Operational measures to mitigate and reverse the potential modal shifts due to environmental legislation
On 1 January 2015, the sulphur upper limit for marine fuels used within sulphur emission control areas was lowered from 1% to 0.1%, with which vessels can comply only through using pricier ultra-low-sulphur fuel, or investing in abatement technologies. A potential increase of fuel prices could lead to closures of services due to the combined effects of loss of market due to higher freight rates, and increased operational costs. This paper builds on previous work allowing the modelling of modal shifts between sea and land-based options, and assesses the potential of operational measures that ship-owners can deploy to cope with the threat of the low-sulphur requirements. The measures include speed reduction, change of service frequency, use of alternative fuels such as liquefied natural gas, investments in scrubber systems, and improved fleet assignment. The proposed measures are tested on a set of case studies for services that are part of a short sea shipping network of a leading Ro-Ro operator. The results of this work can be useful to practitioners seeking to design new strategies that improve the resilience of their network, as well as to regulatory bodies designing new regulation that could have negative implications on certain sectors.

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Prospects of cold ironing as an emissions reduction option

Cold ironing is the process of providing shorepower to cover the energy demands of ships calling at ports. This technological solution can eliminate the emissions of auxiliary engines at berth, resulting in a global reduction of emissions if the grid powering the ships is an environmentally friendly energy source. This paper conducts a literature review of recent academic work in the field and presents the status of this technology worldwide and the current barriers for its further implementation. The use of cold ironing is mandatory in Californian ports for ship operators and as a result terminal and ship operators were required to invest in this technology. In Europe, all ports will be required to have cold ironing
provision by the end of 2025. Other regulations that target local emissions such as Emission Control Areas can have a significant impact on whether cold ironing is used in the future as a potential compliance solution. This paper constructs a quantitative framework for the examination of the technology considering all stakeholders. The role of regulation is shown to be critical for the further adoption of this technology. Illustrative case studies are presented that consider the perspective of ship operators of various ship types, and terminal operators that opt to invest in shorepower facilities. The results of the case studies show that for medium and high fuel price scenarios there is economic motivation for ship operators to use cold ironing. For the port, the cost per abated ton of pollutants is much lower than current estimates of the external costs of pollutants. Therefore, shorepower may be a viable emissions reduction option for the maritime sector, provided that regulatory bodies assist the further adoption of the technology from ship operators and ports. The methodology can be useful to port and ship operators in examining the benefits of using cold ironing as an emissions reduction action.

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Web of Science (2016): Impact factor 2.609
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.02 SJR 1.815 SNIP 1.9
Web of Science (2015): Impact factor 1.994
Web of Science (2015): Indexed yes
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Scopus rating (2012): CiteScore 3 SJR 2.514 SNIP 2.651
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Reducing Sulphur Emissions: Logistical and Environmental Considerations

In recent years the issue of sulphur emissions from maritime transport has seen newfound attention. This chapter presents an overview of the main issues of sulphur emissions and the legislative framework that seeks to reduce the sulphur footprint of the maritime sector. It also analyses potential modal shifts towards less efficient land-based modes which may happen as a result of sulphur regulations, and investigates the related potential economic damage to ship operators. To that effect, this chapter presents findings from a recently finished project at DTU, and the developed methodological framework that can be used to estimate such modal shifts, as well as to measure the efficacy of policy and ship operators’ measures to reverse such shifts.

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A Game theoretic approach to improve compliance to sulphur regulations

The purpose of this paper is to develop a game theoretic modelling framework that improves the effectiveness of sulphur regulations enforcement. The existing legislative framework poses several challenges, stemming (mainly) from a highly non-homogeneous and spatially differentiated system, with cases where the penalty fines are as low as the benefit that the violator enjoyed from not complying. This paper presents the status quo of enforcement in different countries, where the regulation applies, and develops a game theoretic approach for a uniform violation fine system. A mixed strategy game with two players is proposed, representing the ship operator (who can choose to comply or not comply to the regulation), and an enforcement agency (that can opt to inspect or not inspect the ship) respectively. The equilibrium results in an improved penalty system (for both violators and enforcing agencies). Such a system can ensure a level playing field for ship operators that currently have invested heavily in an abatement of options to comply with the sulphur regulations, by promoting good practices among ship operators, while at the same time improve compliance rates and maximize societal environmental benefits. A discussion on the implications of the global sulphur cap of 2020 is concluding the paper, and recommendations for transferability of this framework to other regulations are provided.
Key performance indicators to assess and reverse the negative impacts of SECA policies for Ro-Ro Shipping

The 0.1% sulphur limit within Sulphur Emission Control Areas (SECA) has made compulsory the use of either pricier ultra-low sulphur fuel, or the installation of abatement technologies that require significant capital investments. Due to the unexpectedly low fuel prices, Ro-Ro operators have been able to cope with the new sulphur limits, but recent research has shown that if fuel prices increase some Ro-Ro services may face the risk of closure. This paper proposes three key performance indicators (KPIs) to enable the assessment of the impact of SECAs on Ro-Ro shipping. The KPIs are used on a set of case studies for services of a leading European Ro-Ro operator, and allow benchmarking of a series of operational and policy measures that aim to reverse the negative impacts of SECAs. The operational measures consider speed reduction, new sailing frequency, fleet reconfiguration, as well as investments in abatement technologies. Policy measures include the options of either subsidizing shippers or ship operators, or alternatively introducing new taxes on landbased options. The KPIs can be useful to ship operators seeking to improve the resilience of their network, as well as to regulatory bodies designing new environmental policies and understanding any negative implications these may have on ship operators.

Operational measures and logistical considerations for the decarbonisation of maritime transport

Maritime shipping is widely considered as the most fuel-efficient mode of transport. During the past decade, the relative share of CO2 emissions of the shipping sector has seen a slight reduction that has been attributed to the depressed market conditions that led to the resurface of the slow steaming practice. The sector has seen increasing regulatory pressure to further improve its environmental performance, not only in greenhouse gas (GHG) terms, but also in other pollutant types. Important regulation has been implemented with regards to the maximum allowable content of sulphur in marine fuel from the International Maritime Organization (IMO), whereas the introduction of MRV (monitoring, reporting, verification) in Europe will also assist in the efforts to reduce the environmental impacts of shipping. The European Union has also adopted the Transport White Paper that has set ambitious targets for reductions in GHG emissions compared to 1990 for all transport modes. At the same time, it is noteworthy that international shipping has been excluded from the COP21 climate change agreement in Paris. The discussion on possible pathways to achieve reductions in the maritime sector is currently in a stalemate. While certain Market Based Measures (MBMs) for GHGs have been contemplated at the IMO, a final decision has not been reached. In February 2017, the European Parliament voted to include shipping into the EU Emissions Trading Scheme (ETS) as of 2023, in the event that no global agreement is reached by 2021. This potential solution has been met with criticism as there are concerns that the ETS could lead to distortions in trade, and actually not be an efficient method to reduce GHG emissions. Other measures have been submitted as potential solutions to the IMO such as the introduction of an additional levy on bunker fuel, as well as hybrid proposals that also take into consideration
ETS type solutions, and the EEDI (Energy Efficiency Design Index). In this paper, the implications of these measures are examined in a quantitative context whereby the objective is to identify the potential for emissions reduction in different shipping sectors. In addition to estimations on emissions reduction, logistical considerations are thoroughly examined in the paper. For example, an introduction of a tax levy will result in a higher bunker price and thus operating costs for ship operators, which will de facto alter the optimal sailing speed of the vessel to lower levels. This will result in lower emissions per trip, but may require the deployment of additional vessels to satisfy the total transportation demand, or lead to a modal shift towards other modes due to the shippers’ requirements for a faster service. This sort of distortion has already been observed due to the stricter fuel requirements within SECAs (Sulphur Emission Control Areas), but was rather antclimactic due to the in general very low fuel prices observed in 2015. With regards to the EEDI, it is a well established fact that while the rationale was to improve vessel and engine design, a potential alternative to comply with the limits would be to simply lower the sailing speed, leading to underpowered vessels. In the case studies examined in this paper, a variety of vessel types, sizes, and deployed routes are considered to explore the impacts of the different decarbonisation pathways. This paper presents a new modelling framework that allows the quantitative estimation of the effectiveness of various MBMs in emissions reduction, also considering the total cost for the achieved reduction. The required tax on fuel to reduce emissions is calculated on a parametric analysis that considers desired reduction, sailing speed, carrying capacity, fuel price, and freight rates. Case studies on liner shipping, Ro-Ro shipping, and tankers are considered, with a discussion on the role of the operating area of the vessel (ocean-going vs short sea shipping, outside vs inside SECAs). Finally, using data on the world fleet and the current trade volumes, a range of the potential reduction for CO2 emissions is performed for different values of levies on bunker fuel. The results can be useful in the way forward to decarbonising maritime transport, while also considering the economic and environmental trade-offs due to potential modal shifts, closure of services, and required fleet renewal. The constructed modelling framework is also able of assessing the impact of various other environmental regulation that may be proposed but may have a more local character (for example speed limits near the coastlines, requirements at the port etc.).
The prospects of cold ironing as an emissions reduction option

Maritime shipping is considered the most fuel efficient mode of transport with the lowest contribution in CO2 emissions. However, the sector has seen increasing pressure to improve its environmental performance, particularly when it comes to SOx, NOx, and PM emission pollutants. The majority of academic literature is focusing on the full journey environmental aspects of maritime transport, and less attention is given to ports. Davarzani et al. (2016) conduct a literature review on greening ports in order to identify research areas for further investigation (1). Cold ironing is the process of providing shorepower to cover the energy demands of vessels calling at ports. In California six ports are included to the At-Berth regulation that constitutes mandatory the use of the technology for ocean going vessels (70% of total vessel calls, up to 80% by 2020). The EU regulation on at-berth emissions is targeting only SO2 emissions, the reduction of which is also the objective of Emission Control Areas (ECAs). Therefore, a ship can switch to ultra-low sulfur fuel while at berth or within ECAs, or alternatively use scrubber systems to comply with the regulation (2). The scrubber solution reduces PM emissions as well, but has a limited effect on NOx. A paradox is evident; between 2005 and 2015 (the sulfur limit was 1% within ECA, 0.1% at berth) a vessel calling at EU ports would have a higher incentive to invest in cold ironing as it would replace the use of ultra-low sulfur fuel at the port. The objective of the paper is to start a discussion on the future prospects of cold ironing as a viable option to reduce in port emissions, as well as to present a quantitative framework that can be useful to stakeholders deciding on whether to invest in this technology or not.

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The implications of the new sulphur limits on the European Ro-Ro sector

In an effort to reduce the environmental impacts of maritime transportation, the International Maritime Organization (IMO) designated special Sulphur Emission Control Areas (SECAs) where ships are required to use low-sulphur fuel. In January 2015, the sulphur limit within SECAs was lowered to 0.1%, which can only be achieved if vessels are using pricier ultra-low sulphur fuel, or invest in abatement technologies. The increased operating costs borne by Ro-Ro operators in SECAs due to the stricter limits can result in the shutting down of some routes and a redistribution of cargo flows with land-based alternatives. The exact repercussions of the new sulphur limits are difficult to identify in the wake of significant recent reductions of the fuel prices for both low-sulphur and heavy fuel oil. This paper presents a modal split model that estimates modal shifts vis-a-vis competing maritime and land-based modes available to shippers. This allows examining the
implications of the recent low prices to modal choice, and the influence a potential increase in fuel prices may have. The
model is applied to seven routes affected by the regulation based on data from a leading European Ro-Ro operator.
Sensitivity analyses on market share data, cargo values, freight rates, and haulers rates are conducted. Emissions
inventories are constructed to assess the environmental efficacy of the SECA regulation. The novelty of the proposed
model lies in the examination of the ex-post implications of shutting down a service and the redistribution of transport.
Recommendations to mitigate and reverse the negative side-effects of such environmental legislation are proposed.

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Scopus rating (2015): CiteScore 2.65 SJR 1.157 SNIP 1.366
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Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2 SJR 1.139 SNIP 1.663
Web of Science (2012): Impact factor 1.291
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.86 SJR 0.992 SNIP 1.765
Web of Science (2011): Impact factor 1.659
ISI indexed (2011): ISI indexed yes
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Scopus rating (2010): SJR 0.788 SNIP 1.368
Web of Science (2010): Impact factor 1.108
Payback Period for Emissions Abatement Alternatives: Role of Regulation and Fuel Prices

As of January 2015, the new maximum limit of fuel sulfur content for ships sailing within emission control areas has been reduced to 0.1%. A critical decision for ship owners in advance of the new limits was the selection of an abatement method that complies with the regulations. Two main options exist: investing in scrubber systems that remove sulfur dioxide emissions from the exhaust and switching to low-sulfur fuel when sailing in regulated waters. The first option would involve significant capital costs, while the latter would lead to operating cost increases because of the higher price of the fuel used. This paper presents a literature review of emissions abatement options and relevant research in the field. A cost–benefit methodology to assess emission reduction investments from ship owners is also presented. A study examined the effects of recent drops in bunker fuel price to the payback period of a potential scrubber investment. The results show that lower prices would significantly delay the payback period of such investments, up to two times in some cases. The case studies present the emissions generation through each option for representative short sea shipping routes. The repercussions of low-sulfur policies on large emission reduction investments including cold ironing are examined, along with implications of slow steaming for their respective payback periods. Recommendations are made for research in anticipation of future regulations and technological improvements.

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The implications of the new sulphur limits on the European Ro-Ro sector

In an effort to reduce the environmental impacts of maritime transportation, the International Maritime Organization (IMO) designated special Sulphur Emission Control Areas (SECAs) where ships are required to use low-sulphur fuel. In January 2015, the sulphur limit within SECAs was lowered to 0.1%, which can only be achieved if vessels are using pricier ultra-low sulphur fuel, or invest in abatement technologies. The increased operating costs borne by Ro-Ro operators in SECAs due to the stricter limits can result in the shutting down of some routes and a redistribution of cargo flows with land-based alternatives. The exact repercussions of the new sulphur limits are difficult to identify in the wake of significant recent reductions of the fuel prices for both low-sulphur and heavy fuel oil. This paper presents a modal split model that estimates modal shifts vis-a-vis competing maritime and land-based modes available to shippers. This allows examining the implications of the recent low prices to modal choice, and the influence a potential increase in fuel prices may have. The model is applied to seven routes affected by the regulation based on data from a leading European Ro-Ro operator. Sensitivity analyses on market share data, cargo values, freight rates, and haulers rates are conducted. Emissions inventories are constructed to assess the environmental efficacy of the SECA regulation. The novelty of the proposed model lies in the examination of the ex-post implications of shutting down a service and the redistribution of transport. Recommendations to mitigate and reverse the negative side-effects of such environmental legislation are proposed.

Environmental Balance of Shipping Emissions Reduction Strategies

Maritime shipping is regarded as the most efficient mode of transport; however, its contribution to climate change through greenhouse gas emissions and the health issues related to shipping activity near residential centers cannot be neglected. In recent years, the efforts of regulators, ship operators, and port authorities have led to actions for ship emissions reduction to improve shipping’s environmental performance. This work builds on an activity-based methodology that allows the estimation of emissions and examines environmental effects of slow steaming, fuel regulations, near-port speed-reduction schemes, and cold ironing. Pollutant emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, and black carbon are modeled. A linear programming model minimizes fuel consumption through speed differentiation on a shipping line’s routes based on fuel costs and binding regulations in each segment of the journey. Although the examined emissions-reduction actions may have a positive regional environmental effect by cutting emissions, it is possible that additional emissions are generated elsewhere because of increased sailing speeds beyond regulated areas. Trade-offs between pollutants are observed for reduction actions that may have a positive effect on some emission species but at the same time result in additional particulate matter and black carbon emissions. The presented framework allows key actors to conduct comprehensive studies and design improved emissions reduction actions with fewer negative impacts in other areas.
Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports

Alternative port operating policies have the potential to reduce pollutant emissions from shipping; however, their efficacy is expected to vary from port to port. This paper extends existing literature to present a consistent and transferable methodology for the consideration of such policies for any port based on ship-calling data. Emissions of carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxides (NOₓ), and black carbon (BC) are estimated from near-port container ship activities, including co-consideration of the associated fuel costs. The method is implemented for a set of typical container terminal types and two common emissions reduction policies. Results show that full compliance of all calling vessels with a speed reduction scheme can lead to reductions of 8-20%, 9-40%, and 9-17% for CO₂, SO₂, and NOₓ respectively. In contrast, for BC, speed reduction policies may increase emissions up to 10%. In both cases, these changes are critically dependent on the baseline operating pattern of the ships. For the same terminals, provision of Alternative Marine Power (AMP) for all berthing vessels can lead to reductions of in-port emissions of 48-70%, 3-60%, 40-60%, and 57-70% for CO₂, SO₂, NOₓ, and BC respectively. These benefits rely on suitable equipment being carried by vessels, with large benefits associated with larger vessels. This analysis serves to highlight that emissions are critically dependent on the visiting fleet, berthing durations, sulphur reduction policies in force and the emissions intensity of the port electricity supply. For both speed-reduction schemes and AMP, increased total emissions are possible, making it essential to evaluate and prioritize alternative port operating policies for emissions reduction based on the characteristics of individual ports.

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Projects:

Mitigating and reversing the side-effects of environmental legislation on Ro-Ro shipping in Northern Europe

The main objective of this project is to identify and assess possible technical, operational, regulatory and financial measures for the mitigation and reversal of the negative repercussions of environmental legislation to the market shares of Ro-Ro shipping in Northern Europe. The project builds upon prior research by the Principal Investigator and his colleagues in recent years and will be under the umbrella of Maritime DTU. The project is funded by the Danish Maritime Fund.

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