transportation Model Design Framework: Each Mode Performs the Same Work in One Year (Equal Tonnage Moved Equal Distance)

The Model estimates explicitly the energy-use and emissions during "open-ocean" or "highway" or "line-haul" transit, and estimates separately the average energy-use and emissions during manoeuvring, docking, and cargo transfer operations for each mode.

A4.2.2. Assumptions

Four types of ships are modelled: 1) oil tanker; 2) bulk carrier; 3) container; and 4) general cargo. This Model uses the same baseline characteristics assumed for the case-average ships presented in earlier chapters. For clarity, these are shown again in Table 4.8. Note that though these represent ships on main ocean-going routes, the power/speed relationships with DWT for smaller ships on coastal routes would be different.

Table 4.8. Baseline Characteristics for Case Ships

	Oil Tanker	Bulk Carrier	Container	General Cargo
DWT	275,000	70,000	36,500	12,700
Rated ME Power (kW)	23,800	10,500	21,900	5,200
Engine Type	Slow Speed	Slow Speed	Slow Speed	Medium Speed
Rated Speed (knots)	14	14	20	15

In addition to general ship characteristics, several assumptions are applied to the Model that do not vary across ship modes. Table 4.9 presents the fuel consumption rates for slow- and medium-speed engines, according to manufacturer data as reported by MARINTEK [*MARINTEK*, 1990; *MARINTEK*, 1999; *MARINTEK*, 2000], and for in-service vessels as measured by Lloyd's Register Engineering Services [*Carlton et al.*, 1995; *Lloyd's Register*, 1990; *Lloyd's Register*, 1993]. Because manufacturers generally reports lower fuel-consumption rates than observed for in-service vessels, this Model used the average of the manufacturer and Lloyd's data as shown in Table 4.9.

Table 4.9. Marine Engine Fuel Consumption Rate (Model calculations use average of Manufacturer and Lloyd's data.)

Fuel Consumption (g/kWh)	Slow Speed	Medium Speed
Manufacturer data	170	184
Lloyd's Register	230	243
Average	200	214

The Freight Transportation Model allows the distance between cargo movements (points A and B in Figure 4.8) to vary, but for baseline conditions a distance of 3,218 km (2,000 miles) was chosen. In the Model, 32.2 Million tonnes of cargo is moved by each mode in one year. This tonnage is arbitrary, but roughly represents the amount of cargo moved in a moderately large port annually. Lastly, the carbon content of petroleum fuels (distillate and residual) is nearly constant [*Flagan and Seinfeld*, 1988; *Heywood*, 1988; *Lloyd's Register*, 1990; *Taylor*, 1995], well within the uncertainty bounds of the IPCC emission factor for CO_2 [*Houghton et al.*, 1996] as discussed in Chapter 1. Therefore, the Model applies the same emission factor for CO_2 across all modes. Table 4.10 summarises these common assumptions.

Other assumptions are mode-specific. By setting the annual cargo movements by each mode equal, the Model includes an estimate of time and energy consumption associated with each "turn-around," i.e., terminal approach, cargo transfer, and departure. In this regard, each mode is unique. For example, the Model assumes mode-specific times for ship terminal loading/unloading that begin when the vessel passes the "arrival buoy" and end when the vessel passes the "departure buoy." For a truck, this would represent the period beginning when the vehicle leaves the highway to enter the surface-street traffic near the terminal and ending when the vehicle resumes highway driving. For rail, this represents the period off the main rail line and in the switchyard, while the engine is de-coupled and re-coupled to railcars.

During the period that a ship, train, or truck is in the turn-around phase, the Model assumes a reduced operating speed for each mode. In-port manoeuvring for ships is assumed to average 10 knots; truck and rail speeds are assumed to be 40 km/hr and 24 km/hr, respectively. These assumptions are presented in Table 4.11.

Table 4.10. Common Model Assumptions across Modes

Cargo Movement Distance	3,218 km (2,000 miles)
Cargo Total Movement	32.2 Million Tonnes
CO_2 (kg/tonne fuel)[a]	3,170

a. Fuel-carbon content is nearly equal (within 2%) for diesel fuel used in truck, rail, and marine engines and for residual fuel used in marine engines. Uncertainty reported in emission factor (refer to DNV chapter) exceeds variation between transportation modes.

Also shown in Table 4.11 are average capacity factors, mode-specific emissions rates for NOx, and typical fuel-sulphur contents. Capacity factors used in the Model are the average of the capacity-factor ranges presented in Table 4.6. NOx emissions rates for truck and for rail are from U.S. EPA data for in-service vehicles and trains [*EPA*, 1997a; *EPA*, 1997b; *EPA*, 1997c].

Table 4.11. Mode-specific Assumptions for Truck, Rail, and Case Ships

	Truck	Rail	Oil Tanker	Bulk Carrier	Container	General Cargo
Terminal Loading/Unloading Time (hrs per vehicle/ship)	2	8	36	48	24	36
Manoeuvring Speed[a]	40 km/h	24 km/h	10 knots	10 knots	10 knots	10 knots
Ave. Load Capacity Factor	.85[b]	.65[b]	.65[d]	.65[d]	.65[c]	.65[d]
NO_x (kg/tonne fuel)	33	81	87	87	87	57
Fuel Sulphur (% by weight)	0.03%	0.05%	2.7%	2.7%	2.7%	2.7%

a. Max speed for Truck and Rail modes used in Model equal 88 km/h and 80 km/h, respectively.
b. [*OECD and Michaelis*, 1997]
c. [*Abrams*, 1997; *Corbett*, 1999; *Fairplay*, 1997; *Wilde Mathews*, 1998].
d. Baseline calculations used the same capacity factor as for container shipping

The emission factors used are for in-service engines. However, truck and rail emissions in the U.S. may be lower than emissions for these modes in less regulated countries, which could result in lower Model predictions for these modes. NOx emissions rates for ships are from Lloyd's Register Engineering Services, which measured in-service marine engines on ocean-going ships [*Carlton et al.*, 1995; *Lloyd's Register*, 1990; *Lloyd's Register*, 1993]. Fuel-sulphur contents for typical distillate diesel fuels were used for truck and rail, and average fuel-sulphur contents for residual fuels were used for ships.

To estimate typical fuel consumption for each ship during transit periods, the Model applied the E3 duty cycle, 75% rated power conditions and 91% rated speed conditions, which represents typical cruise speeds [*IMO*, 1998; *ISO*, 1996; *Markle and Brown*, 1996]. During manoeuvring periods, the general speed and power equation [*Laurence*, 1984] was applied to the estimate fuel consumption at lower speeds, where N = vessel speed and P = vessel power according to the following relationship:

$$\left(\frac{N_{Manoevring}}{N_{Cruise}}\right)^3 = \left(\frac{P_{Manoevring}}{P_{Cruise}}\right)$$

Equation 1

The sensitivity of the Model to input assumptions was quantified by allowing the emissions factors, fuel-sulphur content, and speed-power relationship to vary for each ship type. Emissions factor and fuel-sulphur variability were taken from the Annex Emissions Factors [*MARINTEK*, 2000]. However, as shown in Chapter 3 (MARINTEK short-term considerations chapter, Figure 1), the speed and power relationships also vary for a given size and type of vessel. The ranges and correlation for speed and power for each case ship were taken from international ship registry data [*LMIS*, 1996]. Speed-power relationship assumptions used for sensitivity analysis are presented in Table 4.12.

Table 4.12. Variability in Power and Speed Assumptions for Case Ships Taken from Actual Fleet Data for Vessels with the Same DWT as Case Ships

	Oil tanker	Bulk carrier	Container	General Cargo
ME Power (kW)	14,500 – 53,700	6,400 – 15,200	11,900 – 63,100	1,500 – 17,800
Speed (knots)	12 -17	12 - 15	16 - 27	9 - 20
Speed/Power Correlation[a]	0.49	0.47	0.92	0.73

a. Correlations were derived from actual data reported in Lloyd's Registry of Ships [*LMIS*, 1996].

A4.2.3. Freight Transportation Model Calculations and Validation

The Model calculations (see Table 4.13) begin by estimating the cargo that can be carried on each case ship (or truck or train). Because DWT describes more than the cargo carrying capacity of a ship, the DWT reported in Lloyds was multiplied by 80% to obtain an estimate of the maximum cargo tons that could be carried; this is consistent with typical voyage estimating factors [*Packard*, 1991]. This value was multiplied by the capacity factor.

Rated vessel speed and the Model distance of 3,218 km (1,739 nautical miles or 2,000 miles) were used to estimate transit times. The slower average manoeuvring speed of 10 knots was applied during the assumed turn-around time in port. From this information, the number of hours per trip, annual number of trips per vessel, and number of ships required to move the total cargo in one year were calculated.

Engine power at cruising speed was used to estimate average daily fuel consumption during transit. Daily fuel-use during manoeuvring into and out of port regions was estimated by applying Equation 1 to the speed ratio of transit and in-port speeds. Total fuel consumed per trip was estimated by multiplying the daily fuel consumption for transit and turn-around periods by the amount of time spent underway and manoeuvring, respectively. The entire E3 duty cycle was not used in these calculations because turn-around performance was modeled separately. Similar procedures were used for rail and truck.

By multiplying the fuel consumed each trip by the annual number of trips per ship and by the number of ships required, the Model estimates the annual fuel consumption required to move the total cargo tonnage. Total fuel use divided by the total cargo moved results in an estimate of the annual energy intensity, measured as fuel use per ktonne cargo. From this value, conversions can be applied to estimate energy intensity in MJ per ktonne cargo, or to estimate emissions per ktonne cargo.

Figure 4.9 presents the Model results for energy intensity by mode. In general, the Freight Transportation Model reproduces the published energy intensities in Table 4.6. In the Model, energy intensity for heavy-duty trucking can vary between 0.6 and 1.0 MJ/tonne-km, which agrees closely with published data. For rail, the model predicts slightly better performance than in Table 4.6, with energy intensities ranging from 0.26 to 0.6 MJ/tonne-km. Case-average container and general cargo ships have energy intensities between 0.2 and 0.5 MJ/tonne-km, which closely match published data; however, case-average bulk carriers and oil tankers perform significantly better, with energy intensities less than 0.25 MJ/tonne-km. This result suggests that the Freight Transportation Model is generally valid, given the many assumptions listed previously.

Moreover, the Model has the ability to quantify the effect of changing input parameters and assumptions. For example, Figure 4.9 shows that energy intensities for each mode vary with distance, where the same cargo moved over shorter distance results in higher energy intensity per tonne-km. This is a result of the greater effect of energy consumed by the vessel (or vehicle or train) during turn-around on the total energy intensity at shorter distances. However, at distances greater than about 500 km, the curves appear more linear. Other results quantifying Model insights are discussed in Section 5.3.

Table 4.13. Example Calculations for Oil Tanker Case Ship

Per-ship Cargo Estimates	
32,200,000	total tonnes moved
275,000	DWT
220,000	tonnes cargo per ship
0.65	capacity factor
Speed and Time, Trip Number, Ship Number Calculations	
14	rated speed knots
13	cruise speed knots
10	in port knots
1,739	nautical miles distance
137	hrs/trip underway
36	hrs/turn around
173	hrs/trip total
51	trips/yr/ship
4.4	ships/yr
Engine Power and Fuel Use Calculations	
23,800	ME Power (kW)
31,916	ME Power (hp)
89	tpd fuel (cruise load)
43	tpd (in port)
568	tonnes fuel/trip (total)
Energy Intensity and Emissions Performance Calculations	
127,908	tons of fuel to move all cargo
3.97	tons fuel per ktonne cargo

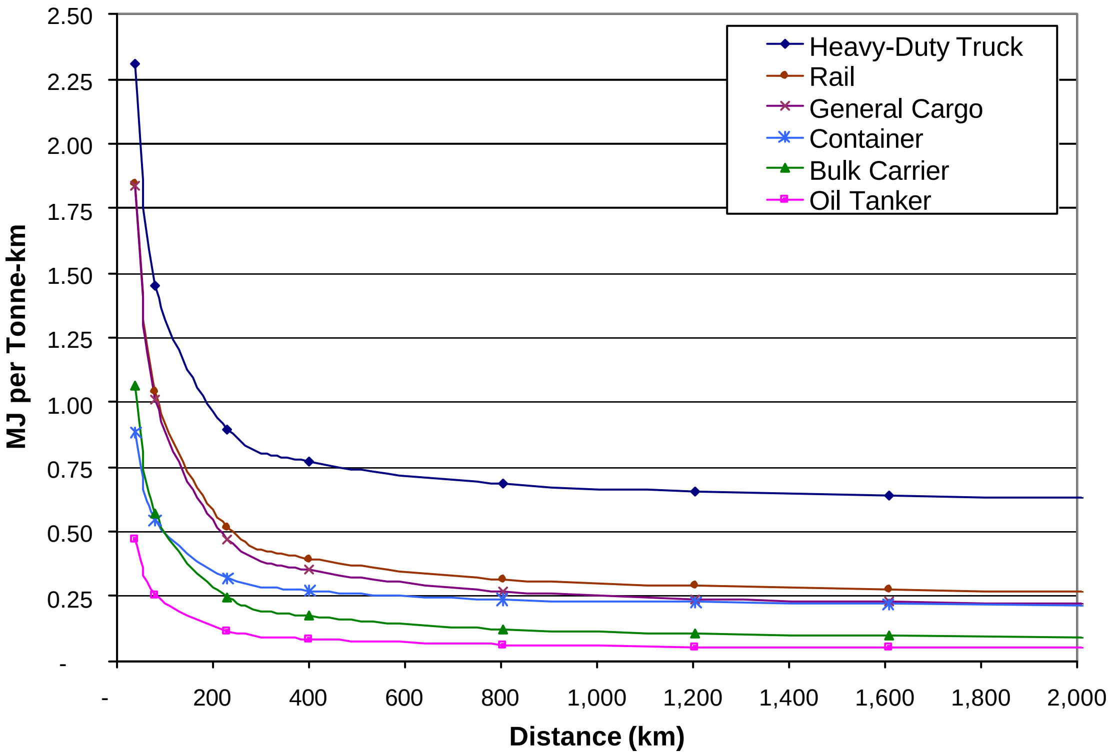


Figure 4.9. Change in Modal Energy Intensity with Variation in Distance Traveled (Model Run with Average Capacity Factor for All Modes)

A4.2.4. Modal Comparisons by Energy Use and Emissions

The Freight Transportation Model can be used to compare modes while varying important input parameters such as capacity factor. Figure 4.10 shows that capacity factor has significant effect on the fuel consumption per ktonne cargo, and that the effect is greatest for trucks. This confirms the qualitative insights from previous analyses about the importance of capacity factor, presented in Section 5.1. Using average capacity factors, trucks consume more than twice as much fuel per ktonne as rail. (All model runs presented in this section use a cargo transportation distance of 3,218 km. The effect of changing transportation distance is discussed in Section 5.4.)

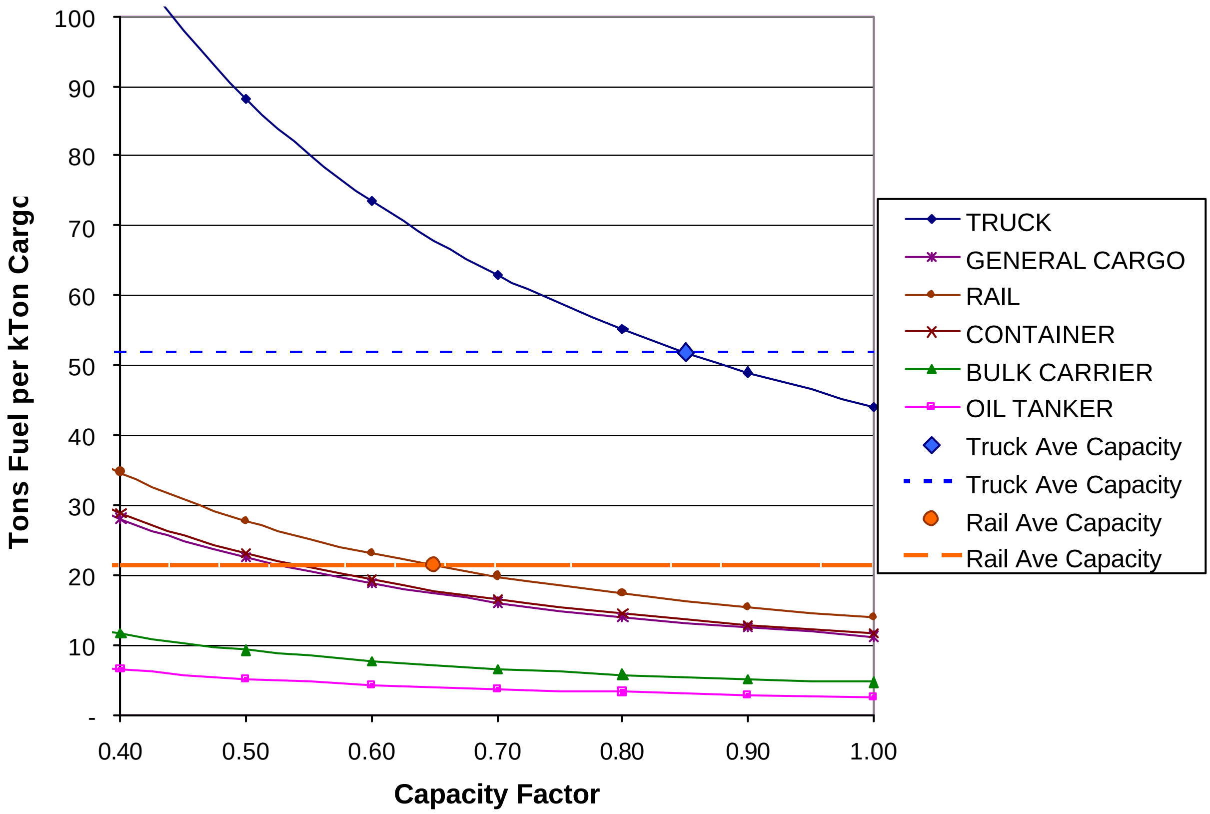


Figure 4.10. Fuel Consumption by Freight Transportation Mode as a Function of Capacity Factor

Figure 4.11 presents similar results for CO_2 emissions per ktonne cargo, including error bars representing the variability introduced by including different speed and power combinations. Three important points should be noted. First, even with error bars the truck mode produces the highest CO_2 emissions per ktonne cargo. Second, rail does not always perform significantly worse than ships, if different speed and power relationships are used for ships of the same type and size as the case-average container and general cargo ships. Third, bulk carriers and oil tankers in the case-average size ranges do perform significantly better than other ships, rail and truck.

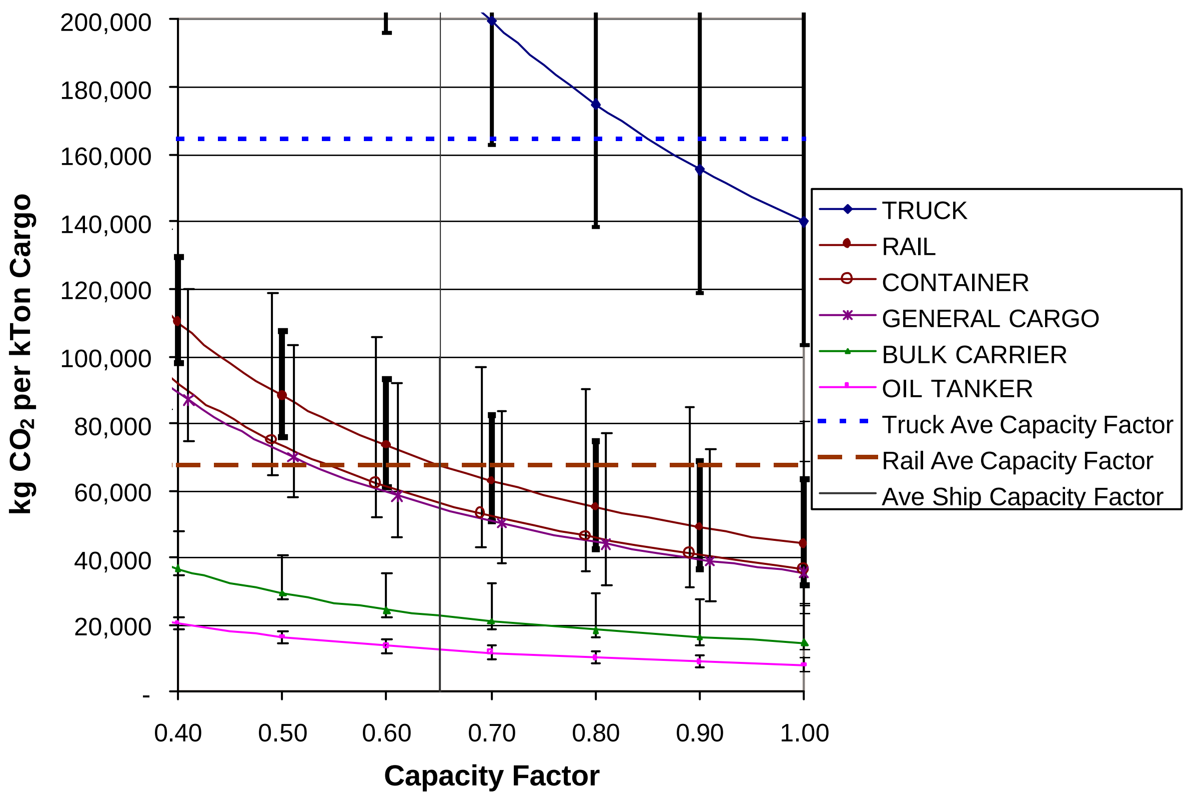


Figure 4.11. CO_2 Emissions Varied by Capacity Factor (with 5th and 95th percentile effects of variability shown)

When other pollutants are considered, the results can be different. NOx comparisons varied by capacity factor are presented in Figure 4.12. Ships still perform better than truck or rail modes, but this difference is not always large. Because significant NOx controls have been required for trucks, their NOx performance improves relative to the other modes. Additionally, more fuel-efficient diesel engines in rail and marine applications tend to operate at higher temperatures and pressures than truck engines, and therefore produce more NOx for the same power. Most interestingly, under average truck and rail capacity factors (85% for truck and 65% for rail), the NOx performance of these modes is nearly identical.

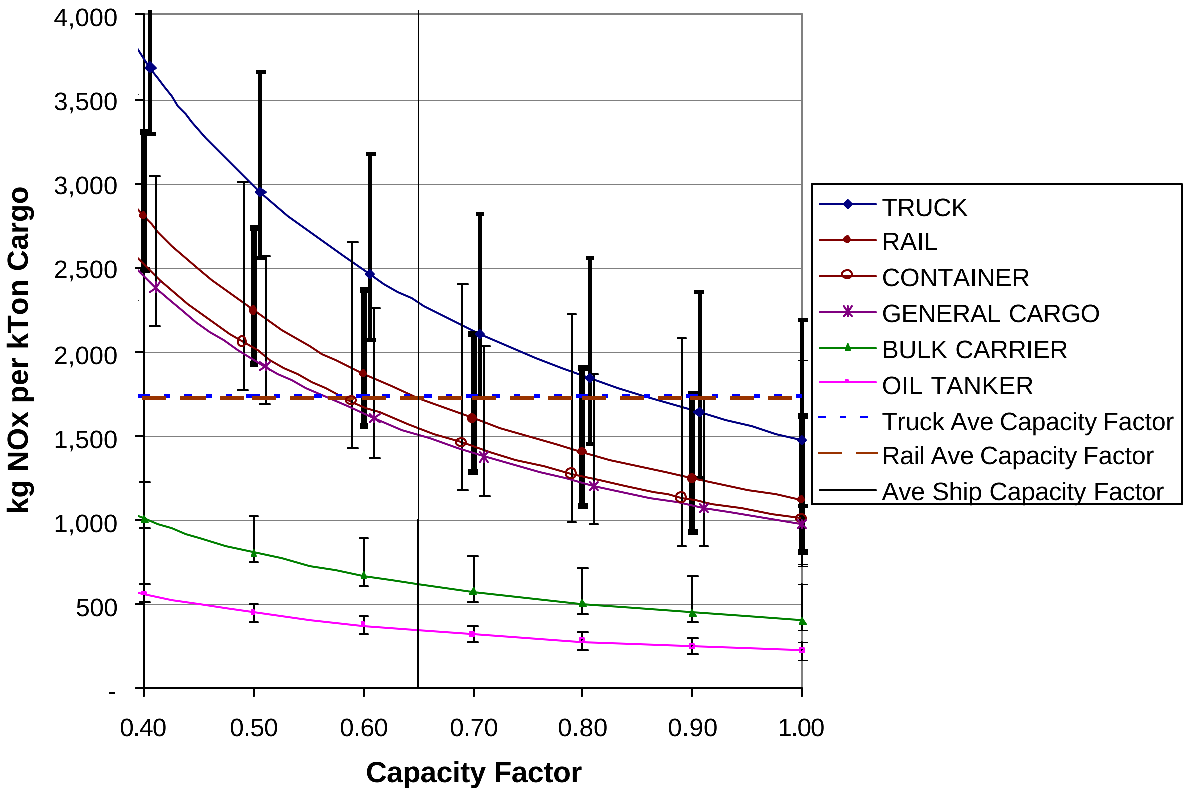


Figure 4.12. NOx Emissions Varied by Capacity Factor (with 5th and 95th percentile effects of variability shown)

Emissions differences between the modes are most noticeable for SOx (Figure 4.13). The fuel-sulphur contents for marine bunkers are much greater than distillate diesel fuels used by truck and rail modes. This results in SOx emissions per ktonne cargo that can be 6 to 26 times higher for ships than for land-based modes.

In summary, capacity-factor differences between the modes are significant, but modal differences between pollutants are much larger. The effects of changing capacity factors are not at all similar across pollutants. This is primarily due to modal differences in emission control, engine design, and fuel specifications. Under baseline model conditions, the CO_2 performance by ships is clearly better than other modes of freight transportation.

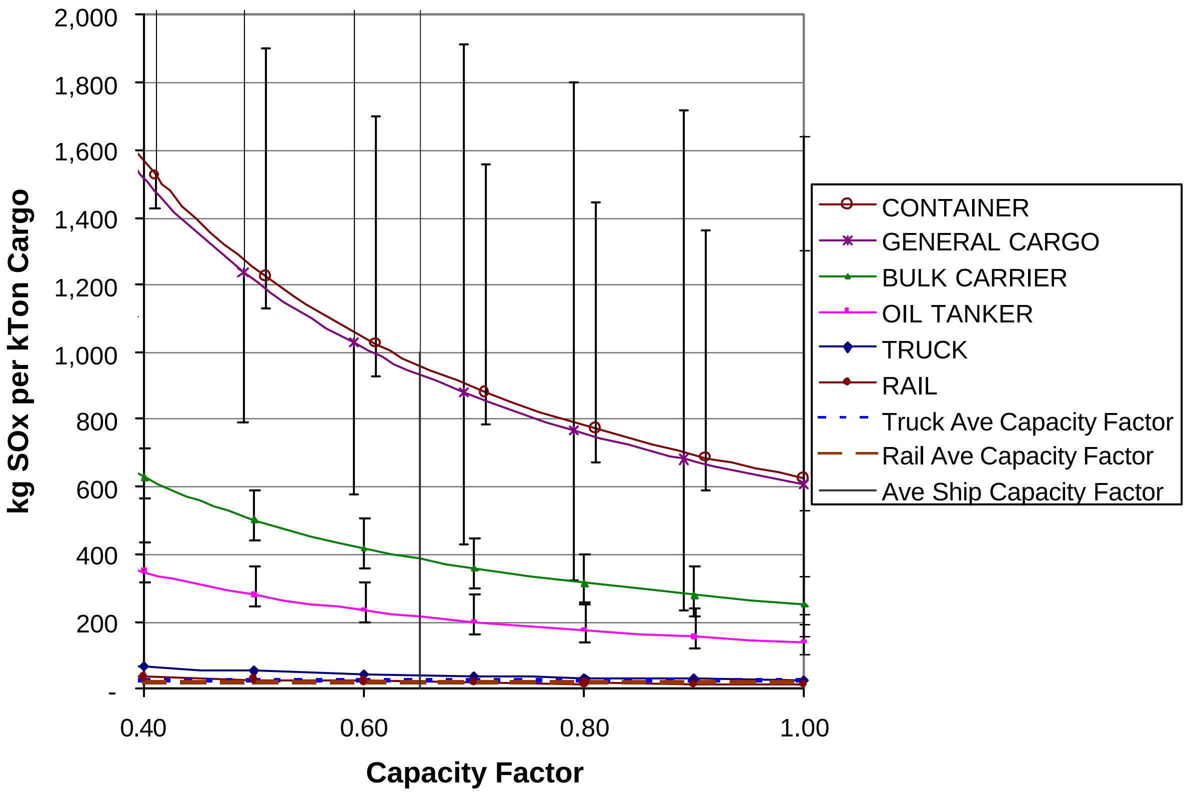


Figure 4.13. SOx Emissions Varied by Capacity Factor (with 5th and 95th percentile effects of variability shown, dominated by fuel-sulfur content)

A4.2.5. Sensitivity of Turn-Around Time

One important input assumption is the turn-around time, because the corresponding energy use during this period can account for 4% to 15% of total energy use per trip for ships under baseline model assumptions. Reducing turn-around time – or at least minimising the energy used by ships during turn-around time – can reduce total energy and emissions intensities in two different ways. The reduced turn-around time per ship can result in more trips per ship per year, thus requiring fewer ships to perform the work. Alternatively, reduced turn-around time can be used to make transit-speed adjustments that maintain constant trip duration; this results in reduced power with the same number of ships performing the cargo movements. Each of these is discussed below.

Figure 4.14 presents the direct effect of reducing turn-around time for each mode, including truck and rail. A 25% reduction in turn-around time can reduce CO_2 emissions by 1% to 4%, depending on the mode. In general, when turn-around times are a larger fraction of total energy use for each trip, reducing turn-around times has a larger effect in reducing CO_2 emissions. (It should be noted that reduced turn-around times also reduce other emissions and improve overall energy performance.)

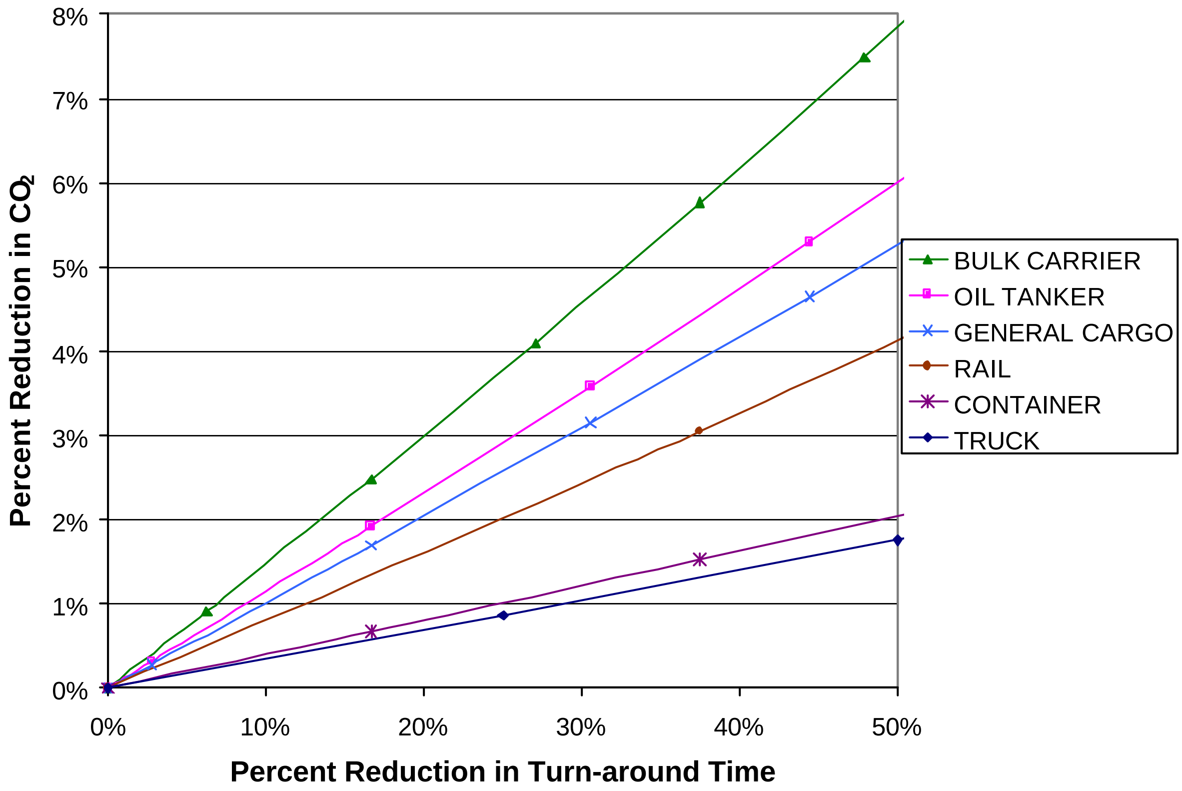


Figure 4.14. Percent Fuel Consumption Variability with Terminal Turn-Around Time (Assuming Full Rated Transit Speed -- fewer ships required)

On the other hand, using these reductions to adjust transit speeds can provide additional reductions in energy use, CO_2 emissions, and emissions of other pollutants. Figure 4.15 shows that given the baseline assumptions, a container ship can reduce transit speed by approximately 1 knot over a 3,218 km (2,000 mile) transit with a 6 hour (25%) reduction in turn-around time. The potential for turn-around time adjustments to reduce transit speed is greatest for faster vessels. For the case-average general cargo ship, the same reduction in turn-around time for the same 3,218 km transit allows for less than 1 knot speed reduction, and for the case-average tanker and bulk carrier the speed reduction is about 0.5 knots.

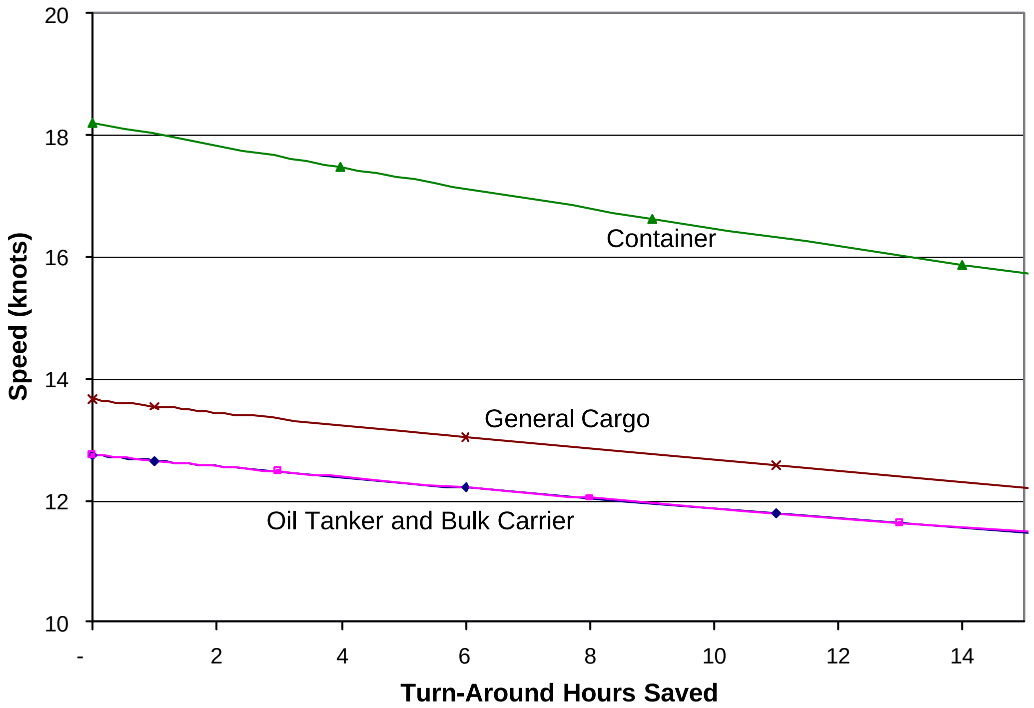


Figure 4.15. Speed Adjustment Potential to Maintain Constant Total Trip Time with Reduced Turn-Around Time for Baseline Scenario Distance of 3,218 km (2,000 miles)

The Freight Transit Model shows that these relatively small reductions in speed afforded by improved turn-around times have the potential to reduce emissions. Figure 4.16 compares the percent CO_2 reduction that results from reducing the required number of trips and ships with the percent CO_2 reduction from transit speed adjustments. While reducing turn-around time alone provides a modest reduction in emissions, additional reductions can be achieved by using these gains to reduce energy and emissions during transit. Under baseline model conditions, a 25% reduction in turn-around time with speed control can reduce CO_2 emissions by 14% to 17%, depending on ship type.

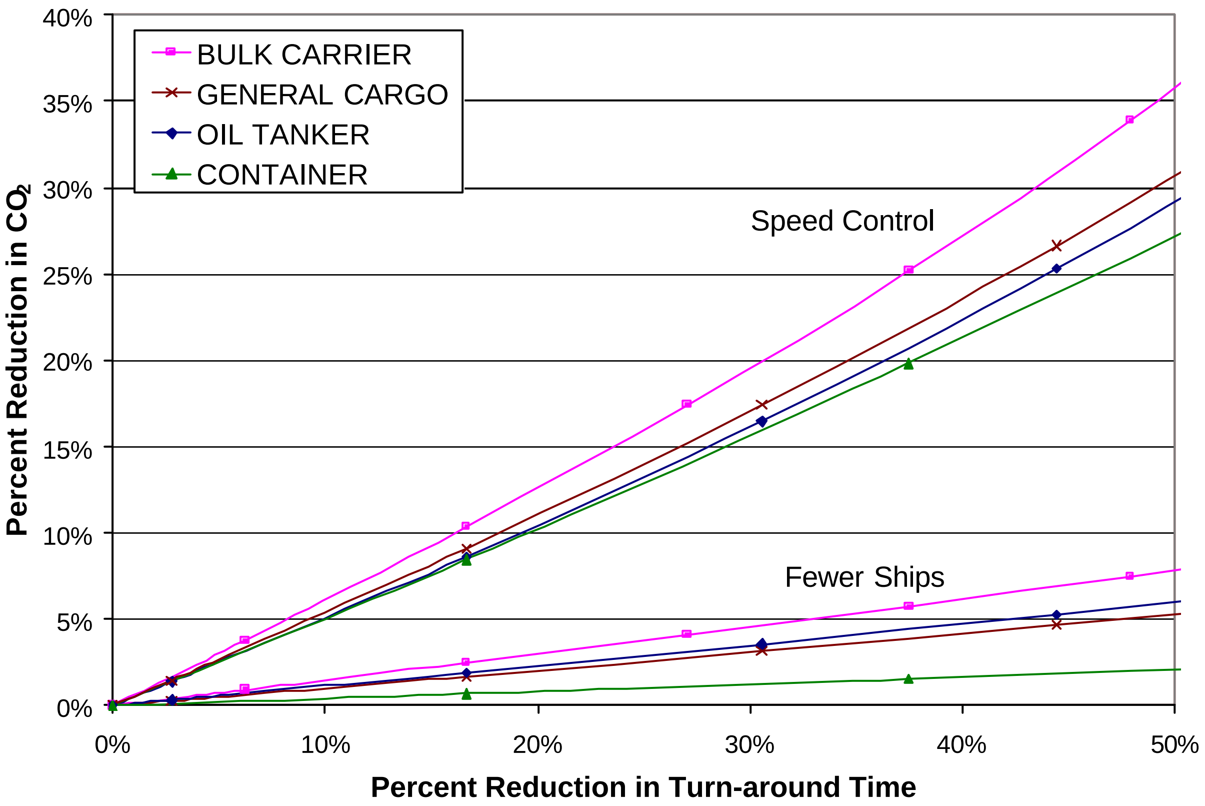


Figure 4.16. Comparison of Percent Fuel Consumption Variability with Terminal Turn-Around Time for Scenarios With and Without Open-Water Transit Speed Reduction

These results would be different under different model scenarios. Particularly, the transit distance has a significant effect on how much speed reduction can be achieved for a given reduction in turn-around time. To illustrate this, Figure 4.17 presents the same calculation for transit-speed reduction for three different distances. The baseline distance used in the model is 3,218 km (2,000 miles). For a distance of 805 km (500 miles), the same reduction in turn-around time can afford a much greater reduction in transit speed, because the turn-around time is a larger fraction of the total trip time. For a distance of 8,045 km (5,000 miles), the effect of reduced turn-around time on transit speed is much less.

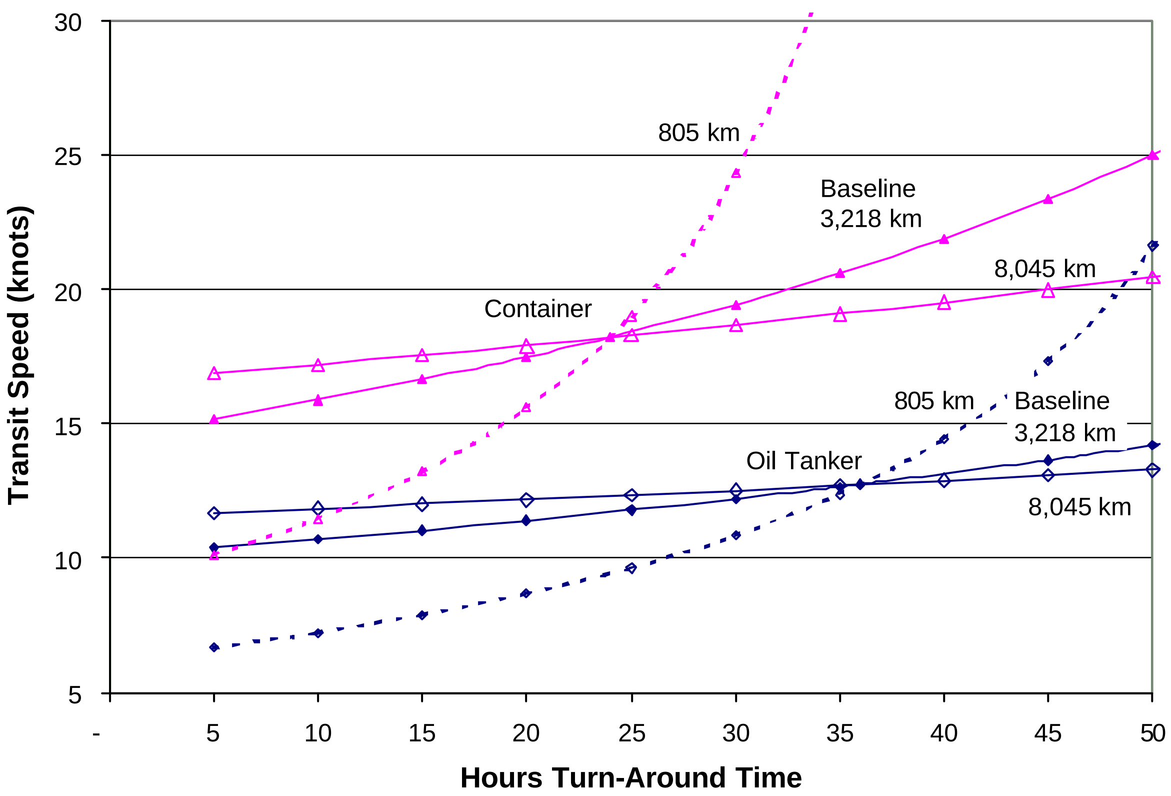


Figure 4.17. Sensitivity of Transit Distance on Speed Adjustment to Maintain Constant Trip Time (Baseline Scenario is 3,218 km)

As demonstrated, the turn-around time and resulting energy consumption are important factors in the overall energy and environmental performance of each mode. While the Model uses reasonable values for each mode, these may vary from port to port. Moreover, vessels different than case-average ships (e.g., mega-container ships or smaller coastal tankers) could require significantly different turn-around times than assumed here. Lastly, the average manoeuvring speeds during turn-around (terminal approach, docking and cargo transfer, and departure) vary from port to port, resulting in different energy and emissions performance even if the turn-around times are comparable. These regionally variable factors can be investigated with this Model.

A4.2.6. Potential for Parity in Emissions Across Modes

The Freight Transportation Model can be used to consider how large the changes in energy and emissions reductions would have to be for the modes to achieve equal performance. Using the best performing mode (case-average oil tanker) at baseline model conditions as a benchmark, Table 4.14 shows that very substantial reductions are required for rail and truck, as well as other types of ships in order to achieve emissions parity. However, this comparison may not be a fair one since wet and dry bulk cargoes do not tend to compete directly with trucks (and compete to a lesser extent with rail). Considering only the modes that can carry general or intermodal cargoes in Table 4.15, energy and CO_2 reductions of 25% and 69% are required for truck and rail, respectively, to achieve parity with general cargo ships. A 20% improvement in NOx performance would be required for these modes to achieve parity, under baseline assumptions (e.g., equal distance).

Table 4.14. Comparison of Values of Fuel Consumption, CO_2, and NOx (and the Percent Change to Equal Oil Tanker) at Average Capacity Factors and Equal Distance

	Tonne Fuel per kTon Cargo		kg CO_2 per kTon Cargo		kg NOx per kTon Cargo	
Oil Tanker	4	(0%)	11,693	(0%)	321	(0%)
Bulk Carrier	7	(-44%)	21,030	(-44%)	577	(-44%)
General Cargo	16	(-77%)	50,517	(-77%)	1,386	(-77%)
Container	17	(-78%)	52,799	(-78%)	1,449	(-78%)
Rail	21	(-83%)	67,712	(-83%)	1,724	(-81%)
Truck	52	(-93%)	164,514	(-93%)	1,735	(-82%)

Table 4.15. Comparison of Values of Fuel Consumption, CO_2, and NOx (and the Percent Change to Equal General Cargo Ship) at Average Capacity Factors and Equal Distance

	Tonne Fuel per kTon Cargo		kg CO_2 per kTon Cargo		kg NOx per kTon Cargo	
General Cargo	16	(0%)	50,517	(0%)	1,386	(0%)
Container	17	(-3%)	52,799	(-3%)	1,449	(-4%)
Rail	21	(-25%)	67,712	(-25%)	1,724	(-20%)
Truck	52	(-69%)	164,514	(-69%)	1,735	(-20%)

A4.2.7. Implications for Fleet and Terminal Development for Marine Transportation System

The Freight Transportation Model results show that the marine transportation system is an integral part of the overall freight transportation function not only in terms of economic measures, but also using energy and environmental performance measures. However, trucks are heavily used in national freight transportation, and often move most of the tonne-km of cargo [*ECMT*, 2000; *DOT*, 1996; *DOT*, 1999]. Moreover, as shown in Table 4.16, at least in the United States [*DOT*, 1996; *DOT*, 1999], the average miles per shipment for trucking is low (144 miles – convert to km), while rail and deep draft vessels move cargo across much larger distances (769 miles and 1,024 miles, respectively). Nearly 90% of the tonne-km of cargo shipments are by single modes. In the U.S., multiple-mode transits move cargo over distances that exceed those travelled by deep draft vessels alone, indicating that the separate modes are used together to cover the longest distances.

This suggests that freight transportation requires a systems approach, in which cargo is moved by each of the modes according to multiple considerations that include cost, timeliness of delivery, energy intensity, and environmental performance. For example, an obvious system improvement would be to optimise capacity factors while minimising deadhead routes for all modes, barring other trade-offs or changes in cost, time, etc.

Table 4.16. Average Distance Cargo Moves by Mode in the United States (CFS, 1997)

Mode	Average kilometers per shipment
Truck	232
Rail	1,237
Water Shallow Draft	285
Water Great Lakes	328
Water Deep Draft	1,648
Truck and Rail	2,167
Truck and Water	2,035
Rail and Water	1,757

When multiple modes can serve the same points, it is unlikely that water routes are the most direct. The Model can investigate the effect of different and unequal cargo transportation distances on the overall system performance as well. Figure 4.18 illustrates how the modal fuel consumption compares when the distances change. Ships perform generally better than truck or rail, and wet and dry bulk cargoes perform best across all but the shortest distances.

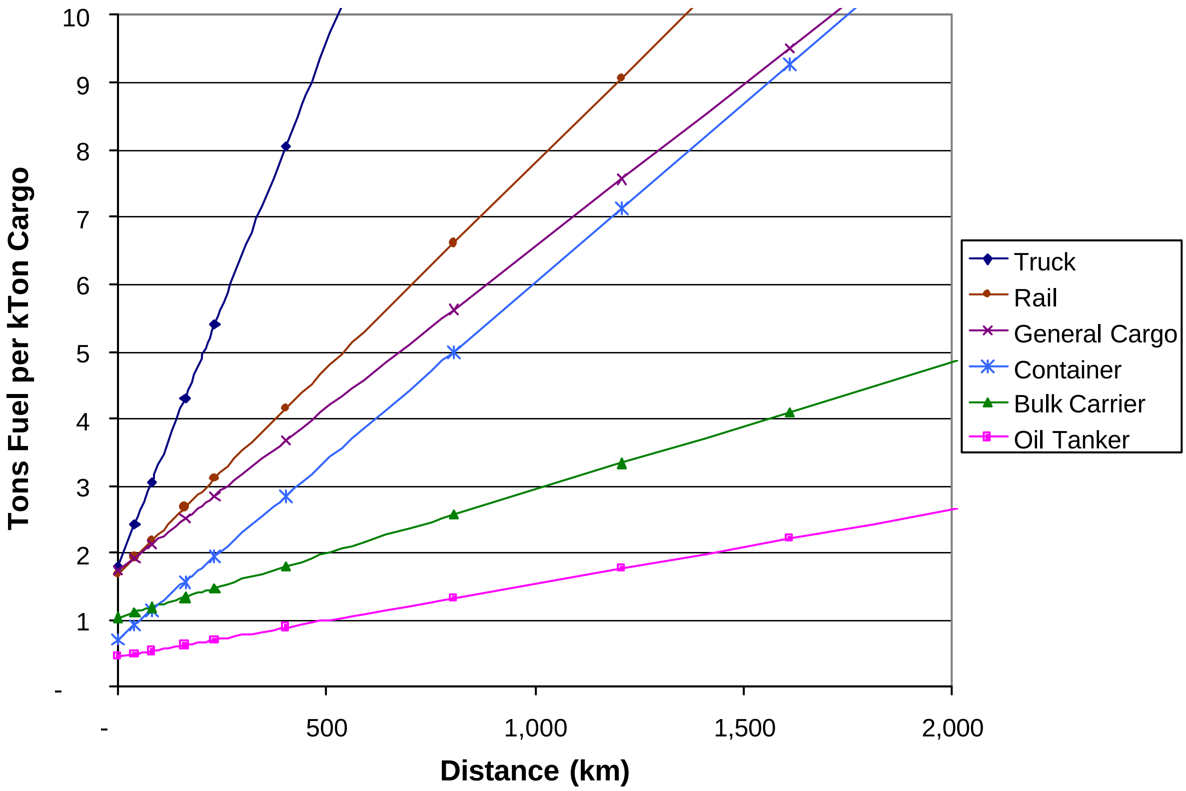


Figure 4.18. Modal Fuel Consumption with Variation in Distance Traveled (Model Run with Average Capacity Factors for All Modes and Constant Turn-Around Time)

For a given cargo that might be carried by truck, rail, general cargo, or container ship, modal comparisons can be made at different cargo movement distances. (In this analysis, wet and dry bulk carriers are shown in the following figures, but not included in the comparisons discussed.) For example, Figure 4.19 shows that container ships are the lowest-CO_2 mode to move cargo over an average truck shipment distance of 232 km, outperforming trucks on their typical shipment distances. However, Figure 4.20 shows that trucks and containers produce similar rates of NOx per ktonne cargo moved at 232 km (containers still perform slightly better). At the average shipping distance for rail (1,237 km), water modes produce the lowest emissions for both CO_2 and NOx.

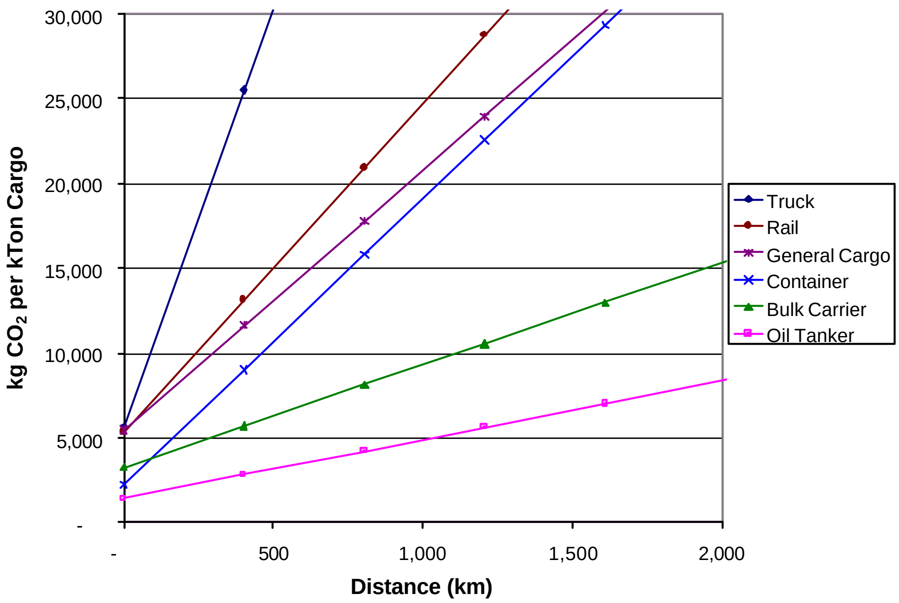


Figure 4.19. Modal CO_2 Emissions with Variation in Distance Traveled (Model Run with Average Capacity Factors for All Modes and Constant Turn-Around Time)

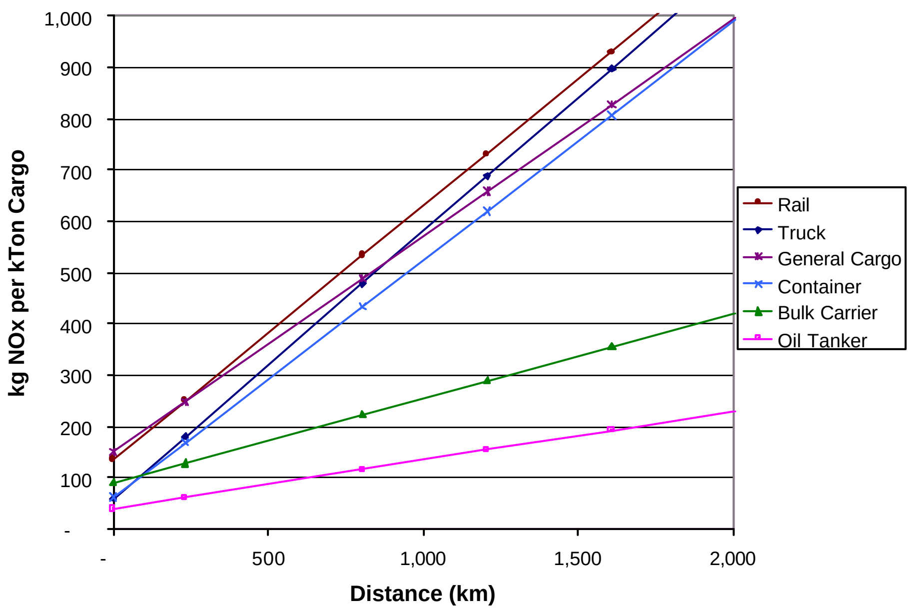


Figure 4.20. Modal NOx Emissions with Variation in Distance Traveled (Model Run with Average Capacity Factors for All Modes and Constant Turn-Around Time)

Another way to make these comparisons is to consider the relative distances that ships can move cargo without increasing the total emissions. Using Figure 4.19, at 15,000 kg CO_2 per ktonne cargo, trucks can move cargo some 200 km while rail can move the same cargo about 500 km (2.5 times as far). General cargo and container ships can move cargo 650 km and

750 km, respectively without increasing CO_2 emissions. This means that the water route can be more than three times longer than the road route for the same CO_2 emissions per ktonne cargo.

NOx emissions per ktonne cargo over different distances vary less by mode (Figure 4.20). However, it is important to acknowledge that uncontrolled emission factors are used for ships while truck NOx emissions reflect years of aggressive pollution regulation. This points to the potential for ships to improve their NOx emissions performance relative to the other modes, through international efforts such as IMO Annex VI [*IMO*, 1998].

A4.2.8. International Cargo Shipment Comparisons by Tonnage and Mode

Of course, modes are selected by shippers for economic reasons – primarily cost and timeliness of shipment. While water transit is the least costly mode of freight movement, trucks in most industrialised nations have increased their share of cargo transportation over the past decade [*ECMT*, 2000; *DOT*, 1996; *DOT*, 1999]. This is illustrated by the modal share time series shown in Figure 4.21 for a) member countries of the European Conference of Ministers of Transport and b) the United States. Figure 4.22 shows the same information for Central and Eastern European countries. International shipping may not be properly reflected in these national statistics, but it is clear that preferences for high-frequency, lower-volume cargo movements favour truck modes in industrialised nations. In order to improve the environmental performance of the freight transportation system, transportation and environmental policy makers could consider maximising the potential for water modes to become economically preferred where feasible through national and international transportation development.

International maritime transportation of trade moves cargo more than 13.3 Trillion tonne-km (or 21.4 Trillion tonne-miles) annually [*OECD and (MTC)*, 1999]. As shown in Figure 4.23, this represents more than 4.5 times as many tonne-km than cargo movements in the United States and Europe combined [*ECMT*, 2000; *OECD and (MTC)*, 1999, DOT, 1999].

A4.2.9. Summary

Clearly, the importance of international maritime transportation to global trade is undisputed, particularly for bulk commodities and raw materials. Even for general and containerised cargoes (assumed to be accounted for in the “other” category in Figure 4.23), the tonne-km of cargo moved annually by international shipping exceed the combined total for the United States and Europe. However, this modal analysis demonstrates that international shipping represents one part of a global transportation system in which other modes (truck and rail) are more often partners than competitors.

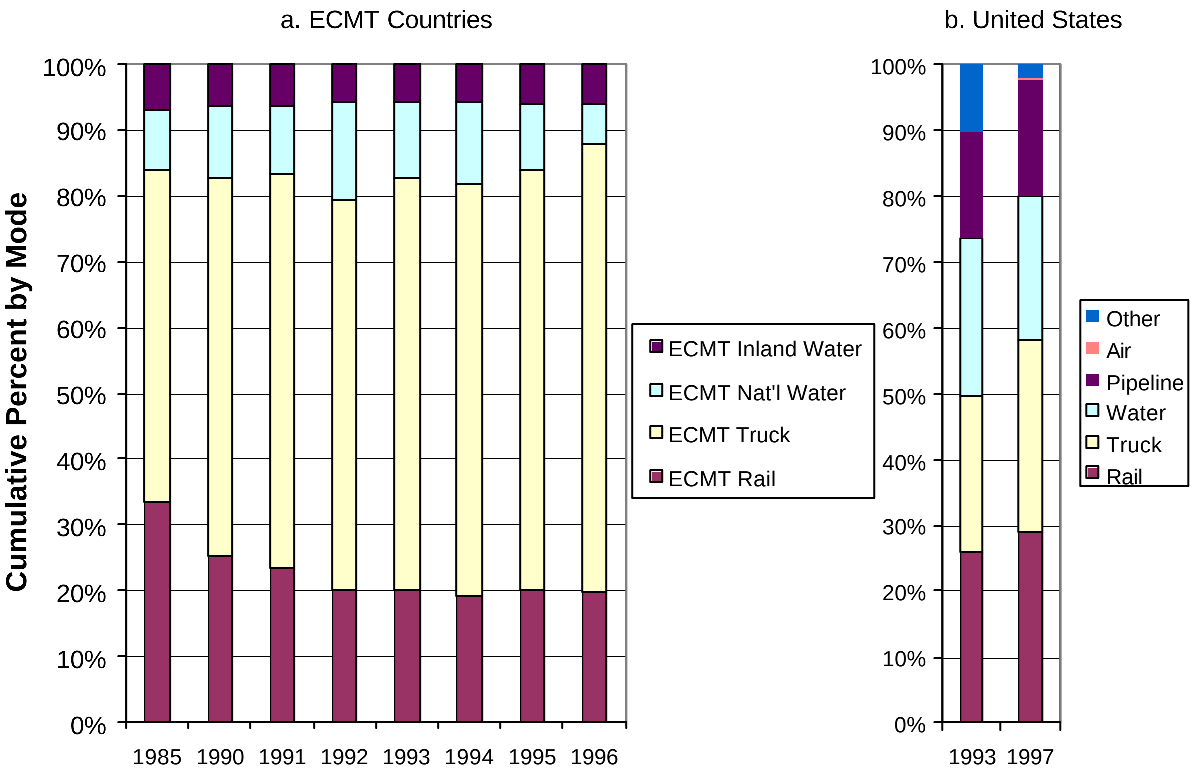


Figure 4.21. Modal Share of Freight Transportation in a) ECMT Countries [*ECMT*, 2000] and b) the United States [*DOT*, 1996; *DOT*, 1999]

Using the Freight Transportation Model presented in this analysis, a modal comparison of energy and environmental performance was made. Ships generally compare well with other modes of freight transportation, but these comparisons vary significantly by type of pollutant. Moreover, the fuel consumption rates and emissions from ships are different for different types of ships. Wet and dry bulk carriers, which are larger and generally slower, perform better than general cargo and container ships. Rail and truck modes differ in terms of energy intensity and CO_2 emissions, but their NOx emissions at average capacity factors are nearly identical. Optimising capacity factors and reducing average turn-around times by improving manoeuvring and cargo handling operations, can provide significant reductions in energy intensity and emissions. These improvements apply to all modes, but the potential may be greatest for ships.

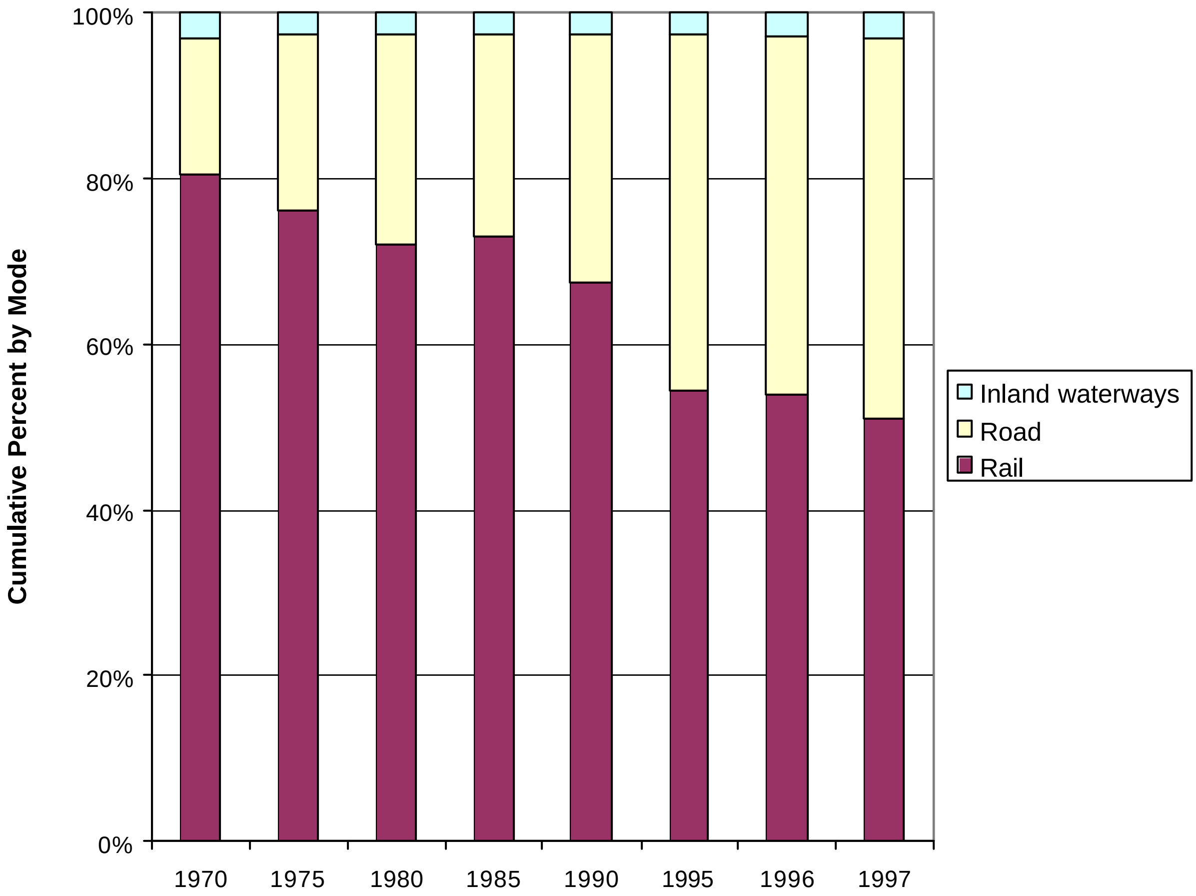


Figure 4.22. Central and Eastern European Countries (CEECS) Modal Shares 1970-1997 [*ECMT*, 1999]

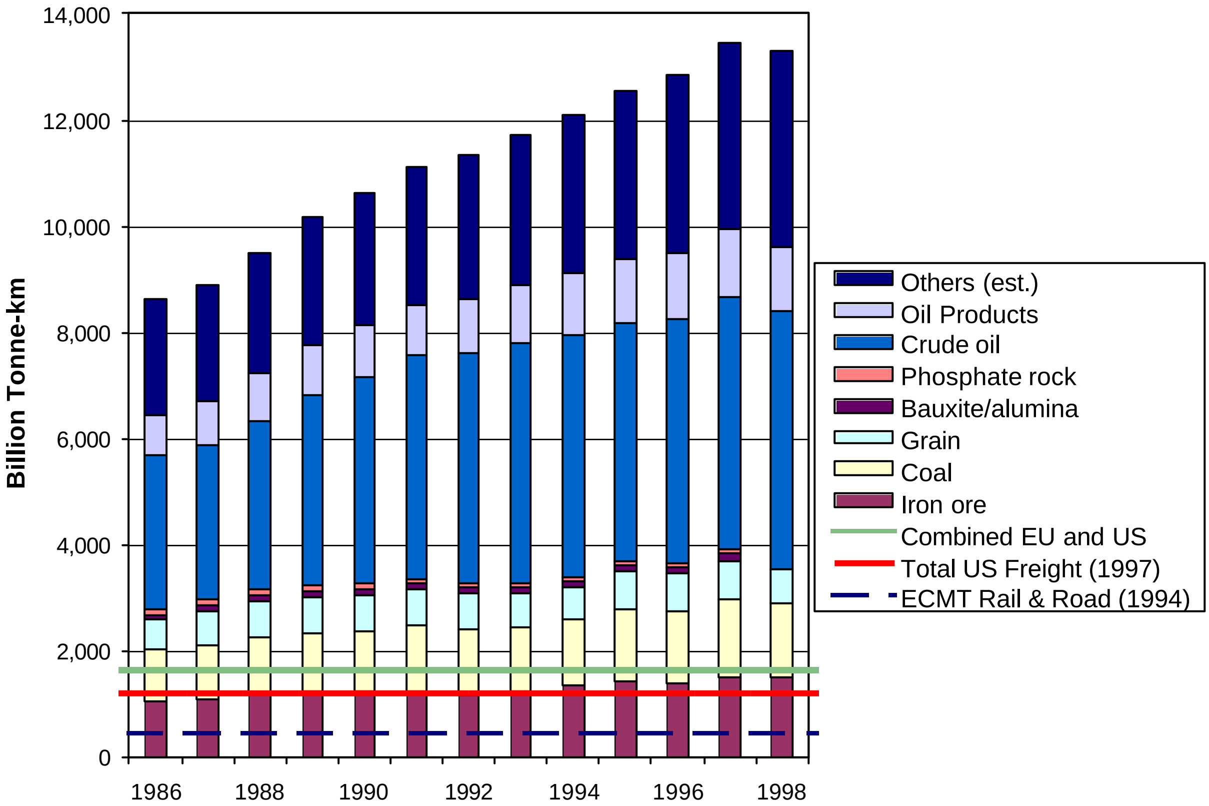


Figure 4.23. Tonne-Miles of Freight Moved by International Shipping With Comparisons to U.S. and ECMT Freight Movements [*ECMT*, 2000; *OECD and (MTC)*, 1999, DOT, 1999]

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A5. International Conventions and Amendments

A5.1. International Convention for the Safety of Life at Sea (SOLAS)

SOLAS cover a wide range of measures designed to improve the safety of shipping and was first adopted in 1914 following the loss of the S/S Titanic. The second and third editions were adopted in 1929 and 1948 respectively.

In order to keep pace with the change and technological developments of the shipping industry, the Convention has undergone continuos upgrading and renewal by the adoption of Amendments.

A completely new Convention was adopted in 1974 including all Amendments as agreed upon and in addition a new Amendment procedure designed to ensure that changes could be made within a specified (and acceptably short) period of time.

The objective of SOLAS is to specify minimum standards for the construction, equipment and operation of ships in order to assure a level of safety. Flag states are responsible for ensuring that ships under their flag comply with these requirements. A number of certificates are prescribed in the convention as proof that this has been done. Control provisions allowing contracting governments to inspect ships of other contracting nations if there are reasons to believe that the ship and its equipment do not comply with the requirements of the Convention follows.

Development milestones of SOLAS are identified in Table 5-1.

A5.1.1. Chapter I

This identify general provisions whereas the most important are those concerning the survey of the various types of ships and the issuing of documents verifying that the ship meets the requirements of the convention. Also included are the provisions for the control of ships in ports of other contracting governments.

A5.1.2. Chapter II

Following main items are dealt with in chapter II;

Subdivision and stability (chapter II-1), included are the subdivision of passenger ships into watertight compartments ensuring that it remains afloat and stable following an assumed damage to the hull. Watertight integrity and bilge pumping arrangements for passenger ships are also laid down as well as stability requirements for both passenger and cargo ships.

Machinery and electrical installations (chapter II-1) are addressed. Particular attention is given that of remaining intact steering ability. Requirements defined are designed to ensure the availability of essential services for the safety of the ship, its crew and passengers under assumed emergency situations.

Fire protection, fire detection and fire extinction including detailed fire safety provisions for passenger vessels as well as for tankers and combination carriers, such as inert gas systems (incorporated in chapter II-2 of the 1974 convention). The provisions are based on the following principles.:

- Division of the ship into main and vertical zones by thermal and structural boundaries.
- Separation of accommodation spaces from remainder of the ship by thermal and structural boundaries.
- Restricted use of combustible materials.
- Detection of any fire in the zone of origin.
- Containment and extinction of any fire in the space of origin.
- Protection of the means of escape or of access for fire fighting purposes.
- Ready availability of fire-extinguishing appliances.
- Minimisation of the possibility of ignition of flammable cargo vapour.

A5.1.3. Chapter III

This chapter deals with life-saving appliances and arrangements (revised by the 1983 amendments which entered into force on 1 July 1986) and is organised in three parts.

Part A identifies general provisions on matters concerning application of requirements, exemptions, definitions, evaluation, testing and approval (appliances and arrangements and production tests).

Part B defines ship requirements. These are devided into a number of sections:
- Section I : Common requirements applicable to both passenger ships and cargo ships;
- Section II : Additional requirements for passenger ships;
- Section III: Additional requirements for cargo ships;

Part C concern actual life-saving appliances and requirements. This part is contain a number of 8 sections:

- Section I: General requirements;
- Section II: Personal life-saving appliances;
- Section III: Signal requirements;
- Section IV: Survival craft;
- Section V: Rescue boat provisions;
- Section VI: Launching and embarkation appliances;
- Section VII: Other life-saving appliances;
- Section VIII: Miscellaneous matters;

A5.1.4. Chapter IV

is subjected to radiotelegraphy and radiotelephony:

- Part A describes the type of facility to be carried.
- Part B identifies requirements for watchkeeping and listening
- Part C defines technical provisions including also those for direction finders and motor lifeboat radiotelegraph installations/ portable radio apparatus for survival craft.
- Part D provides for the obligations of the radio officer regarding logbook entries are listed in part D.

The chapter is compatible to the Radio Regulations of the International Telecommunication Union and was completely revised in October 1988 (see 1988 (GMDSS) amendments).

A5.1.5. Chapter V

Obligations concerning navigation safety services to be provided by contracting states including generally applicable operational provisions applying to all ships on all voyages is addressed. This is in contrast to the Convention as a whole, which only applies to certain classes of ship, engaged on international voyages. The chapter also includes a general obligation for masters to proceed to the assistance of those in distress and for contracting governments to ensure that all ships are sufficiently and efficiently manned from a safety point of view. Other items are also covered;

- Maintenance of meteorological services for ships;
- Ice patrol service;
- Routing of ships;
- Maintenance of search and rescue services.

A5.1.6. Chapter VI

Provisions concerning the carriage of grain in ships focusing on cargo shifting and its consequential effect on ship stability are addressed. The chapter identifies provisions on the securing of grain cargoes (stowing, trimming) including constructional requirements, a loading calculation method (adverse heeling moment due to a shift of cargo), documents of authorisation, grain loading stability data and associated plans of loading. This chapter was revised in 1991 making it applicable to all types of cargo except liquids and gases in bulk.

A5.1.7. Chapter VII

A regime ensuring the safety of transporting dangerous goods onboard ships are established. This contains provisions for the classification, packing, marking, labelling and placarding, documentation and stowage of dangerous goods in packaged form, in solid form in bulk, and liquid chemicals and liquefied gases in bulk. IMO have developed the International Maritime Dangerous Goods (IMDG) code in order to assist governments in issuing instructions at national level . The IMDG code is constantly updated to accommodate new dangerous goods and to supplement or revise existing provisions

A5.1.8. Chapter VIII

This applies to nuclear ships. The chapter is generic in the sense that it only provides basic requirements particularly on the topic of radiation hazards. A detailed and comprehensive Code of Safety for Nuclear Merchant Ships was adopted by the IMO Assembly in 1981 as an indispensable companion document.

A5.1.9. Chapter IX (new chapter adopted in 1994)

The Management for the Safe Operation of Ships was designed to make mandatory the International Safety Management (ISM) code, which was adopted by IMO in November 1993 (Assembly resolution A.741(18)). The amendments introducing the new Chapter IX entered into force on 1 July 1998. The chapter applies to passenger ships and tankers from that date and to cargo ships and mobile drilling units of 500 gross tonnage and above from 1 July 2002.
The Code identifies safety and environmental management objectives:

- to provide for safe and environmentally sound practices in ship operation,
- to establish safeguards against all identified risks,
- to continuously improve safety/ environmental management skills of personnel, including preparing for emergencies.

A5.1.10. Chapter X (new chapter adopted in 1994)

The amendment introduced in this chapter makes mandatory the International Code of Safety for High Speed Craft.

A5.1.11. Chapter XI (new chapter adopted in 1994)

The chapter was developed to resolve differences concerning amendment procedure;

- Regulation 1, organizations entrusted by an Administration with the responsibility for carrying out surveys and inspections shall comply with guidelines adopted by IMO in resolution A.739(18) in November 1993.
- *Regulation 2* extends to bulk carriers aged five years and above, the enhanced programme of surveys applicable to tankers under MARPOL 73/78. The guidelines pay special attention to corrosion.
- *Regulation 3* introduced the IMO ship identification number scheme (all passenger ships of 100 gross tonnage and above and all cargo ships of 300 gross tonnage and above shall be provided with an identification number (A.600(15) in 1987).
- *Regulation 4* makes it possible for port state control officers inspecting foreign ships to check operational requirements "when there are clear grounds for believing that the master or crew are not familiar with essential shipboard procedures relating to the safety of ships".

A5.1.12. Chapter XII (new chapter adopted in 1997)

Additional safety measures for bulk carriers was introduced to ensure sufficient strength to withstand flooding of any one cargo hold, taking into account dynamic effects resulting from presence of water in the hold. The criteria and formulae used to assess whether a ship currently meets the new requirements, for example in terms of the thickness of the steel used for bulkhead structures, or whether reinforcement is necessary, are laid out in IMO standards adopted by the 1997 Conference.

Under Chapter XII, surveyors can take into account restrictions on the cargo carried in considering the need for, and the extent of, strengthening of the transverse watertight bulkhead or double bottom. When restrictions on cargo carrying capacity are imposed, the bulk carrier should be permanently marked with a solid triangle on its side shell.

Table 5-1 - Development milestones of SOLAS

ID	Main points
The Protocol of 1978 International conference on Tanker Safety and Pollution Prevention. Important changes to chapter I. Chapter II-1/ II-2 and V also changed.	Crude oil carriers/ product carriers (20,000 dwt and above), required to be fitted with an inert gas system (new ships). Inert gas system mandatory for existing crude oil carriers of 70,000 dwt and above by 1 May 1983, and by 1 May 1985 for ships of 20,000-70,000 dwt. Crude carriers of 20-40,000 dwt; provision for exemption by flag States where considered unreasonable or impracticable to fit inert gas systems and high-capacity fixed washing machines are not used. Inert gas system is always required when crude oil washing is operated. Inert gas system required on existing product carriers from 1 May 1983 and by 1 May 1985 for ships of 40-70,000 dwt to 20,000 dwt which are fitted with high capacity washing machines. All ships of 1,600 grt. and above shall be fitted with radar, the Protocol requires also that all ships of 10,000 grt and above have two radars, each capable of being operated independently. All tankers of 10,000 grt and above shall have two remote steering gear control systems, each operable separately from the navigating bridge. The main steering gear of new tankers of 10,000 grt and above shall comprise two or more identical power units, and shall be capable of operating the rudder with one or more power units.
The 1981 amendments Adoption: 20 November 1981 Entry into force: 1 September 1984 Most important amendments concern chapter II-1 and chapter II-2,(virtually re-written and updated).	Chapter II-1, updated provisions of resolution A.325(IX) on machinery and electrical requirements. Further amendments to regulations 29 and 30 were agreed following the **Amoco Cadiz** disaster taking into account the 1978 SOLAS Protocol on steering gear. Requirements introduce the concept of duplication of steering gear control systems in tankers. Amendments to chapter II-2 include requirements of resolution A.327(IX), provisions for halogenated hydrocarbon extinguishing systems, special requirements for ships carrying dangerous goods, and a new regulation 62 on inert gas systems. Amendments to chapter II-2 strengthen requirements for cargo ships/ passenger ships to an extent that a complete rearrangement of that chapter became necessary. Minor changes were made to chapter III. Seven regulations in chapter IV were replaced, amended or added. Important changes were also made to chapter V (including that of the addition of new requirements concerning the carriage of shipborne navigational equipment). In addition a number of small changes were made to chapter VII.
The 1983 amendments Adoption: 17 June 1983 Entry into force: 1 July 1986 Minor changes to chapter II-1, IV changes to chapter II-2, VII, extensive changes to chapter III	Chapter III was completely rewritten. The 1974 Convention text differed little from the texts in the 1960 and 1948 SOLAS Conventions. Amendments were designed to take into account the many technical advances which had taken place since then and also to expedite the evaluation and introduction of further improvements. Minor changes were made to chapter IV. The amendments to chapter VII extended its application to chemical tankers and liquefied gas carriers by making reference to two new Codes, the International Bulk Chemical Code and the International Gas Carrier Code. Both relate to ships built on or after 1 July 1986.

The 1988 (April) amendments Adoption: 21 April 1988 Entry into force: 22 October 1989	Following the Herald of Free Enterprise incident In March 1987, the United Kingdom proposed a series of measures designed to prevent a recurrence, the first package of which was adopted in April. They include new regulations 23-2 and 42-1 of Chapter II-1 and are intended to improve monitoring of doors and cargo areas and to improve emergency lighting. Because of the urgency, the 'tacit acceptance' procedure was used to bring the amendments into force only 18 months after their adoption.
The 1988 Protocol Adoption: 11 November 1988 Entry into force: 3 February 2000	A new system of surveys and certification which will harmonise with two other conventions, Load Lines and MARPOL 73/78 is introduced.
The 1988 (GMDSS) amendments Adoption: 11 November 1988 Entry into force: 1 February 1992	The Global Maritime Distress and Safety System has been introduced in stages between 1993 and 1 February 1999.. The GMDSS makes great use of the satellite communications provided by Inmarsat but also uses terrestrial radio. Equipment required by ships varies according to the sea area in which they operate - ships travelling to the high seas will need to carry more communications equipment than those which remain within reach of specified shore-based radio facilities. GMDSS also provides for the dissemination of general maritime safety information (navigational and meteorological warnings/ urgent information to ships).
The 1989 amendments Adoption**:** 11 April 1989 Entry into force**:** 1 February 1992 Main changes relate to chapter II-1/ II-2	Reduction of the number and size of openings in watertight bulkheads in passenger ships and to ensure that they are closed in the event of an emergency. Improvements were introduced to fixed gas fire-extinguishing systems, smoke detection systems, arrangements for fuel and other oils, the location and separation of spaces and several other regulations. The International Gas Carrier Code - which is mandatory under SOLAS - was also amended.
The 1990 amendments Adoption: May 1990 Entry into force: 1 February 1992	Changes made to the way in which the subdivision and stability of dry cargo ships is determined. The amendments introduced a new part B-1 of Chapter II-1 containing subdivision and damage stability requirements for cargo ships based upon "probabilistic" concept of survival. At the same meeting amendments were adopted to the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

The 1991 amendments Adoption: 24 May 1991 Entry into force: 1 January 1994 Revision of Chapter VI, chapter II-2, changes made to Chapter III and Chapter V (safety of navigation).	Chapter VI was extended to include other cargoes. The text was shortened, but two new codes was developed to back it up (International Grain Code (mandatory instrument)/ Code of Safe Practice for Cargo Stowage and Securing (recommendation). The chapter also refers to the Code of Safe Practice for Ships Carrying Timber Deck Cargoes and the Code of Safe Practice for Solid Bulk Cargoes. Fire safety requirements for passenger ships were improved.
The April 1992 amendments Adoption: 10 April 1992 Entry into force: 1 October 1994 Changes to chapter II-1	New standards, stability of existing ro-ro passenger ships after damage, were developed (chapter II-1). The measures were introduced in an 11 year period which began on 1 October 1994. Other amendments adopted where; improved fire safety measures for existing passenger ships (mandatory requirements for smoke detection and alarm and sprinkler systems in accommodation and service spaces, stairway enclosures and corridors); provision of emergency lighting, general emergency alarm systems and other means of communication; stairways of steel-frame construction, for fire-extinguishing systems in machinery spaces, fire doors. The April 1992 amendments are particularly important because they apply to existing ships. In the past, major changes to SOLAS have been restricted to new ships by so-called "grandfather clauses".
The December 1992 amendments Adoption: 11 December 1992 Entry into force: 1 October 1994	Amendments introduced concerned fire safety of new passenger ships Three Codes were also amended. They include the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). Both codes are mandatory under SOLAS and the amendments entered into force on 1 July 1994. Amendments to the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH Code) were also adopted. The Code is voluntary and applies to existing ships.
The May 1994 amendments (Conference) Adoption: 24 May 1994 Entry into force: 1 January 1996 (Chapters X, XI); 1 July 1998 (Chapter IX).	Three new SOLAS Chapters was adopted as well as resolution on an accelerated amendment procedure. Chapter IX, Management for the Safe Operation of Ships (International Safety Management Code (ISM Code)).

The May 1994 amendments (MSC) Adoption: 25 May 1994 Entry into force: 1 January 1996 Amendments to chapter V, II-2	Amendments where made concerning Chapter V, safety of navigation. Three new regulations were added. Regulation 15-, all tankers of 20,000 dwt and above built after 1 January 1996 to be fitted with an emergency towing arrangement to be fitted at both ends of the ship. Tankers built before that date had to be fitted with a similar arrangement not later than 1 January 1999. Regulation 22 was adopted to improve navigation bridge visibility. Regulation, 8-1, deals with ship reporting, making mandatory the use of ship reporting systems approved by IMO. Chapter II-2, (fire safety), was also amended. A number of amendments to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and the Code for the Construction and Equipment of Ships Carrying Liquefied Gases (Gas Carrier Code) were also adopted.
The December 1994 amendments Adoption: 9 December 1994 Entry into force: 1 July 1996 Chapter VI	The Code of Safe Practice for Cargo Stowage and Securing was made mandatory. (The Code was adopted as a recommendation in 1991). The amendments make it mandatory to provide the cargo information required by the Code and for cargo units, including containers, to be loaded, stowed and secured in accordance with a manual that must be at least equivalent to the Code.
The May 1995 amendments Adoption: 16 May 1995 Entry into force: 1 January 1997	Safety of Navigation, chapter V, was amended to make ships' routing systems compulsory. Governments are responsible for submitting proposals for ships' routing systems to IMO in accordance with amendments to the General Provisions on Ships' Routing which were adopted at the same time
The November 1995 amendments (Conference) Adopted: 29 November 1995 Entry into force: 1 July 1997	The amendments were made based on recommendations from the panel of experts on the safety of roll on-roll off passenger ships which was established in December 1994 following the sinking of the ferry Estonia. The SOLAS 90 damage stability standard, which had applied to all ro-ro passenger ships built since 1990, was extended to existing ships as well in accordance with an agreed phase-in programme. A new regulation 8-2 was adopted containing special requirements for ro-ro passenger ships carrying 400 passengers or more. The conference adopted a resolution which permits regional arrangements to be made on special safety requirements for ro-ro passenger ships. Amendments also included life saving appliances and arrangements, include the addition of a section requiring ro-ro passenger ships to be fitted with public address systems, a regulation providing improved requirements for life-saving appliances and arrangements and a requirement for all passenger ships to have full information on the details of passengers on board and requirements for the provision of a helicopter pick-up or landing area. Amendments were also made to Chapter IV (radio communications); Chapter V (safety of navigation and Chapter VI (carriage of cargoes).

The June 1996 amendments Adoption: 4 June 1996 Entry into force: 1 July 1998 Chapter III, chapter II-2, chapter VI, chapter XI	Chapter III on life-saving appliances and arrangements was revised. The amendments to the chapter take into account changes in technology that have occurred since the chapter was last re-written in 1983. Other SOLAS chapters were also amended. In Chapter II-1a new part dealing with the structure of ships was amended (ships to be designed, constructed and maintained in compliance with structural requirements of a recognised classification society or with applicable requirements by the Administration). In Chapter VI (Carriage of cargoes), new text dealing with the loading, unloading and stowage of bulk cargoes was added. The ship must be provided with a booklet giving advice on cargo handling operations and the master and terminal representative must agree on a plan to ensure that loading and unloading is carried out safely. A change was also made to Chapter XI dealing with the authorisation of recognised organizations. The International Bulk Chemicals (IBC) and Bulk Chemicals (BCH) Code were amended. The IBC Code is mandatory under SOLAS and applies to ships carrying dangerous chemicals in bulk that were built after 1 July 1986. The BCH is recommended and applies to ships built before that date.
The December 1996 amendments Adoption: 6 December 1996 Entry into force: 1 July 1998 Chapter II-1, chapter, II-2 Chapter V, Chapter VII	Amendments to Chapter II-1 include a requirement for ships to be fitted with a system to ensure that the equipment necessary for propulsion and steering are maintained or immediately restored in the case of loss of any one of the generators in service. Chapter II-2 was with changes on the general introduction, Part B (fire safety measures for passenger ships), Part C (fire safety measures for cargo ships) and Part D (fire safety measures for tankers). A new International Code for Application of Fire Test Procedures was made mandatory under the revised Chapter II-2 Further, an amendment to Chapter V (Safety of Navigation) aims to ensure that the crew can gain safe access to the ship's bow, even in severe weather conditions. Amendments were also made to two regulations in Chapter VII (Carriage of Dangerous Goods). The IBC Code was also amended.
The June 1997 amendments Adoption: 4 June 1997 Entry into force: 1 July 1999 (Under tacit acceptance)	Vessel Traffic Services (VTS), a traffic management systems for use in busy straits, was adopted. Vessel Traffic Services should be designed to contribute to the safety of life at sea, safety and efficiency of navigation and the protection of the marine environment, adjacent shore areas, worksites and offshore installations from possible adverse effects of maritime traffic. Governments may establish VTS when, in their opinion, the volume of traffic or the degree of risk justifies such services, the Regulation adds. But no VTS should prejudice the "rights and duties of governments under international law" and a VTS may only be made mandatory in sea areas within a State's territorial waters. Chapter II-I, stability concerning passenger ships was also amended.

The November 1997 amendments (Conference) Adoption: 27 November 1997 Entry into force: 1 July 1999 (under tacit acceptance)	A new Chapter XII to the Convention, Additional Safety Measures for Bulk Carriers was developed. The regulations impose additional strength requirements ensuring that all new bulk carriers 150 metres or more in length (built after that date) carrying cargoes with a density of 1,000 kg/m^3 and above should have sufficient strength to withstand flooding of any one cargo hold, taking into account dynamic effects resulting from presence of water in the hold and taking into account the recommendations adopted by IMO. For existing ships (built before 1 July 1999) carrying bulk cargoes with a density of 1,780 kg/m^3 and above, the transverse watertight bulkhead between the two foremost cargo holds and the double bottom of the foremost cargo hold should have sufficient strength to withstand flooding and the related dynamic effects in the foremost cargo hold. The criteria and formulae used to assess whether a ship currently meets the new requirements, for example in terms of the thickness of the steel used for bulkhead structures, or whether reinforcement is necessary, are laid out in IMO standards adopted by the 1997 Conference. Under Chapter XII, surveyors can take into account restrictions on the cargo carried in considering the need for, and the extent of, strengthening of the transverse watertight bulkhead or double bottom. When restrictions on cargoes are imposed, the bulk carrier should be permanently marked with a solid triangle on its side shell. The date of application of the new Chapter to existing bulk carriers depends on their age. Bulk carriers which are 20 years old and over on 1 July 1999 have to comply by the date of the first intermediate or periodic survey after that date, whichever is sooner. Bulk carriers aged 15-20 years must comply by the first periodical survey after 1 July 1999, but not later than 1 July 2002. Bulk carriers less than 15 years old must comply by the date of the first periodical survey after the ship reaches 15 years of age, but not later than the date on which the ship reaches 17 years of age.
The May 1998 Amendments Adoption: 18 May 1998 Entry into force: 1 July 2002 (under tacit acceptance)	Amendments where made to Chapter II-1 (construction/ subdivision and stability, machinery and electrical installations). Chapter IV, radio communications was changed including a new regulation (5-1) requiring Contracting Governments to ensure suitable arrangements are in place for registering Global Maritime Distress and Safety System (GMDSS) identities (including ship's call sign, Inmarsat identities) and making the information available 24 hours a day to Rescue Co-ordination Centres; a new paragraph covering testing intervals for satellite emergency position indicating radio beacons (EPIRBS), a new regulation position updating requiring automatic provision of information regarding the ship's position where two-way communication equipment is capable of providing automatically the ship's position in the distress alert. Amendments to Chapter VI Carriage of Cargoes was made ensuring "all cargoes, other than solid and liquid bulk cargoes" should be loaded, stowed and secured in accordance with the Cargo Securing Manual. A similar amendment was adopted in Chapter VII Carriage of Dangerous Goods also covering stowage and securing.

A5.2. The International Convention for the Prevention of Pollution from Ships

MARPOL identifies a framework for the safeguarding of the environment from unacceptable impacts from international shipping. In its present form it consists of six annexes;

Annex I	Regulations for the Prevention of Pollution by Oil
Annex II	Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk
Annex III	Regulations for the Prevention of Pollution by Harmful Substances in Packaged Form
Annex IV	Regulations for the Prevention of Pollution by Sewage from Ships
Annex V	Regulation for the Prevention of Pollution by Garbage from Ships
Annex VI	Regulations for the Prevention of Air Pollution from Ships

MARPOL is a combination of three treaties;

- *International Convention for the Prevention of Pollution from Ships, 1973,*
- *The Protocol of 1978*
- *The Protocol of 1997*

MARPOL was initiated by the IMO Assembly in 1969 when it was decided to convene an international conference in order to develop international agreements for placing restraints on the contamination of the oceans, land and air caused by international shipping operations. This initiative materialised in the Protocol adopted in November 1973. (International Convention for the Prevention of Pollution from Ships, 1973).

MARPOL addresses all technical aspects of pollution from ships, with the exception of disposal of waste into the sea by dumping. It applies to ships of all types. However, it does not apply to pollution arising from exploration/ exploitation associated to sea-bed mineral resources.

The development milestones of MARPOL are identified in Table 5-2.

A5.2.1. Annex I

Prevention of pollution by oil (enforced on 2. October 1983) include oil discharge criteria (prescribed in the 1969 amendments to the 1954 Oil Pollution Convention) providing maximum limitations of oil to be discharged on a ballast voyage of new oil tankers.

The Convention introduced the concept of "special areas". These are areas considered to be vulnerable requiring particular protection against pollution by oil (discharges within them have been completely prohibited, with minor and well-defined exceptions). The Mediterranean Sea, the Black Sea, the Baltic Sea, the Red Sea and the Gulfs area are major special areas.

All oil-carrying vessels are required to be capable of operating the method of retaining oily wastes on board through the "load on top" system or for discharge to shore reception facilities. This involves the fitting of appropriate equipment, including an oil-discharge monitoring and control system, oily-water separating equipment and a filtering system, slop tanks, sludge tanks, piping and pumping arrangements.

New oil tankers (i.e. those for which the building contract was placed after 31 December 1975) of 70,000 tons dead-weight and above, was required fitted with segregated ballast tanks large enough to provide adequate operating draught without the need to carry ballast water in cargo oil tanks.

Secondly, new oil tankers where required to meet certain subdivision and damage stability requirements.

A5.2.2. Annex II

The Control of pollution by noxious liquid substances deals with the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk. The Annex entered into force on 6 April 1987.

A list of substances commonly carried by ships representing a considerable environmental risk was identified and included in a appendix to the Convention. The discharge of their residues is allowed only to reception facilities until certain concentrations and conditions (which vary with the category of substances) are complied with. No discharge of residues containing noxious substances was permitted within 12 miles of the nearest land. Further restrictions were made applicable to the Baltic and Black Sea areas.

A5.2.3. Annex II

The prevention of pollution by harmful substances carried in packaged form include that of freight containers or portable tanks or road and rail tank wagons. The Annex entered into force on 1 July 1992.

A5.2.4. Annex III

The Prevention of Pollution by Harmful Substances in Packaged Form is an optional Annex. It contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications for preventing pollution by harmful substances. The International Maritime Dangerous Goods (IMDG) Code has , since 1991, included marine pollutants.

A5.2.5. Annex IV (optional)

The Prevention of pollution by sewage enters into force 12 months after the ratification by 15 states whose combined fleets of merchant shipping constitute at least 50% of the world fleet. The Annex has at present not entered into force.

A5.2.6. Annex V (optional)

The Prevention of Pollution by Garbage from Ships entered into force on 31 December 1988. The annex addresses different types of garbage and specifies the distances from land and also methods in which they may be disposed of. The requirements are much stricter in a number of "special areas". The Annex imposed a complete ban on the dumping of all forms of plastic materials into the sea.

A5.2.7. Annex VI (optional)

The Prevention of Air Pollution from Ships, was adopted on 26 September 1997 and enters into force 12 months after being accepted by at least 15 states with not less than 50% of world merchant shipping tonnage. A conference adopted the Protocol (1997) and added a new Annex VI to the Convention. It should be noted that a Resolution has been adopted inviting the MEPC to identify any impediments to entry into force of the Protocol, if the conditions for entry into force have not been met by 31 December 2002. Furthermore, it should be noted that the requirements associated to limitations of NO_x have a retroactive mechanism following a future entry into force.

The rules set limits on sulphur oxide (a global cap of 4.5% m/m on sulphur content of the fuel) and nitrogen oxide emissions from ship exhausts and prohibit deliberate emissions of ozone depleting substances. The Annex calls on IMO to monitor the world-wide average sulphur content of fuel once the Protocol comes into force.

Annex VI contains provisions allowing for special SO_x Emission Control Areas to be established. The Baltic Sea is designated as a SO_x Emission Control area in the Protocol.

Annex VI prohibits deliberate emissions of ozone depleting substances, including halons and chlorofluorocarbons (CFCs). New installations containing ozone depleting substances are prohibited on all ships. New installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

The requirements of the IMO Protocol are in accordance with the Montreal Protocol of 1987, as amended in London in 1990. Annex VI sets limits on emissions of nitrogen oxides (NO_x) from diesel engines. A mandatory NO_x Technical Code, has been developed by IMO defining how required limitations are to be verified.

The Annex introduces restrictions in relation to additions to fuel and further prohibits the incineration on board ship of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Table 5-2 - Development milestones of MARPOL

ID	Main points
The Protocol of 1978 Adoption: 17 February 1978 Entry into force: 2 October 1983	The International Conference on Tanker Safety and Pollution Prevention, 6 to 17 February 1978, resulted in the adoption of a number of measures, including Protocols to SOLAS,1974. The Conference decided that the SOLAS Protocol should be a separate instrument, and should enter into force after the parent convention. For MARPOL, the Conference adopted a different approach. At that time the principal problems preventing early ratification of the MARPOL Convention were those associated with Annex II. The changes envisaged by the Conference involved mainly Annex I. Therefore, one decided to adopt the agreed changes and to allow Contracting Countries to defer implementation of Annex II for three years after the date of entry into force of the Protocol. (i.e. until 2 October 1986). By then it was expected that the technical problems would have been solved. The Protocol made a number of changes to Annex I of the parent convention. Segregated ballast tanks (SBT) was made mandatory for all new tankers of 20,000 dwt and above The Protocol also required that SB's be protectively located in the sense that they must be positioned in such a way that they will help protect the cargo tanks in the event of a collision or grounding. Another important innovation concerned crude oil washing (COW), which had recently been developed by the oil industry and offered major benefits. (COW: the tanks are washed with the cargo itself (crude oil)). COW was accepted as an alternative to SB's on existing tankers (made additional requirement for new tankers). For existing crude oil tankers a third alternative was permissible (for a period of two to four years after entry into force of MARPOL 73/78). This, dedicated clean ballast tanks (CBT), is a system where certain tanks are dedicated solely to the carriage of ballast water. It is cheaper than a full SBT system since it utilises existing pumping and piping. Requirements associated to drainage and discharge arrangements were also changed. As some tankers solely operate in specific trades between ports which are provided with adequate reception facilities and others never use water as ballast, the TSPP Conference recognised that such ships should not be subject to all MARPOL requirements (exempted from the SBT, COW and CBT requirements).
The 1984 amendments Adoption: 7 September 1984 Entry into force: 7 January 1986 Annex I	Amendments (Annex I) was adopted to make implementation easier and more effective. Changes where made to prevent oily water being discharged in special areas. Some other requirements was also strengthened. Some discharges was permitted below the waterline.
The 1985 Adoption: 5 December 1985 Entry into force: 6 April 1987	Amendment took into account technological developments since the Annex was drafted in 1973 intending also to simplify its implementation (reduce the need for reception facilities for chemical wastes and to improve cargo tank stripping efficiencies). The amendments also made the International Bulk Chemical Code mandatory. The Code itself was revised to take into account anti-pollution requirements. The amendments included an explicit requirement to report incidents involving discharge into the sea of harmful substances in packaged form.
The 1987 amendments	The amendments extended Annex I Special Area status to the Gulf of Aden.

Adoption: December 1987 Entry into force: 1 April 1989	
1989 (March) amendments Adoption: March 1989 Entry into force: 13 October 1990	The IBC Code is mandatory under both MARPOL 73/78 and SOLAS. The BCH Code is mandatory under MARPOL 73/78 but is voluntary under SOLAS 1974. Amendments where made affecting these. The amendments include a revised list of chemicals. Amendments also affecting Annex II of MARPOL was made.
The October 1989 amendments Adoption: 17 October 1989 Entry into force: 18 February 1991	The amendments made the North Sea a "special area" under Annex V of the convention.
The 1990 (HSSC) amendments Adoption: March 1990	Entry into force will coincide with the entry into force of the 1988 SOLAS and Load Lines Protocols, i.e. 3 February 2000 (under tacit acceptance). Amendments made to harmonised system of survey and certificates (HSSC) into MARPOL 73/78. The harmonised system (MARPOL/ SOLAS/ Load Lines) will alleviate the problems caused by survey dates and intervals between surveys which do not coincide, so that a ship should no longer have to go into port or repair yard for a survey required by one convention shortly after doing the same thing in connection with another instrument.
The 1990 (IBC Code) amendments Adoption: March 1990	The amendments introduce the HSSC into the IBC Code. Enters into force on the same date as the March 1990 HSSC amendments i.e. 3 February 2000
The 1990 (BCH) amendments Adoption: March 1990	The amendments introduce the HSSC into the BCH Code. Enters into force on the same date as the March 1990 HSSC amendments i.e. 3 February 2000.
The 1990 (Annexes I and V) amendments Adoption: November 1990 Entry into force: 17 March 1992	The amendments extend Special Area Status under Annexes I and V to the Antarctic.
The 1991 amendments Adoption: 4 July 1991 Entry into force: 4 April 1993	The Wider Caribbean is made a Special Area under Annex V. Other amendments include a new chapter IV to Annex I requiring ships to carry an oil pollution emergency plan.
The 1992 amendments Adoption: 6 March 1992	Amendments to Annex I of the convention introduced the "double hull" requirements for tankers, applicable to new ships (tankers ordered after 6 July, whose keels were laid on or after 6 January 1994 or which are delivered on or after 6 July 1996) as well as existing ships built before that date, with a phase-in period.

Entry into force: 6 July 1993	New tankers are covered by Regulation 13F, while regulation 13G applies to existing crude oil tankers of 20,000 dwt and product carriers of 30,000 dwt and above. Regulation 13G came into effect on 6 July 1995. Regulation 13F: All new tankers (5,000 dwt and above) to be fitted with double hulls separated by a space of up to 2 metres (on tankers below 5,000 dwt the space must be at least 0.76m). As an alternative, tankers may incorporate the "mid-deck" concept under which the pressure within the cargo tank does not exceed the external hydrostatic water pressure. Tankers built to this design have double sides but no double bottom. Another deck is instead installed inside the cargo tank with the venting arranged in such a way that there is an upward pressure on the bottom of the hull. There is made an opening for the acceptance of other methods of design if found acceptable (ensuring at least the same level of protection against oil pollution in the event of a collision or stranding and are approved in principle by the MEPC based on guidelines developed by IMO). Oil tankers of 20,000 dwt and above, new requirements have been introduced concerning subdivision and stability. Amendments also reduced the amount of oil which can be discharged into the sea from ships. Permission to discharge oil or oily mixtures at the rate of 60 litres per nautical mile was reduced to 30 litres. For non-tankers of 400 grt and above the permitted oil content of the effluent which may be discharged into the sea is cut from 100 parts per million to 15 parts per million. Regulation 24(4), (limitation of size and arrangement of cargo tanks) was modified. Regulation 13G applies to existing crude oil tankers of 20,000 dwt and product carriers of 30,000 dwt and above. Tankers that are 25 years old and not constructed according to the requirements of the 1978 Protocol to MARPOL 73/78, have to be fitted with double sides and double bottoms. The Protocol applies to tankers ordered after 1 June 1979, which were begun after 1 January 1980 or completed after 1 June 1982. Tankers built according to the standards of the Protocol are exempt until they reach the age of 30. Existing tankers are to be subject to an enhanced programme of inspections during their periodical, intermediate and annual surveys. Tankers that are five years old or more must carry on board a completed file of survey reports together with a conditional evaluation report endorsed by the flag Administration.
The 1994 amendments Adoption: 13 November 1994 Entry into force: 3 March 1996	Amendments affect the implementation procedures on four of the Convention's six technical annexes (I, II, III, and V). They will made it possible for ships to be inspected when in the ports of other Parties to the Convention to ensure that crews are able to carry out essential shipboard procedures relating to marine pollution prevention (contained in resolution A.742 (18), which adopted by the IMO Assembly in November 1993).
The 1995 amendments Adoption: 14 September 1995 Entry into force: 1 July 1997	Amendments concern Annex V and was designed to improve the way the Convention is implemented.
The 1996 amendments Adoption: 10 July 1996 Entry into force: 1 January 1998	Amendments concerning provisions for reporting incidents involving harmful substances was made. More precise requirements for the sending of such reports where defined. Other amendments bring requirements in MARPOL concerning the IBC and BCH Codes into line with amendments adopted to SOLAS.

The 1997 amendments Adoption: 23 September 1997 Entry into force: 1 February 1999	Amendment makes the North West European waters a "special area" under Regulation 10 of Annex 1. The waters cover the North Sea and its approaches, the Irish Sea and its approaches, the Celtic Sea, the English Channel and its approaches and part of the North East Atlantic immediately to the West of Ireland. Other special areas already designated under Annex I of MARPOL include: the Mediterranean Sea area; the Baltic Sea area; the Red Sea area; the Gulf of Aden area and the Antarctic area.
The Protocol of 1997 (Annex VI) Adoption: 26 September 1997	The Protocol was adopted at a Conference held from 15 to 26 September 1997 and adds the Annex VI on Regulations for the Prevention of Air Pollution from Ships to the Convention. Requirement limits sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibit deliberate emissions of ozone depleting substances among others.

Many of the tankers built in the 1970s are now approaching their 25th birthday - if they have not already done so. If they do not comply with Regulation 13F, their owners must decide whether to convert them to the standards set out in regulation 13F, or to scrap them. Another set of tankers built according to the standards of the 1978 protocol, will soon be approaching their 30th birthday - and the same decisions must be taken.

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
19.11.52	SOLAS 1948		New ships	
26.05.65	SOLAS 1960		New ships	
21.07.68	ICLL 1966		New ships	
15.07.77	COLREG 1972		New ships	
25.05.80	SOLAS 1974		New ships	
01.05.81	SOLAS 1978 Protocol		All ships	
15.07.81	COLREG 1972	E/38	Existing ships	Range of lights and colour specification
18.07.82	1969 Tonnage		New ships	
02.10.83	MARPOL 73/78	Annex I	All ships	Annex I enters into force. Oil
01.09.84	1981 SOLAS Amendments	Ch. II-1	New ships	Completely revised Ch.II-1
		Ch. II-2	New ships	Completely revised Ch.II-2
		II-2/17	Existing tankers	Fireman's outfit
		II-2/20	Existing ships	Fire control plans
		II-2/62 & 60.5	Existing tankers	Inert gas, tankers DWT ≥ 70000
		IV/4-1, 17 & 19	All ships	VHF radiotelephone
		IV/7 & 8	All ships	Watches/operators
		IV/10	All ships	Two-tone alarm
		V/12	All ships	Gyro compass, echo sounding device, rudder angle indicator, revolution indicator
		V/12(j)	New ships	ARPA, ships GRT ≥ 10000
01.01.85	1981 SOLAS Amendments	V/12(j)	Existing tankers	ARPA, tankers GRT ≥ 40000
01.05.85	1981 SOLAS Amendments	II-2/62 & 60.5	Existing tankers	Inert gas, tankers 40000 ≤ DWT < 70000
01.01.86	1981 SOLAS Amendments	V/12(j)	Existing tankers	ARPA, tankers 10000 ≤ GRT < 40000
01.07.86	1983 SOLAS Amendments	III	New ships	Completely revised Ch.III
		III/8 & 53	Existing ships	Muster list and emergency instructions
		III/9	Existing ships	Operating instructions
		III/10	Existing ships	Manning and supervision of survival craft
		III/18	Existing ships	Abandon ship training and drills
		III/19	Existing ships	Operational readiness, maintenance and inspections
		VII, Part B	New chemical tankers	IBC Code mandatory under SOLAS
		VII, Part C	New gas carriers	IGC Code mandatory under SOLAS
15.07.86	COLREG	E/38	Existing ships	Navigation lights, positioning and sound signals
01.09.86	1981 SOLAS Amendments	II-1/29	Existing tankers	Steering gear, tankers GRT ≥ 10000
		V/12(j)	Existing ships	ARPA, non-tankers GRT ≥ 40000

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
06.04.87	MARPOL 73/78	Annex II	Oil tankers and chemical tankers, new and existing ships	Annex II enters into force. Noxious liquid substances
	1st set of Amendments to IBC Code 11th set of Amendments to BCH Code			The codes extended to include pollution
01.09.87	1981 SOLAS Amendments	V/12(j)	Existing ships	ARPA, non-tankers 20000 ≤ GRT < 40000
01.09.88	1981 SOLAS Amendments	II-1/29	Existing tankers	Steering gear, tankers GRT ≥ 40000
		V/12(j)	Existing ships	ARPA, non-tankers 15000 ≤ GRT < 20000
31.12.88	MARPOL 73/78	Annex V		Annex V (optional) enters into force. Garbage
01.04.89	1987 MARPOL, Annex I Amendments	10(1)(f)	All ships	Gulf of Aden is special area. However, effective one year after reception facilities confirmed by coast states.
01.01.90	ITU Regulations (ref. SOLAS, Ch.IV, Reg.2(a))	Appendix 7	All ships	Stricter frequency tolerances for all radio transmitters
13.10.90	1989 MARPOL, Annex II Amendments 1992 IBC Code amendments 12th set of Amendments to BCH Code		Oil tankers and chemical tankers, new and existing ships	Product lists revised and supplemented
01.07.91	1983 SOLAS Amendments	III/1.4.5	Existing ships	Life-saving appliances installed or replaced shall be tested and approved according to 1983 Amendments
		III/6.2.3	Existing ships	Fit two EPIRBs
		III/6.2.4	Existing ships	Fit at least three two-way radiotelephone apparatus (see also entry into force date 01.02.95)
		III/26.3	Cargo ships, existing ships	Liferaft capacity for 100% of persons on board + extra raft forward and/or aft if more than 100 m away
		III/27.2	Cargo ships, existing ships	All lifejackets to be fitted with light
		III/27.3	Cargo ships, existing ships	Provide for each lifeboat at least three immersion suits. In addition the ship shall carry thermal protective aid for all persons on board not provided with immersion suits, or instead immersion suits for all on board
		III/30.2.7	Existing ships	Life-saving appliances to be fitted with retro-reflective material
01.02.92	November 1988 SOLAS Amendments	GMDSS		GMDSS enters into force
		I/12	All ships	New forms for SOLAS Certificates

Table A – Cargo Ships				
Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.02.92	1989 SOLAS Amendments	II-1/11.8 & /11.9	New cargo ships	W.T. bulkhead(s) betw. machinery space and cargo/passenger space. W.T. enclosure (or equivalent) of stern tube
		II-1/12-1	New dry cargo ships	Double bottom required
		II-1/21	New ships	Internal drainage for enclosed spaces where the deck edge is immersed at 5º heel.
		II-1/23-1	New dry cargo ships	Damage control Damage control plan
		II-2/4.3.3.2.5	New cargo ships	Emergency fire pump suction head: Minor adjustment.
		II-2/13-1	New ships	Requirements for sample extraction smoke detection systems.
		II-2/15.2.6 & /15.3	New ships	Sounding pipes for oil fuel tanks should not terminate in machinery spaces (general rule) (lub. oil may).
		II-2/18.2.4	New tankers (flush point < 60º C)	Restrictions in use of heat affective materials in valves, fittings, etc..
		II-2/18.8	New ships	Helicopter decks, requirements specified
		II-2/44	New cargo ships	Area limit changed from $2m^2$ to $4m^2$ for some spaces (fire risk categories).
		II-2/50.3	New cargo ships	Revised specifications for the use of combustible materials (veneers) on bulkheads and ceilings
		II-2/53.2.1 & /53.3	New cargo ships carrying vehicles	More specific requirements for fire detection of vehicle decks. Sample extraction smoke detection system may be used except for ro-ro cargo spaces.
		II-2/54.1.1	New cargo ships < 500 GRT carrying dangerous goods	Requirements extended to also applying to cargo ships < 500 GRT.
		II-2/54.2.3	New ships carrying dangerous goods	More specific requirements for fire detection. Sample extraction smoke detection system may be used
		II-2/55.5	Existing and new chemical tankers and gas carriers	Revised requirements for inert gas systems.
		II-2/56	New tankers	Reg. 56 (location and separation of spaces) is rewritten. A single failure in deck or bulkhead shall not permit entry of gas or fumes from cargo tanks into accommodation etc..
		II-2/58	New tankers	Area limits changed from $2m^2$ to $4m^2$ for some spaces (fire risk categories).
		II-2/59.2	New tankers	Flame arrestors not needed when velocity > 30m/s (cargo tank purging/gas freeing (not provided with inert gas system)).
		II-2/62.19	New tankers	Editorial changes (alarms, inert gas systems).
		V/12(f)	New ships > 500 GRT	Gyro repeater at emergency steering position
			All ships	Heading information to emergency steering position shall consist of telephone (or similar).
		II-2/4.7	All ships	Fire hoses to be of non-perishable material. Also applicable to existing ships when hoses are renewed.
		II-2/18.7	All ships	Fire extinguishing arr. in paint lockers and lockers for flammable liquids.
		V/13	All ships	Minimum Safe Manning Certificate.
		V/16	All ships	Life saving signals are not described in SOLAS any longer. Instead it is referred to IMO Resolutions A.229 (VII), A.439 (XI) and A.80 (IV).

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.02.92	1990 SOLAS Amendments	Ch. II-1 Part B-1	Dry cargo ships, new ships	New part B-1. Regulations for sub division and damage stability
17.03.92	1990 MARPOL Amendments	Annexes I and V	All ships	Antarctic is special area
01.07.92	MARPOL 73/78	Annex III		Annex III (optional) enters into force. Harmful substances in packaged forms
04.04.93	1991 MARPOL, Annex I Amendments	26	New ships	Shipboard oil pollution emergency plan
		17(3), 20	Every ship ≥ 400 tons gross tonnage	Piping for oil residues (sludge). Piping to and from sludge tanks. Revised format of Oil Record Book .
06.07.93	1992 MARPOL, Annex I Amendments	9, 10, 16, 21 and suppl. A & B	All ships	Various replacements of existing regulation texts (discharge criteria)
		1(8)(c), 13F, 13G, and suppl. B	New tankers > 600 DWT	Various new regulations (double hull or (mid deck)).
		24(4)	New tankers	Maximum permitted length of cargo tanks changed
01.08.93	November 1988 SOLAS Amendments (GMDSS)	IV/1.4	All ships	All ships must carry NAVTEX and float-free satellite EPIRB (406 MHz)
01.01.94	1991 SOLAS Amendments	II-2/20.3 & III/18	All ships	Fire drills and on-board training, extended requirements
		V/17	New installations	Pilot transfer arrangements
		Ch.VI	As applicable	The carriage of cargoes (new Ch.VI), the International Grain Code mandatory under SOLAS
		VII/5	Ships carrying dangerous goods	Packing certificate, list of dangerous goods carried
		VII/7-1		Reporting of incidents
28.02.94	1992 MARPOL, Annex III Amendments	Annex III	All ships carrying harmful substances in packaged form	The whole Annex III (optional) is revised: References to freight containers, portable tanks or tank wagons deleted. "Harmful substances" are identified in the IMDG Code. Guidelines for identification. Marking shall stand 3 months immersion in the sea. Marking and freight document shall include "Marine Pollutant". Copy of freight document to port authorities.
01.07.94	MARPOL, Annex II	P & A standards	New chemical tankers	Revised prewash procedures
01.07.94	1992 MARPOL, Annex II Amendments	1(7), 1(9a) & 5(14)	All chemical tankers	Antarctic is special area
		1(6), 2(7), 3(3), 4, 5, 8(3), 14, App.II, App.III	All chemical tankers	Revised list of chemicals. The list of chemicals for IBC and BCH Codes and MARPOL, Annex II will in the future only be published in the IBC Code. Reissue of certificates necessary. Revised requirements for fire fighting for individual substances. Carriage of chemical wastes.
01.07.94	1992 BCH Code Amendments	1.1, 1.4, 3.16, Ch.VI, Ch.VII, Ch.VIII		
01.07.94	1992 IBC Code Amendments	Ch.11, Ch.12 & Ch.14 Ch.17, Ch.18 & Ch.20		
		Ch.8	Chemical tankers constructed after 01.01.94	Cargo tank venting and gas freeing.

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.07.94	1992 IGC Code Amendments	All chapters Ch.4, Ch.16, Ch.17, Ch.19	Gas carriers constructed on or after 01.10.94	Many minor or editorial changes. Mechanical stress relief. Cargo as fuel. Ammonia stress corrosion cracking. New cargoes: Pentane, Pentene
18.07.94	1969 Tonnage	Article 3(2)(d)	All ships	All ships must have tonnage certificate according to the 1969 International Tonnage Convention
01.10.94	December 1992 SOLAS Amendments	II-1/12-2	New oil tankers	Access to spaces in the cargo area
		II-1/37	New ships	Communication between bridge and machinery spaces (modified text)
		II-1/42, 43, 44	New ships	Emergency generator starting: Clarification of text
		II-1/45.3	New ships	Locally earthed systems, clarification
		II-1/45.4	New tankers	Clarifications regarding earthing
		II-2/4.3.3.2	New cargo ships	The space containing the emergency fire pump shall not be contiguous to machinery spaces or space for main fire pumps (bulkhead may be insulated)
		II-2/4.3.3.3	New ships	Emergency fire pump for cargo ships < 2000 GRT
		II-2/4.4.2	New ships	Pressure in fire lines, new requirements
		II-2/5.2	New CO_2 installations	Separate operations for opening the storage bottles and for discharging into protected space
		II-2/5.3	New installations	New Halon installations prohibited
		II-2/13.1	New (or modified) installations	Fire detection systems: Requirements modified in respect of addressable systems
		II-2/59.4	New oil tankers	Air supply to double hull and double bottom. Inerting of double hull. Instruments for measuring of oxygen and flammable vapour concentrations.
		III/50	New ships	General emergency alarm shall continue to sound until manually turned off. Requirements for sound pressure level.
		IV/13	GMDSS ships	Revised specification of capacities for radio batteries.
02.10.94	MARPOL 73/78	Annex II, Reg. 5A	Existing chemical tankers	Interim Regs. 5A(2) (b) and 5A(4) (b) for Category B and C substances respectively cease to be valid
01.02.95	November 1988 SOLAS Amendments	GDMSS	New ships	New ships must comply with GMDSS
01.02.95	November 1988 SOLAS Amendments (GMDSS)	III/6.2.1	Existing ships	Two-way radiotelephone apparatus to be of VHF-type and to comply with IMO Resolution A.605 (15)
		III/6.2.2	Existing ships	Fit two radar transponders complying with IMO Resolution A.604 (15)
		V/12(g)	Existing ships	One radar installation to operate in 9GHz band
04.04.95	1991 MARPOL, Annex I Amendments	26	Existing ships	Shipboard oil pollution emergency plan
06.07.95	1992 MARPOL, Annex I Amendments	13 G(3)	Crude oil tankers = 20000 DWT and > 5 years. Product tankers = 30000 DWT and > 5 years	Enhanced survey requirements enter into force.
		13 G	Pre MARPOL crude oil tankers = 20000 DWT and pre MARPOL product tankers = 30000 DWT > 25 years	30% side or bottom protection or equivalent.

Table A – Cargo Ships				
Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
			Pre MARPOL crude oil tankers = 20000 DWT and pre MARPOL product tankers = 30000 DWT > 30 years	Compliance with Reg. 13F required (i.e. double hull (or mid deck)) or phase out.
04.11.95	1993 COLREG amendments		General	Several changes, mostly applicable to fishing vessels < 29 m.
01.01.96	May 1994 SOLAS Amendments	Ch.XI (new)		Special Measures to Enhance Maritime Safety.
		Reg.1	Organisations acting on behalf of Administrations	Authorisation of recognised organisations (Res. A.739(18) made mandatory).
		Reg.2	Bulk carriers and oil tankers in service	Enhanced surveys (Res. A.744(18) made mandatory).
		Reg.3	All cargo ships ≥ 300 GRT	Ship identification numbers (IMO Nos.) mandatory (Res. A.600(15)).
		Reg.4		Port state control of operational requirements (Res. A.742(18) made mandatory).
01.01.96	May 1994 SOLAS Amendments	V/8-1 (new regulation)	All ships	Ship reporting systems introduced. Ref. Res. MSC.43(64). Also ref. Res. A.648(16).
		V/15-1 (new regulation)	New tankers ≥ 20000 TDW	Emergency towing arrangement to be fitted at both ends. Ref. Res. MSC.35(63).
			Existing tankers ≥ 20000 TDW	Same arrangement shall be fitted at the first scheduled dry docking but not later than 01.01.99.
01.07.96	December 1994 SOLAS Amendments	VI/2.1	Carriage of cargoes	The information required by subchapter 1.9 of Res. A.714(17) to be provided prior to loading.
		VI/5.6	Loading, stowing and securing of cargoes	Approved Cargo Securing Manual required, to comply with Res. A.714(17) (subchapters 1.6 and 1.7).
		VII/5.6	Loading, stowing and securing of dangerous goods	
		VII/6.1	Carriage of dangerous goods	Editorial change (including "loaded", "secured" in the text in addition to "stowed").
01.01.97	May 1995 SOLAS Amendments	V/8	All ships	Ships' routeing systems may be made mandatory for all ships.
01.02.97	1995 STCW Amendments		Seafaring	The STCW convention totally revised. The STCW code has been introduced and is mandatory.
01.07.97	1995 MARPOL, Annex V Amendments	Reg. 9	New ships	The STCW convention totally revised. The STCW Code has been introduced, and is mandatory.
			L ≥12 m	(Garbage) plackards
			L ≥ 12 m, in international trade	Garbage record book
			GRT ≥ 400 or persons ≥ 15	Garbage management plans
01.01.98	1996 MARPOL, Protocol I Amendments	Article II (1)	All ships, L ≥ 15 m	Reporting on incidents involving harmful substances(enhanced requirements).
01.07.98	May 1994 SOLAS Amendments	Ch.IX (new)		Management of the Safe Operation of Ships.
			Oil tankers, chemical carriers, gas carriers, bulk carriers, cargo high speed craft ≥ 500 GRT	The International Safety Management (ISM) Code (Res. A.741(18)) made mandatory. Shipowning companies to hold a Document of Compliance and the ship to hold a Safety Management Certificate.

Table A – Cargo Ships				
Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.07.98	May 1994 SOLAS Amendments	II – 2/15 new sub-paragraphs 2.9 – 2.11	New ships	Stricter requirements for protection of oil fuel lines (jacketed piping for high-pressure pipes, insulation of surfaces with temp. above 220ºC, screening).
		V/3(b)	All ships	Explanation of the phrase "Tropical storms".
		V/4(b)(ii)	All ships	Meteorological issues increased from once to twice daily
		V/22 (new regulation)	New ships, L ≥ 45 m	Requirements for visibility from navigation bridge introduced.
		V/22(b) (new)	Existing ships L ≥ 45 m	Paragraphs (a)(i) and (a)(ii) of Reg. V/22 shall as far as practicable apply to existing ships.
01.07.98	June 1996 SOLAS Amendments	Ch. II-1		The word "structure" is added in the title of Ch. II-1, which now reads: "Construction - Structure, Subdivision and Stability, Machinery and Electrical Installations".
		Ch. II-1, Part A-1		New part A-1
		II-1/3-1 (new regulation)	All ships	Ships shall be built and maintained according to the requirements of a classification society recognised by the Administration or to equivalent national standards.
		II-1/3-2 (new regulation)	New oil tankers. New bulk carriers.	Dedicated seawater ballast tanks to have efficient corrosion prevention system. To be approved, based on Res. A.798 (19).
		II-1/25-1.1	New dry cargo ships	Part B-1 (sub-division and damage stability) made applicable also to ships 80 m ≤ Ls ≤ 100 m
		II-1/25-3.2	New dry cargo ships	Definition of sub-division index for ships 80 m ≤ Ls ≤ 100 m
		II-1/45.1.1.1	New ships	The limit 55 V is changed to 50 V
		Ch. III	New requirements do in general apply to new ships	Completely revised Ch. III, introduction of International Life-Saving Appliances (LSA) Code, which is mandatory. Many regulations are changed to a greater or lesser extent, e.g. requirements for free-fall lifeboats. The technical requirements for the life-saving appliances are moved to the LSA Code.
		III/20	All ships	Operational readiness, maintenance and inspection of life-saving appliances: Yearly inspection of falls and renewal within 4 years as an alternative to "end for ending". Marking of stowage locations. 5 yearly examination and overload testing of launching appliances. On-load release gears: Biannual examination by properly trained personnel, 5 yearly overhaul and overload testing.
		VI/2.2.2	Carriage of bulk cargo	Cargo information to include likelihood of shifting and angle of repose
		VI/7	Carriage of bulk cargo	Loading, unloading and storage. Reg. 7 is revised, more extensive.
		XI/1	Organisations acting on behalf of Administrations	Reg. 1 revised, more extensive.
01.07.98	December 1996 SOLAS Amendments	II-1/3-3 (new regulation)	New oil, gas and chemical tankers	Means according to Res. MSC. 62 (67) to be provided to gain safe access to the bow
		II-1/3-4 (new regulation replaces V/15-1(b))	All oil, gas and chemical tankers ≥ 20 000 TDW	Emergency towing arrangements according to Res. MSC. 35 (63) shall be fitted at both ends of the ship. Ships constructed before 01.01.96 to comply at first scheduled dry-docking after 01.01.96, but not later than 01.01.99
		II-1/17-1 (new regulation)	New ships	Openings in shell plating below freeboard deck. Now ships shall comply with Res. II-1/17 where "margin line" shall mean "freeboard deck"

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-1/26.9 (new paragraph)	All ships	Survey of non-metallic expansion joints in piping systems penetrating the ship's side.
		II-1/26.10 (new paragraph)	All ships	Language to use in instructions and drawings essential for ship's machinery and equipment.
		II-1/26.11 (new paragraph)	New ships	Location and arrangement for vent pipes for fuel oil service, settling and lub. oil tanks. Two fuel oil service tanks for each fuel type.
		II-1/31.5 (new paragraph)	New ships	Machinery controls. Paragraph 5 introduces amendments to paragraphs 1 to 4 applicable to new ships.
		II-1/41.5 (new paragraph)	New ships	Supply of electrical power when it is necessary for propulsion and steering of the ships.
		II-1/43.3.4 (new sub-paragraph)	New cargo ships	Restart of propulsion within 30 min. after blackout.
01.07.98 continued	December 1996 SOLAS Amendments continued	II-2/1		Editorial.
		II-2/3		Changes in several definitions (mostly by referring to Fire Test Procedures Code). For materials which shall have low flame spread characteristics a new test for smoke and toxicity is required. This implies that most products previously approved must carry out an additional test.
		II-2/12.1.2	New sprinkler installations	Editorial changes.
		II-2/16 .1.1	New cargo ships	Combustible ducts, where allowed, shall have low flame spread characteristics.
		II-2/16.11 (new paragraph)	New cargo ships	Fire testing of fire dampers and A-class penetrations.
		II-2/18.8	New ships	Provisions for helicopter facilities shall be in accordance with Res. A.855(20).
		II-2/49.2 & .3	New cargo ships	Reference to Fire Test Procedure Code.
		II-2/50.3.1	New cargo ships	Low flame spread characteristics of vapour barriers
		II-2/53.1.2 & .1.3	New cargo ships	Fire protection of cargo spaces. Revised sub-paragraphs, clarifications.
			All cargo ships	Any of the mentioned exemptions to be stated in an Exemption Certificate
		II-2/53.2.5 (new sub-paragraph)	Ro-ro cargo spaces, new cargo ship	Ventilation openings not to endanger survival craft stowage and embarkation areas, service spaces and control stations.
		II-2/54.2.4.3 (new sub-paragraph)	New cargo ships	Natural ventilation required in enclosed cargo spaces for solid dangerous goods in bulk if not provided with mechanical ventilation.
		II-2/54.2.10	New cargo ships	Separation of ro-ro spaces for dangerous goods
		II-2/54 Table 54.1 Table 54.2 Table 54.3	Carriage of dangerous goods	The tables are revised
		II-2/56.7	New tankers	Exterior boundaries as specified to be constructed of steel (with A-60 insulation)
		II-2/56.8.3	New tankers	Windows in exterior boundaries as specified to be A-60
		II-2/56.9 (new paragraph)	New tankers	Any permanent access from a pipe tunnel to the main pump room shall be fitted with a watertight door
		II-2/59.1.2.3 (new sub-paragraph)	New tankers	Secondary means of full flow release of vapour from cargo tanks, alternatively pressure sensors with monitoring

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-2/59.1.3.2	New tankers	Supervision of operational status of isolating valves where combined tank venting
		II-2/59.1.3.3 (new sub-paragraph)	New tankers	Sub-paragraph .1.2.3 must be complied with if an isolated tank shall be loaded, ballasted or discharged
		II-2/59.5 (new paragraph)	All tankers	Portable instrument for measuring flammable vapour concentrations, spares and means of calibration to be provided
		II-2/62.11.2.1	New tankers	Positive means of indication of operational status for control systems for isolating branch pipes in inert gas systems
		V/15-1	Tankers	Regulation deleted and replaced by Reg. II-1/3-4
		VII/2	Carriage of dangerous goods	Class 6.1 and Class 9 reworded
01.07.98	1994 IGC Code Amendments	Reg. 15.1.5 (new paragraph)	All gas carriers with cargo tank type C, excluding type 1G ships	Option to use Reg. 8.2.18.(Interim arrangements have been accepted since 1993)
		Reg. 8.2.18 (new paragraph)		Increased filling limits
01.07.98	1995 MARPOL, Annex V Amendments	Reg. 9	Pre 01.07.97 ships:	
			L ≥ 12 m	(Garbage) plackards
			L ≥ 12 m, in international trade	Garbage record book
			GRT ≥ 400 or persons ≥ 15	Garbage management plans
01.07.98	1996 IBC Code Amendments (and 1956 BCH Code Amendments	Item 16.6.4	Chemical tankers	Heat sensitive cargoes in deck tanks
		Ch. 17 & 18	Chemical tankers	New products in List of Products
01.07.98	December 1996 IBC Code Amendments)		Chemical tankers	Editorial changes (in general: several references to acceptance by the Administration have been replaced with references to recognised standards)
First scheduled dry-docking after 01.07.98	December 1996 SOLAS Amendments	II-1/3-3.2 (new regulation)	Existing oil, gas and chemical tankers	Means according to Res. MSC. 62 (67) to be provided to gain safe access to the bow. (To be provided not later than 01.07.2001)
		II-2/59.1.11	Existing tankers. However, not applicable to chemical tankers carrying oil, for which IBC 8.1 & 8.3.3 or BCH 2.14.3 apply , ref. MEPC/Circ. 362 = MSC/ Circ.929	To comply with paragraphs .1.2.3 and .1.3.3 of Reg. II-2/59 (secondary means for full flow release of vapour from cargo tanks, alternatively pressure sensors with monitoring). (To be complied with not later than 01.07.2001)
06.07.98	1992 MARPOL, Annex I Amendments	9, 10, 16	All existing ships	Change in discharge criteria (phase out of 100 ppm oily water separators).
01.01.99	December 1996 SOLAS Amendments	II-1/3-4 (replaces Reg. V/15-1 (b))	Existing oil, gas and chemical tankers ≥ 20000 TDW	Emergency towing arrangements. Final date for compliance with Reg. II-1/3-4.
01.02.99	November 1988 SOLAS Amendments	GDMSS	Existing ships	Existing ships must comply with GMDSS

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.02.99	1997 MARPOL, Annex I Amendments	25 A (new regulation)	Oil tankers ≥ 5000DWT	Intact stability
01.07.99	June 1997 SOLAS Amendments	V/8-2 (new regulation)		Vessel traffic services
01.07.99	November 1997 SOLAS Amendments	Ch. XII (new chapter)	Bulk carriers with single side skin, L ≥ 150 m	Ch. XII enters into force
		XII/4	New ships carrying solid bulk cargoes with density ≥ 1000 kg/m^3	Damage stability requirement
		XII/5		Structural strength of holds
		XII/8		Information booklet. Marking on ship's sides (density ≥ 1780 kg/m^3)
		XII/10		Solid bulk cargo declaration
		XII/11		Loading instrument
Implementation depending on ship's age on 01.07.99 Schedule as in Reg. XII/3		XII/4	Existing ships carrying solid bulk cargoes with density ≥ 1780 kg/m^3	Damage stability requirements
		XII/6		Structural strength of holds
		XII/7		Restrictions for ships > 10 years to carry bulk cargo with density ≥ 1780 kg/m^3. Subject to enhanced periodical survey.
		XII/8		Information booklet. Marking on ship's sides.
		XII/9		Requirements for ships not being capable of complying with Regs. 4.2 and 6.
		XII/10		Solid bulk cargo declaration.
		XII/11		Loading instrument
01.08. 99	1997 MARPOL, Annex I Amendments	Reg. 10	All ships	North West European waters special area
01.01.2000	1997 MARPOL, Annex VI Protocol	Reg. 13	(New) diesel engines	NO_x emission. Note that engines for ships the keels of which are laid on or after this date shall comply with these (retroactive) requirements. The same applies to conversions and new installations on or after this date.
		Reg. 16	Installation of incinerators	Shipboard incineration. Note that incinerators installed on or after this date shall be approved according to these (retroactive) requirements.
03.02. 2000	1988 SOLAS Protocol		All ships	Harmonised certification and survey system enters into force (HSSC). New certificate forms. Five year certificates.
	1988 LL Protocol			
	1988 LL Protocol	I/10(a)(v)	Cargo ships	Min. two bottom surveys each 5 year period
		22(2), 27	New ships	Drainage of enclosed cargo spaces. Damage extent, residual stab. after damage
		10, 44	New and existing ships	Inclining test. CL-lifeline for timber freeboard
		Article VI 2(f) (ii) & 22 (g) (ii)		Tacit acceptance procedure for amendments to Annex B of the LL Protocol
03.02. 2000	1990 MARPOL Amendments		According to the respective convention or code	Harmonised certification and survey system enters into force
	1990 IBC Code Amendments			

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
	1990 BCH Code Amendments 1990 IGC Code Amendments			
Expected 01.01. 2001	May 1999 SOLAS Amendments	VII/1.3	Ships carrying INF cargo (also cargo ships <500 GRT)	Reference to INF cargo in the application.
		Ch. VII, Part D (new Part)		INF Code (Res. MSC. 88 (71) made mandatory. (INF cargo means packaged irradiated fuel, plutonium and high-level radioactive wastes carried as cargo)
Expected 01.01. 2001	1999 MARPOL, Annex I Amendments	Appendix II to Annex I	All tankers ≥ 150 GRT and all other ships ≥ 400 GRT	Contents of Supplement to IOPP Certificate updated
01.07. 2001	December 1996 SOLAS Amendments	II-1/3-3.2 (new regulation)	Existing oil, gas and chemical tankers	Final date for providing means according to Res. MSC .62(67) to gain safe access to the bow.
		II-2/59.1.11 (new sub-paragraph)	Existing tankers	Final date for complying with paragraphs .1.2.3 and .1.3.3 of Reg. II-2/59 (secondary means for full flow release of vapour from cargo tanks, alternatively pressure sensors with monitoring).
First periodical survey after 01.07. 2001	June 1996 SOLAS Amendments	III/32.2.3	Pre 01.07.98 cargo ships	Lights of lifejackets shall comply with paragraph 2.2.3 of the LSA Code.
01.07. 2002	May 1994 SOLAS Amendments	Ch. IX		Management of the Safe Operation of Ships.
			Cargo ships ≥ 500 GRT for which the ISM Code did not enter into force on 01.07.98 Mobile offshore drilling units ≥ 500 GRT	The International Safety Management (ISM) Code (Res. A.741(18)) made mandatory. Shipowning companies to hold a Document of Compliance and the ship/unit to hold a Safety Management Certificate.

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
Expected: 01.07. 2002	1998 SOLAS Amendments	II-1 /14.1	New ships	Testing of watertight compartments (filling with water not compulsory)
		IV /1.1	All ships	”unless provided otherwise” is inserted in Application
		IV / 2.1.16 (new sub-paragraph)	All ships	Definition of GMDSS *identity*
		IV / 2.2	All ships	Reference to definitions in the Radio Regulations and SAR Convention
		IV / 5.1 (new regulation)	All ships	Governments to register GMDSS identity
		IV / 13.8	All ships	Continuous supply of information to navigation receiver
		IV /15.9	All ships	Testing of EPIRBs at 12 months intervals
		IV / 18 (new regulation)	All ships	Position-updating of two-way communication equipment
		VI / 5.6	Securing of cargo	Rewording (excluding solid and liquid bulk cargoes)
		VII / 5.6	Carriage of dangerous goods	Paragraph 6(?) is deleted
		VII / 6		New heading: ”Stowage and securing”
		VII /6.6		New paragraph or rewording of existing paragraph in Consolidated Edition 1997: Loading, stowing and securing to be in accordance with the approved Cargo Securing Manual
Proposed: 01.07.2002	2000 SOLAS Amendments	II-2/7.7 (new paragraph)	New cargo ships = 2000 GRT	Fixed water-based (or equivalent) local fire extinguishing arrangements in category A machinery spaces > 500 m^3 in gross volume. (This new requirement will be incorporated in the revised Ch. II-2).

Table A – Cargo Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
Expected: First dry docking after 01.07. 2002	1999 IBC Code Amendments	Ch. 8, 8.1 & 8.3.3	Ships holding IBC Code Certificates	Secondary means for full flow release of vapour from cargo tanks, alternatively pressure sensors with monitoring. (To be complied with not later than 01.07.2005).
	1999 BCH Code Amendments	Ch. 2 2.14.3	Ships holding BCH Code Certificates	
Expected 01.01. 2003	1998 STCW Code Amendments	Tables A-II/1 & A-II/2	Deck officers engaged in cargo handling and stowage	The specifications have been made more detailed
Expected 01.01. 2003	1999 MARPOL, Annex I Amendments	13 G (1)	Pre MARPOL product tankers between 20 000 DWT and 30 000 DWT and > 25 years	The requirement (enhanced survey, 30% side or bottom protection or equivalent, compliance with Reg. 13 F or phase out) extended to apply to ships between 20 000 and 30 000 DWT.
		26(3) (new paragraph)	All oil tankers = 150 GRT, all other ships = 400 GRT certificated to carry noxious liquid substances in bulk	SOPEP plan may be combined with the Shipboard Marine Pollution Emergency Plan for Noxious Liquid Substances required by Annex II, Reg. 16
Expected 01.01. 2003	1999 MARPOL, Annex II Amendments	Reg. 16 (new reg.)	All ships = 150 GRT certificated to carry noxious liquid substances in bulk	Ship shall carry Shipboard Marine Pollution Emergency Plan for Noxious Liquid Substances.
01.07. 2003	May 1994 SOLAS Amendments	II-2/15.2.12	Ships constructed before 01.07.98	Paragraphs 2.9, 2.10 and 2.11 of Reg. 15 to be complied with within this date, i.e. stricter requirements for protection of oil fuel lines (jacketed piping for high-pressure pipes, insulation of surfaces with temp. above 220ºC, screening).
Expected 01.07. 2005	1999 IBC Code Amendments	Ch.8, 8.1 & 8.3.3	Ships holding IBC code certificates	Final date for complying with IBC code 8.1 & 8.3.3 or BCH code 2.14.3 respectively (secondary means for full flow release of vapour from cargo tanks, alternatively pressure sensors with monitoring).
	1999 BCH Code Amendments	Ch.2, 2.14.3	Ships holding BCH code certificates	

12 months after accep-tance	1997 MARPOL, Annex VI Protocol	New Annex VI	All ships	Regulations for the Prevention of Air Pollution from ships
		Regs. 5 & 6	GRT ≥ 400	Survey & inspection. Certificate required
		Reg. 13	Diesel engines ≥ 130 kW, ship keel laid ≥ 01.01.2000 or conversions/new installations	NO_x emission. Retroactive requirements.
		Reg. 16	Incinerators installed ≥ 01.01.2000	Shipboard incineration only allowed in approved incinerators. Retroactive requirements.

ENTRY INTO FORCE DATES OF INTERNATIONAL CONVENTIONS

The below table shows the date of coming into force of the various international conventions and their amendments.

Note:
"New ships" means new in relation to the enter into force date of the respective convention/amendments, while an "existing ship" means a ship constructed before that date.

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
19.11.52	SOLAS 1948		New ships	
26.05.65	SOLAS 1960		New ships	
21.07.68	ICLL 1966		New ships	
15.07.77	COLREG 1972		New ships	
25.05.80	SOLAS 1974		New ships	
		Ch. II-2, Part F	Existing passenger ships	Upgrading of fire safety measures
01.05.81	SOLAS 1978 Protocol		All ships	
15.07.81	COLREG 1972	E/38	Existing ships	Range of lights and colour specification
18.07.82	1969 Tonnage		New ships	
02.10.83	MARPOL 73/78	Annex I	All ships	Annex I enters into force. Oil
01.09.84	1981 SOLAS Amendments	Ch. II-1	New ships	Completely revised Ch.II-1
		Ch. II-2	New ships	Completely revised Ch.II-2
		II-2/17	Existing passenger ships	Fireman's outfit
		II-2/20	Existing ships	Fire control plans
		IV/4-1, 17&19	All ships	VHF radiotelephone
		IV/7 & 8	All ships	Watches/operators
		IV/10	All ships	Two-tone alarm
		V/12	All ships	Gyro compass, echo sounding device, rudder angle indicator, revolution indicator
		V/12(j)	New ships	ARPA, ships GRT $\geq$ 10000
01.07.86	1983 SOLAS Amendments	III	New ships	Completely revised Ch.III
		III/8 & 53	Existing ships	Muster list and emergency instructions
		III/9	Existing ships	Operating instructions
		III/10	Existing ships	Manning and supervision of survival craft
		III/18	Existing ships	Abandon ship training and drills
		III/19	Existing ships	Operational readiness, maintenance and inspections
		III/25	Existing passenger ships	Drills
15.07.86	COLREG	E/38	Existing ships	Navigation lights, positioning and sound signals
01.09.86	1981 SOLAS Amendments	V/12(j)	Existing ships	ARPA, GRT $\geq$ 40000
01.09.87	1981 SOLAS Amendments	V/12(j)	Existing ships	ARPA, 20000 $\leq$ GRT < 40000
01.09.88	1981 SOLAS Amendments	V/12(j)	Existing ships	ARPA, 15000 $\leq$ GRT < 20000

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
31.12.88	MARPOL 73/78	Annex V		Annex V (optional) enters into force. Garbage
01.04.89	1987 MARPOL Annex I Amendments	10(1)(f)	All ships	Gulf of Aden is special area. However, effective one year after reception facilities confirmed by coast states.
22.10.89	April 1988 SOLAS Amendments	II-1/23-2	Passenger/Ro-Ro/ car carriers, new ships	Indicators on bridge for leakage through shell doors etc.
			Passenger/Ro-Ro/ car carriers, new and existing ships	Indicators on bridge for closing of shell doors etc. Surveillance of vehicle decks
		II-1/42-1	Passenger/Ro-Ro/ car carriers, new ships	Supplementary emergency lighting
01.01.90	ITU Regulations (ref. SOLAS, Ch.IV, Reg.2(a))	Appendix 7	All ships	Stricter frequency tolerances for all radio transmitters
29.04.90	October 1988 SOLAS Amendments	II-1/8	Passenger ships, new ships	Residual stability after damage ("SOLAS '90 Standard")
			Passenger ships, new and existing ships	Upgrading of stability info, draught marks, determination of stability before departure
		II-1/20-2	Passenger ships, new and existing ships	Before proceeding to sea: closing of all shell doors etc. and logging same
		II-1/22	Passenger ships, new and existing ships	Lightweight survey at 5 year intervals
22.10.90	April 1988 SOLAS Amendments	II-1/42-1	Passenger/Ro-Ro/ car carriers, existing ships	Supplementary emergency lighting
01.07.91	1983 SOLAS Amendments	III/1.4.5	Existing ships	Life-saving appliances installed or replaced shall be tested and approved according to 1983 Amendments
		III/6.2.3	Existing ships	Fit two EPIRBs
		III/6.2.4	Existing ships	Fit at least three two-way radiotelephone apparatus (see also entry into force date 01.02.95)
		III/21.3	Passenger ships, existing ships	All lifejackets to be fitted with light (not required for ships on short international voyage (see, however, Reg. III/24-15 in force after 01.07.98)).
		III/21.4	Passenger ships, existing ships	Provide for each lifeboat at least three immersion suits and provide one thermal protective aid for the rest of the persons allowed to be accommodated in the lifeboat
		III/30.2.7	Passenger ships, existing ships	Life-saving appliances to be fitted with retro-reflective material
01.02.92	November 1988 SOLAS Amendments	GMDSS		GMDSS enters into force
		I/12	All ships	New forms for SOLAS Certificates
01.02.92	1989 SOLAS Amendments	II-1/15	New passenger ships	New Reg.15. Stricter requirements for W.T. doors.
		II-1/21	New ships	Internal drainage for enclosed spaces where the deck edge is immersed at 5º heel.
		II-1/42.4.2	New passenger ships	Battery power for W.T. doors: Minor adjustment.
		II-2/13-1	New ships	Requirements for sample extraction smoke detection systems.
		II-2/15.2.6 & /15.3	New ships	Sounding pipes for oil fuel tanks should not terminate in machinery spaces (general rule) (lub. oil may).

Table B – Passenger Ships				
Date of entry into force	*Conventio n*	*Reg. No.*	*Applicable to*	*Subject*
		II-2/18.8	New ships	Helicopter decks, requirements specified.
		II-2/26	New passenger ships > 36 passengers	Lockers and store rooms: Fire risk category depending on area < or> 4m^2.
		II-2/27	New passenger ships < 36 passengers	Area limit changed from 2m^2 to 4m^2 for some spaces (fire risk categories).
01.02.92 continued	1989 SOLAS Amendments continued	II-2/38 & /40.2	New passenger ships	Sample extraction smoke detection system may be used in cargo spaces
		II-2/54.2.3	New ships carrying dangerous goods	More specific requirements for fire detection. Sample extraction smoke detection system may be used.
		V/12(f)	New ships > 500 GRT	Gyro repeater at emergency steering position.
			All ships	Heading information to emergency steering position shall consist of telephone (or similar).
		II-2/4.7	All ships	Fire hoses to be of non-perishable material. Also applicable to existing ships when hoses are renewed
		II-2/18.7	All ships	Fire extinguishing arr. in paint lockers and lockers for flammable liquids.
		V/13	All ships	Minimum Safe Manning Certificate
		V/16	All ships	Life saving signals are not described in SOLAS any longer. Instead it is referred to IMO Resolutions A.229 (VII), A.439 (XI) and A.80 (IV).
		VII/ 7	All passenger ships	Reg. 7 rewritten. New specification for which explosives may be carried in passenger ships.
17.03.92	1990 MARPOL Amendments	Annexes I and V	All ships	Antarctic is special area
01.07.92	MARPOL 73/78	Annex III		Annex III (optional) enters into force. Harmful substances in packaged forms
22.10.92	April 1988 SOLAS Amendments	II-1/23-2.2	Passenger/Ro-Ro/ car carriers , existing ships	Indicators on bridge for leakage through shell doors etc. (See also the revision in force after 01.07.97).
04.04.93	1991 MARPOL, Annex I Amendments	26	New ships	Shipboard oil pollution emergency plan
		17(3), 20	Every ship ≥ 400 tons gross tonnage	Piping for oil residues (sludge) Piping to and from sludge tanks Revised format of Oil Record Book.
06.07.93	1992 MARPOL, Annex I Amendments	9, 10, 16, 21 and suppl. A & B	All ships	Various replacements of existing regulation texts (discharge criteria)
01.08.93	November 1988 SOLAS Amendments (GMDSS)	IV/1.4	All ships	All ships must carry NAVTEX and float-free satellite EPIRB (406 MHz)
01.01.94	1991 SOLAS Amendments	Ch.II-2	New passenger ships	Means of escape and smoke extraction system for large, multi-deck open spaces and sprinkler and smoke detection system for the whole zone.
		II-2/20.3 & III/18	All ships	Fire drills and on-board training, extended requirements
		V/17	New installations	Pilot transfer arrangements
		Ch.VI	As applicable	The carriage of cargoes (new Ch.VI).
		VII/5	Ships carrying dangerous goods	Packing certificate, list of dangerous goods carried
		VII/7-1		Reporting of incidents

Table B – Passenger Ships				
Date of entry into force	*Conventio n*	*Reg. No.*	*Applicable to*	*Subject*
28.02.94	1992 MARPOL, Annex III Amendments	Annex III	All ships carrying harmful substances in packaged form	The whole Annex III (optional) is revised: References to freight containers, portable tanks or tank wagons deleted. "Harmful substances" are identified in the IMDG Code. Guidelines for identification. Marking shall stand 3 months immersion in the sea. Marking and freight document shall include "Marine Pollutant". Copy of freight document to port authorities.
18.07.94	1969 Tonnage	Article 3(2)(d)	All ships	All ships must have tonnage cert. according to the 1969 International Tonnage Convention.
01.10.94	April 1992 SOLAS Amendments	II-1/8	Pre 29.04.90 passenger ships with car decks, A/Amax < 70	Upgrading of damage stability to SOLAS '90 standard
		II-2/17	All passenger ships	Fireman's outfits, extended requirements
		II-2/41-1 & II-2/41-2	Pre 01.10.94 passenger ships	Upgrading of fire safety (Fire Control Plans, walkie-talkies for fire patrol, waterfog applicators, portable foam applicators, dual purpose hose nozzles).
01.10.94	December 1992 SOLAS Amendments	II-1/37	New ships	Communication between bridge and machinery spaces (modified text)
		II-1/42,43,44	New ships	Emergency generator starting: Clarification of text
		II-1/45.3	New ships	Locally earthed systems, clarification
		II-2/3.33	New passenger ships	New definition of "Main vertical zone" also limiting the breadth (40m)
		II-2/4.3.3.3	New ships	Emergency fire pump for passenger ships < 1000 GRT
		II-2/4.4.2	New ships	Pressure in fire lines, new requirements
		II-2/5.2	New CO_2 installations	Separate operations for opening the storage bottles and for discharging into protected space
		II-2/5.3	New installations	New Halon installations prohibited
		II-2/13.1	New (or modified) installations	Fire detection systems: Requirements modified in respect of addressable systems
		II-2/20	All passenger ships > 36 passengers	Fire control plan to include information specified in IMO Res. A.756 (18)
		II-2/24.1.1	New passenger ships > 36 passengers	All main fire zone (MFZ) divisions to be A-60
		II-2/24.2	New passenger ships	Stricter requirements w.r.t. W.T.- and MFZ-bulkheads being in line, length of MFZ may extend to 48m, but area not to exceed 1600m^2.
		II-2/25.2 & .3	New passenger ships > 36 passengers	Modified requirements to B-class bulkheads since sprinklers are required
		II-2/26	New passenger ships	Tables 26.1 and 26.3 (MFZ boundaries) deleted (see Reg. II-2/24.1.1). Also other revisions
		II-2/28	New passenger ships	Dead end corridors prohibited Requirements for external open stairways and passageways. Requirements for width of stairways, doors, corridors and landings. Stairways for more than 90 persons to be aligned fore and aft. Low location marking (0.3m) (light/photoluminescent strips) in escape routes (ref. Res. A.752 (18)). Two means of escape from engine control rooms within machinery space.
		II-2/29.2	New passenger ships	Clearer text with respect to prohibition of cabins etc. in stairway enclosures.

Table B – Passenger Ships				
Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-2/30	New passenger ships	Stricter requirements to fire doors (rate of closure, warning alarms, remote and local (both sides) release, local power accumulators for 10 movements). Openings for fire hoses.
		II-2/31	New passenger ships	Slightly stricter requirements for B-class doors. Cabin doors to be self-closing without holdbacks.
		II-2/32	New passenger ships	Stairway enclosures shall be ventilated - separate fan and ducting. Inspection and cleaning hatches for ventilation ducts. More details for galley ventilation
		II-2/33	New passenger ships	Stricter requirements for windows (A-class) in way of embarkation areas and escape routes.
		II-2/34	New passenger ships	Restrictions regarding furniture in stairway enclosures and corridors.
01.10.94 continued	December 1992 SOLAS Amendments continued	II-2/36	New passenger ships > 36 passengers	Sprinkler system required in service, control and accommodation spaces. Smoke detectors also required.
		II-2/37	New passenger ships with car deck, > 36 passengers	Special category spaces to have A-60 boundaries
		II-2/40	New passenger ships > 36 passengers	Walkie-talkies for fire patrols. Continuously manned central control station for fire detection alarms, remote closing of fire doors, shutting down of fans, reactivation of fans, fire door indicators. Supply from main and emergency source of power, fail-safe principle.
		III/50	New ships	General emergency alarm shall continue to sound until manually turned off. Requirements for sound pressure level.
		IV/13	GMDSS ships	Revised specification of capacities for radio batteries.
01.02.95	November 1988 SOLAS Amendments	GDMSS	New ships	New ships must comply with GMDSS
01.02.95	November 1988 SOLAS Amendments (GMDSS)	III/6.2.1	Existing ships	Two-way radiotelephone apparatus to be of VHF-type and to comply with IMO Resolution A.605 (15)
		III/6.2.2	Existing ships	Fit two radar transponders complying with IMO Resolution A.604 (15)
		V/12(g)	Existing ships	One radar installation to operate in 9GHz band
04.04.95	1991 MARPOL, Annex I Amendments	26	Existing ships	Shipboard oil pollution emergency plan
04.11.95	1993 COLREG Amendments	General	General	Minor changes
		Annex I, new section 13	High speed craft	Masthead light
01.01.96	May 1994 SOLAS Amendment	Ch.X (new)	New high speed craft	High Speed Craft Code (Res. MSC.36(63)) enters into force and is made mandatory as a part of SOLAS.
		Ch.XI (new)		Special Measures to Enhance Maritime Safety
		Reg.1	Organisations acting on behalf of Administrations	Authorisation of recognised organisations (Res. A.739(18) made mandatory).
		Reg.3	All passenger ships ≥ 100 GRT	Ship identification numbers (IMO Nos.) mandatory (Res. A.600(15)).
		Reg.4		Port state control of operational requirements (Res. A.742(18) made mandatory).

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Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
01.01.96	May 1994 SOLAS Amendments	V/8-1 (new regulation)	All ships	Ship reporting systems introduced. Ref. Res. MSC.43(64). Also ref. Res. A.648(16).
01.07.96	December 1994 SOLAS Amendments	VI/2.1	Carriage of cargoes	The information required by subchapter 1.9 of Res. A.714(17) to be provided prior to loading.
		VI/5.6	Loading, stowing and securing of cargoes	Approved Cargo Securing Manual required, to comply with Res. A.714(17) (subchapters 1.6 and 1.7).
		VII/5.6	Loading, stowing and securing of dangerous goods	
		VII/6.1	Carriage of dangerous goods	Editorial change (including "loaded", "secured" in the text in addition to "stowed").
01.10.96	April 1992 SOLAS Amendments	II-1/8	Pre. 29.04.90 Passenger ships with car decks, 70 ≤ A/Amax <75	Upgrading of damage stability to SOLAS '90 standard
01.01.97	May 1995 SOLAS Amendments	V/8	All ships	Ships' routeing systems may be made mandatory for all ships.
01.02.97	1995 STCW Amendments		Seafaring	The STCW convention totally revised. The STCW Code has been introduced, and is mandatory.

First yearly inspection after 01.04.97	Stockholm Agreement (regional agreement)	Annex 2	Passenger ships with car decks, A/Amax < 85, operating in North West Europe or the Baltic Sea	To comply with specific stability requirements taking into account accumulated sea water on car deck

01.07.97	1995 MARPOL, Amex V Amendments	Reg. 9	New ships:	
			L ≥ 12 m	(Garbage) plackards
			L ≥ 12 m, in international trade	Garbage record book
			GRT ≥ 400 or persons ≥ 15	Garbage management plans
01.07.97	November 1995 SOLAS Amendments	II-1/1.3.2	Passenger ships	Reference to Reg. 8.9 is replaced with reference to Reg. 8-1
		II-1/2.13 (new paragraph)	Ro-ro passenger ships	Definition of "ro-ro passenger ship" introduced (same as in Reg. II-2/3.34)
		II-1/8 II-1/8.7.4	Passenger ships Passenger ships	Editorial to comply with above. Determination of stability shall be made by calculation.
		II-1/8-2 (new regulation)	New ro-ro passenger ships >400 passengers	Must be two compartment ships
		II-1/10.3, .4 & .5	New passenger ships	New requirements for bow doors and extension of collision bulkhead/inner ramp
		II-1/15.6.5 (new sub-paragraph)	Pre 01.02.92 passenger ships	W.T. doors shall be kept closed during navigation and so logged.
		II-1/19.2 (new paragraph)	New passenger ships	Ventilation trunks penetrating bulkhead deck shall be capable of withstanding pressure of water trapped on the ro-ro deck
		II-1/19.3 (new paragraph)	New ro-ro passenger ships	Ventilation trunks penetrating the main ro-ro deck shall be capable of withstanding impact pressure of sloshing of water trapped on the deck.

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-1/20.3 (new paragraph)	New passenger ships	Internal open ends of air pipes to be min. 1 m above heeled waterline (or terminate through superstructure side).
		II-1/20-2.1 (new regulation)	New ro-ro passenger ships	Access to spaces below bulkhead deck shall unless otherwise permitted by the Administration, have sill-/coaming height min. 2.5 m. Vehicle ramps may be flush, but shall be weathertight and have alarm and indication, closed at sea and logged.
		II-1/20-3 (new regulation)	Ro-ro passenger ships	Passengers shall not have access to an enclosed ro-ro deck while the ship is underway (see also Reg. 23-2.3).
		II-1/20-4 (new regulation)	Ro-ro passenger ships	On the ro-ro deck all transverse or longitudinal bulkheads effective to confine accumulated sea water on deck shall be secured in place while the ship is at sea.
		II-1/23-2.1	Ro-ro passenger ships	This paragraph is rewritten, stricter, more precise and extended (hull doors): Audible alarm if a secured item becomes open, "harbour/see voyage" mode, audible alarm if the ship leaves with any doors not closed. (For most existing ships some upgrading will be necessary).
01.07.97 continued	November 1995 SOLAS Amendments continued	II-1/23-2.2	New ro-ro passenger ships	This paragraph is rewritten and made stricter. Both television surveillance and water leakage detection for hull doors including both inner and outer bow door with indication both on Bridge and engine control room.
		II-1/23-2.3 & .4	Ro-ro passenger ships	Paragraph 3 is rewritten: If patrolling of vehicle deck is chosen , the patrolling shall be continuous. New paragraph 4. Documented operating procedures for closing and securing of hull doors.
		II-2/3.34 (new paragraph)	Ro-ro passenger ships	Definition of "ro-ro passenger ship" introduced.
		II-2/28-1.1 (new regulation)	New ro-ro passenger ships	Handrails or other handhold shall be provided in all corridors along the entire escape route. Escape routes shall be provided from every normally occupied space on the ship to an assembly station. Cabin and stateroom doors and doors in escape routes shall not require keys to unlock. Decks shall be sequentially numbered, starting with "1" on tank top or lowest deck. "You are here" mimic panels showing escape routes to be displayed in each cabin and in public spaces.
		II-2/28-1.2 (new regulation)	New ro-ro passenger ships	The lowest 0.5 m of bulkheads and vertical divisions along escape routes shall have strength for walking on (750 N/m) when ship heavily heeled. Straight escape routes. Passenger spaces not to be more than two decks above or below assembly stations or open deck from which there is routes to embarkation stations.
		II-2/37.2.1.2 (new sub-paragraph)	Ro-ro passenger ships	Discharge valves for scupper with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements of the ICLL, shall be kept open while the ships are at sea. Operation of these valves shall be recorded in log book.
		III/3.19 (new paragraph)	Ro–ro passenger ships	Definition of "ro-ro passenger ship" introduced (same as in Reg. II-2/3.34)
		III/6.5 new paragraph)	New passenger ships	New and stricter requirements to Public Address (PA) systems. Two loops sufficiently separated, two independent amplifiers, performance standards introduced, to be connected to the emergency source of power, etc.

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Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		III/24-2 (new regulation)	All passenger ships	Passengers shall be counted, and details of persons with need of special care in emergency situations to be recorded. Data are also to be kept ashore.
		III/24-3 (new regulation)	New ro-ro passenger ships	Helicopter pick-up area to be provided.
		III/24-4 (new regulation)	New passenger ships	Decision-support system for emergency management.
		IV/6.4 (new paragraph)	New passenger ships	A distress panel shall be installed at the conning position. The panel shall contain one button that initiates a distress alert using all required radiocommunication installation on board, or one button for each installation.
		IV/6.5 (new paragraph)	New passenger ships	Information on the ship's position shall be continuously and automatically provided to all relevant radio-communication equipment to be included in the initial distress alert
		IV/6.6 (new paragraph)	New passenger ships	A distress alarm panel for receiving distress alerts shall be installed at the conning position.
		IV/7.5 (new paragraph)	New passenger ships	Every passenger ship shall be provided with means for two-way on-scene radio communications for search and rescue purposes using the aeronautical frequencies 121.5 MHz and 123.1 MHz.
01.07.97 continued	November 1995 SOLAS Amendments continued	IV/16.2 (new paragraph)	Passenger ships	In passenger ships, at least one person qualified in accordance with paragraph 1 shall be assigned to perform only radiocommunication duties during distress incidents.
		V/10	All ships	Distress messages: Obligations and procedures. The text of this regulation is revised.
		V/10-1 (new regulation)	All ships	Master's discretion for safe navigation
		V/13 (c) (new paragraph)	Passenger ships	A working language shall be established and entered in log book. All plans/lists required to be posted are to be translated to the working language.
		V/15 (c) (new paragraph)	Passenger ships	Ships on fixed routes shall have a plan for co-operation of search and rescue services in event of emergency. To be developed in co-operation with the rescue services. To be approved by the Administration
		V/23 (new regulation)	New passenger ships	A list of operational limitations and exemptions shall be kept on board.
		VI/5.6 (new paragraph)	All ships carrying cargo	Before the ship leaves the berth all cargo units, including vehicles and containers, shall be loaded, stored and secured in accordance with an approved Cargo Securing Manual
First periodical survey after 01.07.97	November 1995 SOLAS Amendments	II-1/10.3, .4 & .6	Existing passenger ships (especially ro-ros)	New and enjoining requirements for bow doors and extension of collision bulkhead/inner ramp
		II-1/19.2 & .4 (new paragraphs)	Existing passenger ships	Ventilation trunks penetrating bulkhead deck shall be capable of withstanding pressure of water trapped inside the trunk
		II-1/19.3, &.4 (new paragraphs)	Existing ro-ro passenger ships	Ventilation trunks penetrating the main ro-ro deck shall be capable of withstanding impact pressure of sloshing of water trapped on the ro-ro deck
		II-1/20-2.2 (new regulation)	Existing ro-ro passenger ships	Accesses from the ro-ro deck to spaces below shall be made weatertight. (*DVN uses 3.5 m water pressure in the necessary calculations).*To be closed before the ship leaves the berth and kept closed at sea. Indication to be provided on the Bridge. Entries to be made in log book.

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-1/23-2.2	Existing ro-ro passenger ships	This paragraph is rewritten and made stricter. Both television surveillance and water leakage detection for hull doors including both inner and outer bow door with indication both on Bridge and engine control room
		II-2/28-1.1 (new regulation)	Existing ro-ro passenger ships	Handrails or other handhold shall be provided in all corridors along the entire escape route. Escape routes shall be provided from every normally occupied space on the ship to an assembly station. Cabin and stateroom doors and doors in escape routes shall not require keys to unlock. Decks shall be sequentially numbered, starting with “1” on tank top or lowest deck. “You are here” mimic panels showing escape routes to be displayed in each cabin and in public spaces.
		III/6.5 (new paragraph)	Existing passenger ships	New and stricter requirements for Public Address (PA) systems are introduced. Sub-paragraphs 5.2, 5.3 and 5.5 are also applicable to existing ships. Sub-paragraph 5.6 allows upgrading to be omitted if existing PA systems comply substantially with the new requirements.
		III/24-3 (new regulation)	Existing ro-ro passenger ships	Helicopter pick-up area to be provided.
First periodical survey after 01.07.97 continued	November 1995 SOLAS Amendments continued	IV/6.4 (new paragraph)	Existing passenger ships	A distress panel shall be installed at the conning position. The panel shall contain one button that initiates a distress alert using all required radiocommunication installation on board, or one button for each installation
		IV/6.5 (new paragraph)	Existing passenger ships	Information on the ship’s position shall be continuously and automatically provided to all relevant radio-communication equipment to be included in the initial distress alert
		IV/6.6 (new paragraph)	Existing passenger ships	A distress alarm panel for receiving distress alerts shall be installed at the conning position
		IV/7.5 (new paragraph)	Existing passenger ships	Every passenger ship shall be provided with means for two-way on-scene radio communications for search and rescue purposes using the aeronautical frequencies 121.5 MHz and 123.1 MHz.
		V/23 (new regulation)	Existing passenger ships	A list of operational limitations and exemptions shall be kept on board.
01.10.97	April 1992 SOLAS Amendments	II-2/41-1 II-2/41-2	Pre. 01.10.94 passenger ships	Upgrading of fire safety (smoke detection, fire doors, galley exhaust, stairway enclosures, low location (0.3m) marking of escape routes (light/ photoluminescent strips ref. Res. A.752 (18)), general emergency alarm system, P.A. system.
		II-2/41-1.2.2 II-2/41-2.5	Pre. 25.05.80 Passenger ships	Automatic sprinkler, fire detection and fire alarm system.
01.01.98	1996 MARPOL, Protocol I Amendments	Article II (1)	All ships, L ≥ 15 m	Reporting of incidents involving harmful substances (enhanced requirements)
01.07.98	May 1994 SOLAS Amendments	Ch.IX (new)		Management of the Safe Operation of Ships
			Passenger ships, passenger high speed craft	The International Safety Management (ISM) Code (Res. A.741(18)) made mandatory. Shipowning companies to hold a Document of Compliance and the ship to hold a Safety Management Certificate.
01.07.98	May 1994 SOLAS Amendments	II-2/15 new subparagraphs 2.9 – 2.11	New ships	Stricter requirements for protection of oil fuel lines (jacketed piping for high-pressure pipes, insulation of surfaces with temp. above 220ºC, screening).

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Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		V/3(b)	All ships	Explanation of the phrase "Tropical storms".
		V/4(b)(ii)	All ships	Meteorological issues increased from once to twice daily.
		V/22 (new regulation)	New ships, L ≥ 45 m	Requirements for visibility from navigation bridge introduced.
		V/22(b) (new)	Existing ships L ≥ 45 m	Paragraphs (a)(i) and (a)(ii) of Reg. V/22 shall as far as practicable apply to existing ships.
01.07.98	1995 MARPOL, Annex V Amendments	Reg. 9	Pre. 01.07.97 ships:	
			L ≥ 12 m	(Garbage) plackards
			L ≥ 12 m, in international trade	Garbage record book
			GRT ≥ 400 m or persons ≥ 15	Garbage management plans
01.07.98	November 1995 SOLAS Amendments	II-1/45.5.3	Ro-ro passenger ships	New installations of cabling for emergency alarms and Public Address systems shall comply with recommendations from IMO
		III/24-1.2.3 & .2.4 (new regulation)	New ro-ro passenger ships	Every liferaft to be fitted with a boarding ramp. Every liferaft to be self-righting or reversible.
		III/24-1.3 (new regulation)	New ro-ro passenger ships	At least one of the rescue boats shall be a “fast rescue boat”. Special training of crew.
		III/24-1.4 (new regulation)	New ro-ro passenger ships	Ship to be provided with means for recovery of survivors.
		III/24-1.5 (new regulation)	New ro-ro passenger ships	A sufficient number of lifejackets shall be stowed in the vicinity of the assembly stations so that the passengers do not have to return to their cabins to collect their lifejackets. Each lifejacket shall have light.
01.07.98	June 1996 SOLAS Amendments	Ch. II-1		The word “structure” is added in the title of Ch. II-1, which now reads: “Construction - Structure, Subdivision and Stability, Machinery and Electrical Installations”
		Ch. II-1, Part A-1		New Part A-1
		II-1/3-1 (new regulation)	All ships	Ships shall be built and maintained according to the requirements of a classification society recognised by the Administration or to equivalent national standards.
		II-1/8.2.3.1 & .2.3.3	New passenger ships	Range of positive stability in damaged condition (may be reduced to 10°).
		II-1/45.1.1.1	New ships	The limit 55 V is changed to 50 V
		Ch. III	New requirements are mostly applicable to new ships	Completely revised Ch. III, introduction of International Life-Saving Appliances (LSA) Code, which is mandatory. Many regulations are changed to a greater or lesser extent, mentioned here are: Maritime evacuation systems (MES), anti-exposure suits. The technical requirements of the life-saving appliances are moved to the LSA code.
		III/20	All ships	Operational readiness, maintenance and inspection of life-saving appliances: Yearly inspection of falls and renewal within 4 years as an alternative to “end for ending”. Servicing and deployment of MES. Marking of stowage locations. 5 yearly examination and overload testing of launching appliances. On-load release gear: Yearly examination by properly trained personnel, 5 yearly overhaul and overload testing.

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Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		III/22.3	All passenger ships	Light on lifejackets (existing lights not complying with paragraph 2.2.3 of LSA Code to be replaced within first periodical survey after 01.07.2002).
		XI/1	Organisations acting on behalf of Administrations	Reg. 1 revised, more extensive.
01.07.98	December 1996 SOLAS Amendments	II-1/17-1 (new regulation)	New ships	Openings in shell plating below bulkhead deck. New ships shall comply with Reg. II-1/17 where "margin line" shall mean "bulkhead deck".
		II-1/26.9 (new paragraph)	All ships	Survey of non-metallic expansion joints in piping systems penetrating the ship's side.
		II-1/26.10 (new paragraph)	All ships	Language to use in instructions and drawings essential for ship's machinery and equipment.
		II-1/26.11	New ships	Location and arrangement for vent pipes for fuel oil service, settling and lub. oil tanks. Two fuel oil service tanks for each fuel type.
		II-1/31.5 (new paragraph)	New ships	Machinery controls. Paragraph 5 introduces amendments to paragraphs 1 to 4 applicable to new ships.
01.07.98 continued	December 1996 SOLAS Amendments continued	II-1/41.5 (new paragraph)	New ships	Supply of electrical power when it is necessary for propulsion and steering of the ships.
		II-1/42.3.4 (new sub-paragraph)	New passenger ships	Restart of propulsion within 30 min. after blackout.
		II-2/1		Editorial
		II-2/3		Changes in several definitions (mostly by referring to Fire Test Procedures Code) For materials which shall have low flame spread characteristics a new test for smoke and toxicity is required. This implies that most products previously approved must carry out an additional test.
		II-2/12.1.2	New sprinkler installations	Indicating unit shall be on the Navigation Bridge.
		II-2/16.1.1	New passenger ships ≤ 36 passengers	Combustible ducts, where allowed, shall have low flame spread characteristics.
		II-2/16.11 (new paragraph)	New passenger ships.	Fire testing of fire dampers and A-class penetrations.
		II-2/17.3.1.1	Passenger ships	Additional fireman's equipment not needed in stairway enclosures constituting individual MVZ or in small MVZs at the ends of the ship
		II-2/18.8	New ships	Provisions for helicopter facilities shall be in accordance with Res.A.855(20).
		II-2/24.1.1	New passenger ships > 36 passengers	MVZ divisions between fuel oil tanks may be A-O
		II-2/26.1 & Table 26.1	New passenger ships > 36 passengers	Spaces within the perimeters of muster stations
		II-2/28.1.11 (new sub-paragraph)	All passenger ships > 36 passengers	Low location lighting in crew accommodation areas.
		II-2/30.4	New passenger ships	New requirements for fire doors in MVZ bulkheads, galley boundaries and stairway enclosures.
		II-2/30.6	New passenger ships	Clarification of requirements for doors in outer boundaries.
		II-2/32.1.1	New passenger ships > 36 passengers	The new paragraph 11 in Reg. II-2/16 shall apply.
		II-2/32.1.4.3.1	New passenger ships > 36 passengers	Short lengths of ducts of combustible material to have low flame spread characteristics.

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Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
		II-2/34.2	New passenger ships	Low flame spread characteristics of vapour barriers.
		II-2/34.7 & .8	New passenger ships	Reference to Fire Test Procedures Code.
		II-2/37.1.2.1	Special category spaces, new passenger ships >36 passengers	Fuel oil tanks may have A-O division to special category space above.
		II-2/37.4 (new paragraph)	Special category spaces, new passenger ships	Ventilation openings not to endanger survival craft stowage and embarkation areas, service spaces and control stations
		II-2/38.5 (new paragraph)	Cargo spaces for motor vehicles, new passenger ships	
		II-2/38.6 (new paragraph)	Ro-ro cargo spaces, new passenger ships	Paragraphs 1.1, 1.2 and 1.3 fo the new Reg. II-2/38-1 to be complied with.
		II-2/38-1 (new regulation)	Closed and open ro-ro cargo spaces, new passenger ships	Requirements for vehicle cargo spaces not covered by Regs. II-2/37 or II-2/38 introduced.
		VII/2	Carriage of dangerous goods	Class 6.1 and class 9 reworded
		VII/7.1.5 (new sub-paragraph)	All passenger ships	Carriage of explosive articles in compatibility group N
First periodical survey after 01.07.98	November 1995 SOLAS Amendments	III/24-1.5	Pre. 01.07.98 ro-ro passenger ships	A sufficient number of lifejackets shall be stowed in the vicinity of the assembly stations so that the passengers do not have to return to their cabins to collect their lifejackets. Each lifejacket shall have light.
06.07.98	1992 MARPOL, Annex I Amendments	9, 10, 16	All existing ships	Change in discharge criteria (phase out of 100 ppm oily water separators).
First periodical survey after 01.10.98	November 1995 SOLAS Amendments	II-1/8-1 (new regulation, replaces II-1/8.9 of April 1982 Amendments)	Pre 01.07.97 ro-ro passenger ships, A/Amax < 85	Upgrading of damage stability to comply with Reg. 8 (SOLAS ’90 standard)
First yearly inspection after 21.12.98	Stockholm Agreement (regional agreement)	Annex 2	Passenger ships with car decks, 85 ≤ A/Amax < 90	To comply with specific stability requirements taking into account accumulated sea water on car deck
01.01.99	November 1995 SOLAS Amendments	III/24-2.3	All passenger ships	Names and gender of all persons on board, distinguishing between adults, children and infants shall be recorded for search and rescue purposes.
01.02.99	November 1988 SOLAS Amendments	GDMSS	Existing ships	Existing ships must comply with GMDSS
01.07.99	November 1995 SOLAS Amendments	II-2/28-1.3	New ro-ro passenger ships	Evacuation analysis of escape routes.
		III/24-3.3	New passenger ships, L ≥ 130 m See footnote 1)	To be fitted with helicopter landing area (approval: ref. Res.A.855(20)).
01.07.99	June 1997 SOLAS Amendments	V/8-2 (new regulation)		Vessel traffic services.

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
First periodical survey after 01.07.99	November 1995 SOLAS Amendments	III/24-4	Pre. 01.07.97 passenger ships	Decision-support system for emergency management
01.08.99	1997 MARPOL, Annex I Amendments	Reg. 10	All ships	North West European waters special area.
First yearly inspection after 31.12.99	Stockholm Agreement (regional agreement)	Annex 2	Passenger ships with car decks, 90 ≤A/Amax < 95	To comply with specific stability requirements taking into account accumulated sea water on car deck.
01.01. 2000	1997 MARPOL, Annex VI Protocol	Reg. 13	(New) diesel engines ≥ 130 kW	NO_x emission. Note that engines for ships the keels of which are laid on or after this date shall comply with these (retroactive) requirements. The same applies to conversions and new installations on or after this date.
		Reg. 16	Installation of incinerators	Shipboard incineration. Note that incinerators installed on or after this date shall be approved according to these (retroactive requirements).
03.02. 2000	1988 SOLAS Protocol		All ships	Harmonised certification and survey system enters into force (HSSC). New certificate forms.
	1988 LL Protocol			
	1988 LL Protocol	22(2)	New ships	Drainage of enclosed cargo spaces.
		10	New and existing ships	Inclining test.
		Article VI 2(f) (ii) & (g) (ii)		Tacit acceptance procedure for amendments to Annex B of the LL Protocol
03.02. 2000	1990 MARPOL Amendments			Harmonised certification and survey system enters into force.
First periodical survey after 01.07. 2000	November 1995 SOLAS Amendments	III/24-1.2.1 & .2.2	Pre. 01.07.86 ro-ro passenger ships	All liferafts shall be served either by MES or launching appliances. Every liferaft shall be provided with float-free stowage arrangement.
		III/24-1.2.3 & .2.4	Pre. 01.07.98 ro-ro passenger ships	Every liferaft to be fitted with a boarding ramp. Every liferaft to be self-righting or reversible.
		III/24-1.3	Pre. 01.07.98 ro-ro passenger ships	At least one (of the rescue boats shall be a) “fast rescue boat”. Special training of crew.
		III/24-1.4	Pre. 01.07.98 ro-ro passenger ships	Ship to be provided with means for recovery of survivors.
01.10. 2000	April 1992 SOLAS Amendments	II-2/41-1 II-2/41-2	Pre. 01.10.94 passenger ships	Upgrading of fire safety (stairway enclosures, fire extinguishing in cat. A machinery spaces, ventilating ducts, special category spaces, fire doors)
First periodical survey after 01.10. 2000	November 1995 SOLAS Amendments	II-1/8-1 (replaces II-1/8.9 of April 1992 Amendments)	Pre. 01.07.97 ro-ro passenger ships, 85 ≤ A/Amax < 90	Upgrading of damage stability to comply with Reg. 8 (SOLAS ’90 standard)
First yearly inspection after 31.12. 2000	Stockholm Agreement (regional agreement)	Annex 2	Passenger ships with car decks, 95 ≤ A/Amax < 97.5	To comply with specific stability requirements taking into account accumulated sea water on car deck.

Table B – Passenger Ships

Date of entry into force	*Convention*	*Reg. No.*	*Applicable to*	*Subject*
First yearly inspection after 31.12. 2001 but not later than 01.10. 2002	Stockholm Agreement (regional Agreement)	Annex 2	Passenger ships with car decks, 97.5 ≤ A/Amax	To comply with specific stability requirements taking into account accumulated sea water on car deck.
01.07. 2002	June 1997 SOLAS Amendments	II-1/8-3 (new regulation)	New (non ro-ro) passenger ships ≥ 400 persons	Must comply with two compartment standard.
Expected: 01.07. 2002	1998 SOLAS Amendments	II-1/14.1	New ships	Testing of watertight compartments (filling with water not compulsory)
		IV/ 1.1	All ships	"unless expressly provided otherwise" is inserted in Application
		IV/2.1.6 (new sub-paragraph)	All ships	Definition of GMDSS *identity*
		IV/2.2	All ships	Reference to definitions in the Radio Regulations and SAR Convention
		IV/5-1 (new regulation)	All ships	Governments to register GMDSS identities
		IV/13.8	All ships	Continuous supply of information to navigation receiver
		IV/15.9 (new paragraph)	All ships	Testing of EPIRBs at 12 months intervals
		VI/18	All ships	Position up-dating of two-way communication equipment
Proposed: 01.07.2002	2000 SOLAS Amendments	II-2/7.7 (new paragraph)	New passenger ships = 500 GRT	Fixed water-based (or equivalent) local fire extinguishing arrangements in category A machinery spaces > 500 m^3 in gross volume. (This new requirement will be incorporated in the revised Ch. II-2).
First periodical survey after 01.07. 2002	June 1996 SOLAS Amendments	III/22.3.2	Pre. 01.07.98 passenger ships	Lights on lifejackets shall comply with paragraph 2.2.3 of the LSA Code.
01.10. 2002	Stockholm Agreement (regional agreement)	Annex 2	Passenger ships with car decks, 97.5 ≤ A/Amax	Final date for complying with specific stability requirements taking into account accumulated sea water on car deck.
First periodical survey after 01.10. 2002	November 1995 SOLAS Amendments	II-1/8-1 (replaces II-1/8.9 of April 1992 Amendments)	Pre. 01.07.97 ro-ro passenger ships, 90 ≤ A/Amax < 95	Upgrading of damage stability to comply with Reg. 8 (SOLAS '90 standard)
		II-1/8-2 (new regulation)	Pre. 01.07.97 ro-ro passenger ships > 1500 persons, A/Amax < 95, age ≥ 20 years	To comply with two-compartment standard
Expected 01.01. 2003	1998 STCW Code Amendments	Tables A-II/1 & A-II/2	Deck officers engaged in cargo handling and stowage	The specifications have been made more detailed

Table B – Passenger Ships				
Date of entry into force	*Conventio n*	*Reg. No.*	*Applicable to*	*Subject*
01.07. 2003	May 1994 SOLAS Amendments	II-2/15.2.12	Ships constructed before 01.07.98	Paragraphs 2.9, 2.10 and 2.11 of Reg. 15 to be complied with within this date, i.e. stricter requirements for protection of oil fuel lines (jacketed piping for high-pressure pipes, insulation of surfaces with temp. above 220º C, screening).
First periodical survey after 01.10. 2004	November 1995 SOLAS Amendments	II-1/8-1 (replaces II-1/8.9 of April 1992 Amendments)	Pre. 01.07.97 ro-ro passenger ships, 95 ≤ A/Amax < 97.5	Upgrading of damage stability to comply with Reg. 8 (SOLAS ’90 standard)
		II-1/8-2	Pre. 01.07.97 ro-ro passenger ships > 1500 persons, 95 ≤ A/Amax < 97.5, age ≥ 20 years	To comply with two-compartment standard.
Proposed: 01.10.2005	2000 SOLAS Amendments	II-2/7.7 (new paragraph)	Existing (i.e. pre. 01.07.2002) passenger ships = 500 GRT	Fixed water-based (or equivalent) local fire extinguishing arrangements in category A machinery spaces > 500 m^3 in gross volume. (This new requirement will be incorporated in the revised Ch. II-2).
01.10. 2005	April 1992 SOLAS Amendments	II-2/41-1.3.4 II-2/41-2.5	Pre. 01.10.94 but after 25.05.80 passenger ships	Automatic sprinkler, fire detection and fire alarm system
First periodical survey after 01.10. 2005	November 1995 SOLAS Amendments	II-1/8-1 (replaces II-1/8.9 of April 1992 Amendments)	Pre. 01.07.97 ro-ro passenger ships, A/Amax ≥ 97.5	Upgrading of damage stability to comply with Reg. 8 (SOLAS ’90 standard)
First periodical survey after 01.10. 2006	November 1995 SOLAS Amendments	II-1/8-2	Pre. 01.07.97 ro-ro passenger ships 1000 ≤ persons < 1500, A/Amax < 97.5	To comply with two-compartment standard
First periodical survey after 01.10. 2008	November 1995 SOLAS Amendments	II-1/8-2	Pre. 01.07.97 ro-ro passenger ships, age ≥ 20 years, 600 ≤ passengers < 1000, A/Amax < 97.5	To comply with two-compartment standard
01.10. 2010	April 1992 SOLAS Amendments	II-2/41-1.2.4	Pre. 25.05.80 passenger ships	Upgrading to complying with Ch.II-2 of SOLAS 1974
First periodical survey after 01.10. 2010	November 1995 SOLAS Amendments	II-1/8-2	Pre. 01.07.97 ro-ro passenger ships ≥ 400 persons, age ≥ 20 years not already complying with two-compartment standard	To comply with two-compartment standard

12 months after accep-tance	1997 MARPOL, Annex VI Protocol	New Annex VI	All ships	Regulations for the Prevention of Air Pollution from Ships.
		Regs. 5 & 6	GRT ≥ 400	Survey & inspection / Certificate required
		Reg. 13	Diesel engines ≥ 130 kW, ships keel laid ≥ 01.01.2000 or conversions / new installations	NO_x emission. Retroactive requirements
		Reg. 16	Incinerators installed ≥ 01.01.2000	Shipboard incineration only allowed in approved incinerators. Retroactive requirements.

1) IMO’s Maritime Safety Committee meeting in May 1999 (MSC 71) approved an amendment to SOLAS Reg. III / 28.2 to change the words ”Passenger ships” to ”Ro-ro passenger ships”, i.e. that this requirement shall only be applicable to ro-ro passenger ships. This amendment is subject to adoption by MSC 72 (May 2000) and is intended to enter into force 01.07.2002. MSC 71 also approved MSC/ Circ. 307 recommending non ro-ro passenger ships being constructed in the period 01.07.1999 to 01.02.2002 to be accepted without helicopter landing area.