The relationship between transport logistics, future ship design and whole system efficiency

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Abstract

This paper reports on the ongoing work of a team of researchers at Newcastle and Hull universities, as part of the Low Carbon Shipping research consortium, on the logistics aspects of shipping and the quest to reduce shipping related emissions. Our focus is on investigating maritime logistics trends and developments and how these interact with evolving shipping technologies with a view to making the whole shipping system more efficient in terms of carbon emissions. Our emphasis is largely on the UK and containers. The paper first details the (historical and projected) growth in shipping and related emissions. The various components of maritime logistics that are relevant in the context of reducing whole system emissions are then detailed and various trends are examined. In addition, pertinent trends in shipping technology are also briefly reviewed. The difficulties in understanding what future maritime logistics networks will look like are evidenced through the findings of interviews with seven industry experts and a scenario planning approach for looking at the future is also introduced. What becomes apparent is that global geopolitical influences will ultimately dictate the (derived) demand for shipping and thus its associated emissions. Our work is ongoing in endeavouring to understand and recommend how maritime logistics can contribute to reducing shipping related emissions.

Keywords: logistics, supply chains, transport chains, ports, emissions, sustainability, whole systems.

1. Growth in international seaborne trade

Transport logistics is concerned *inter alia* with the movement of freight around the world. Shipping is the dominant mode for the majority (>90%) of international freight movements, Table 1 summarises the growth of international seaborne trade since 1970.

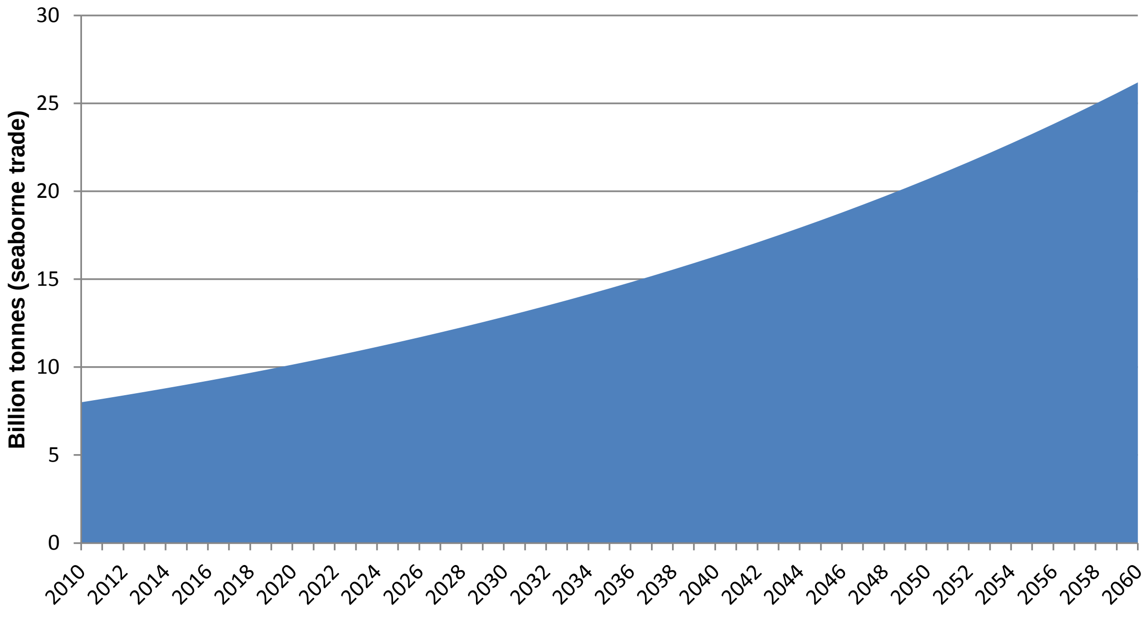
Table 1 – Development of international seaborne trade (millions of tonnes loaded)

Year	Oil	Main bulks	Other dry cargo	Total (all cargoes)
1970	1 442	448	676	2 566
1980	1 871	796	1 037	3 704
1990	1 755	968	1 285	4 008
2000	2 163	1 288	2 533	5 984
2006	2 698	1 836	3 166	7 700
2007	2 747	1 957	3 330	8 034
2008	2 742	2 059	3 428	8 229
2009	2 642	2 094	3 122	7 858
2010	2 752	2 333	3 323	8 408

Source: UNCTAD (2011)

This growth in international seaborne trade corresponds closely to world economic growth (and contraction, as evidenced for example by the decline in seaborne trade in 2009 concomitant with the global economic recession). It is generally accepted that in the medium term, international trade (and thus demand for shipping) will continue to grow, driven by various forces such as *inter alia* increased globalisation, lowering of trade barriers, increased trade in commodities and natural resources, and continued development of emerging economies. Figure 2 for example, which is based on research by Stopford (2010), claims that international seaborne trade could potentially increase to be in excess of 25 billion tonnes by 2060 assuming that there is an average annual increase of 2.4% in global seaborne trade over the next 50 years.

Figure 2 – Global seaborne trade extrapolated at 2.4% per annum from 8 billion tonnes in 2010 to 26 billion tonnes by 2060



Source: Created on Stopford's (2010) assertion of an annual 2.4% increase in global maritime trade between 2010 and 2060.

Many forecasts point to significant trade growth in the medium term. Citigroup (2011) for example project that world trade in goods and services could grow from $37 trillion in 2010 to $371 trillion in 2050. Despite a 20% decline during the financial crisis, they expect world trade to increase from 61% of global GDP in 2010 to 86% in 2050. They anticipate that the top 10 countries that will dominate world trade in 2050 will be China, India, US, Korea, Indonesia, Germany, Thailand, Japan, Singapore and Hong Kong. Developing countries will account for two thirds of world trade by 2050, and China will be involved in 4 of the 5 largest bilateral trade relationships.

Clearly then if world trade continues to increase at these levels there is the potential for significant pollution from shipping. UNCTAD's Multi-Year Expert Meeting on Transport and Trade Facilitation document (2009) summarised nine different studies published between 2000 and 2009 on the subject of CO2 emissions from international shipping. The findings of the various research projects showed that CO2 emissions from worldwide shipping have increased rapidly over a relatively short time period. Buhaug et al (2009) claimed that in 2007 total world shipping (including domestic and international) was responsible for emitting 1.046 billion tonnes of CO2, which is equivalent to approximately 3.3% of total global CO2 emissions (Figure 2).

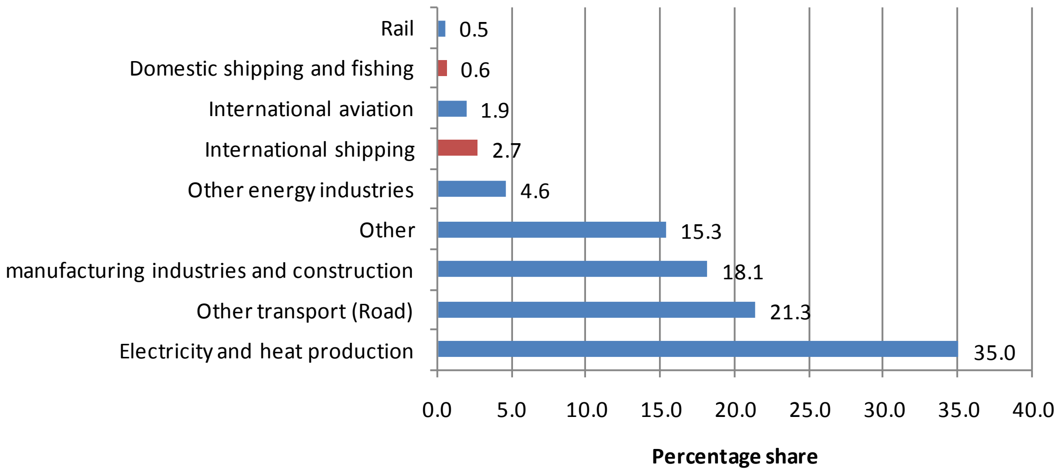


Figure 2 - Emissions of CO2 from shipping compared with global emissions from other industries (2007). Source: Buhuag et al (2009).

UNCTAD (2009) has estimated that CO2 emissions from shipping are projected to increase by a factor of between 2.2 and 3.1 between 2007 and 2050 in the absence of technological, operational or market based measures. Container ships are worthy of special mention when considering shipping and pollution, as largely because of their speed, they account for a disproportionately larger share of emissions than is the case with other vessels (see for example Mangan et al, 2011). The ISL Shipping Statistics Yearbook (2009) shows the global fleet development of different types of ships over a ten year time period from 2000-2009. It is clear from the data presented in Table 2 that container ship growth has witnessed the largest increase in the number of ships over those ten years: 90.36% in ten years is equivalent to an average (mean) annual increase of approximately 7.42%. This is a substantially higher annual average increase than has been the case for oil tankers and dry bulk vessels which have seen average annual increases in fleet size of 2.74% and 2.82% respectively. Within the projected growth of international seaborne trade, container ships are likely to play an increasingly significant role (and thus cause more pollution) given the nature of the cargo that they carry.

Table 2 - Percentage increase in global fleet size for three ship types for years 2000-2009

Ship Type	Fleet size in 2000	Fleet size in 2009	Percentage increase
Oil Tanker	7195	9159	27.30
Dry Bulk	5763	7395	28.32
Container	2437	4639	90.36

Source: ISL Shipping Statistics Yearbook (2009)

To summarise then, shipping activity is set to grow significantly over the coming decades, with the potential for increased negative impact on the environment. The purpose of the ongoing work briefly reported in this paper is to gauge how this growth in shipping will interact with logistics systems as they too evolve and, conscious of trends in future ship design, how logistics systems can 'collude' to mitigate the environmental disbenefits associated with increased shipping

2. Transport logistics and whole system efficiency

Shipping is a derived demand, it exists not for itself but in response to demand from consignors to transport freight to consignees. Transport logistics systems, of which shipping is a key component, respond to trade demands and help to 'lubricate' the global economy by providing nodes and links (ports, distribution centres, transport services, etc) to facilitate the demands for product movement. Transportation, and particularly shipping, thus plays a critical role in the global economy and as such is one of the key enablers of globalisation. In order then to understand the role and activity of shipping it is necessary to also consider shipping's role within the wider transport system, and in turn to understand what drives the demand for international freight transport. This demand for international freight transport occurs within 'end-to-end' supply chains linking sources of production with the ultimate consumer. The supply chain is an important and apposite concept in our quest to understand the demand for shipping. It is now generally accepted that supply chains, and not individual firms or products, are the basis of competition in the global marketplace (a concept first put forward by Christopher (1992)), where the supply chain can be defined (*ibid*) as the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer. Many successful organisations have learned how to use their supply chains both to differentiate their offerings from those of the competition and to compete with other actors in the market. Today then, many organisations are aware of the fundamental importance of using effective and efficient logistics and supply chain management practices in order to both drive down costs and add value to their marketplace propositions. Shipping and ports constitute important links and nodes within many supply chains, both in terms of their costs and their performance.

When seeking to mitigate the (growing) CO_2 footprint associated with shipping activity, we need then to understand the fit between shipping and the wider supply chains and logistics systems within which shipping operates. The focus of the work being conducted by the authors of this paper is on the logistics dimension of shipping, specifically how can logistics practices mitigate the (growing) CO_2 footprint associated with shipping activity. Such logistics practices encompass, but are not limited to:

- Vessel operations, routing and efficiency;
- Landside routing of freight;
- Overall supply chain structures and cost drivers;
- Port strategies and activities.

The remainder of this paper will focus on reporting some of our work to date (our focus is largely UK centric with an emphasis on containers) around how logistics and supply chain activities can help mitigate the carbon footprint associated with shipping. We believe that this can be best investigated by:

a) Understanding pertinent trends that will impact maritime logistics flows;
b) Gauging the views of industry and other experts;
c) Exploring trends in the ports sector;
d) Mapping supply chains and showing how the carbon footprint of the maritime transport chain can be reduced;
e) Investigating the impact on shipping of trade and traffic projections.

This paper will, because of space constraints, only report on items (a) and (b), and in part (c) (other papers, referenced later, report on this topic in more detail). Item (e) is ongoing and work to date on item (d) (supply chain mapping) is reported in two other recent papers: Mangan et al (2012a) and Lalwani et al (2012).

With regard to methodology, in summary our work to date has comprised *inter alia* extensive desk research, detailed analysis of the relevant DfT, UNCTAD and other statistics, analysis of AIS data, analysis of traffic data provided by our industry partners, interviews with various industry experts, and mapping of candidate supply chains.

Shipping technology is not of course a static entity and in order to understand how logistics and shipping will interact in the future with shipping, we first have to understand how shipping technology itself will evolve into the future.

3. Future ship design

There is no certainty around the widespread future adoption of any single technology application (for example nuclear, biofuel, …) or future ship design which will radically reduce the carbon (and other) emissions associated with shipping (in the context of this paper we set aside the impact of regulatory and other system changes). Buhaug et al (2009) reviewed a variety of technologies and changes (such as hull redesign, use of low-carbon fuels, revised power and propulsion systems, etc) and concluded that combined they could reduce CO2 emissions from shipping by between 10% to 50% (a rather wide envelope).

Two generic trends in terms of shipping technology can however be elicited from the extant literature and that is that many ships may become over time (cognisant of the fact that ships tend to have a long lifespan and that industry wide changes and impacts can take many years to take effect) *slower* and / or *bigger*. With regard to the latter, industry may demand ever larger ships and / or more larger ships within the fleet mix. With regard to speed, two dimensions are relevant, lower speed and the reliability issues associated with maintaining low speed operations.

The remainder of this paper will review logistics trends and strategies, in the context of the aforementioned interpretation of how shipping technology is evolving, with a view to showing to what degree they can contribute to reducing the carbon emissions associated with shipping. It should be noted that the aforementioned study by Buhaug et al (2009) also suggested that operational changes (fleet management, logistics, voyage optimisation, energy management) could yield a further combined 10% to 50% reduction of CO2 emissions (again a very wide range). Notwithstanding the broad generality of this finding, it is this envelope of savings that our research is focused upon. A focus on operational improvements (as opposed to vessel and propulsion technologies) is not a new domain of research, Qi and Song (2012) for example have looked at using optimisation tools to minimise fuel emissions in liner networks. What is perhaps less common though is a research focus on *all* aspects of maritime logistics (ports, shipping company strategies, route networks, etc.) and seeing how these intersect with evolving shipping technologies in the context of an overarching goal to reduce emissions.

4. Trends in maritime logistics and their impact on shipping emissions

A variety of trends in the maritime logistics sector are relevant in the quest to reduce shipping emissions. Some of these trends pertain to the activities of the commercial companies that operate in the sector. For example in the port terminal sector consolidation among service providers is increasingly evident with many companies chasing the benefits of scale economies that consolidation can bring, as well of course giving them the advantages of market dominance and creating high entry barriers for new entrants. A good example is the global port terminal sector which is now dominated by the four big players (DPW, PSA, HW and DPW). Many shipping companies also see scale as a way of both achieving efficiencies and reducing unit environmental impact (Maersk's Triple E vessels being a case in point). Our analysis is ongoing concerning the shifts in the vessel size composition of the global fleet. While bigger can generally be better, there are constraints in terms of port and cargo handling capabilities for such larger vessels. Taking the container sector as an example, our analysis (Mangan, 2012b) of data from UNCTAD's liner shipping connectivity index (UNCTAD, 2010) illustrates the trends evident in Figure 3, which could be summarised as: companies are merging, providing fewer services, but carrying more TEUs, and on larger vessels. In this scenario the carbon emissions per TEU carried are likely to be smaller; the unknown factor though is transhipment as we need to know to what extent extra journeys to and from feeder ports on smaller (less efficient per TEU) vessels are necessary to feed the larger vessels that now only operate between the key hub ports. We are currently analysing levels of container transhipment to and from the UK (our investigations to date suggest approximately 10% of UK containers are transhipped). Once an appropriate apportionment regime is agreed upon, it will be possible to conduct a trade-off analysis around emissions and the optimum vessel size and transhipment mix.

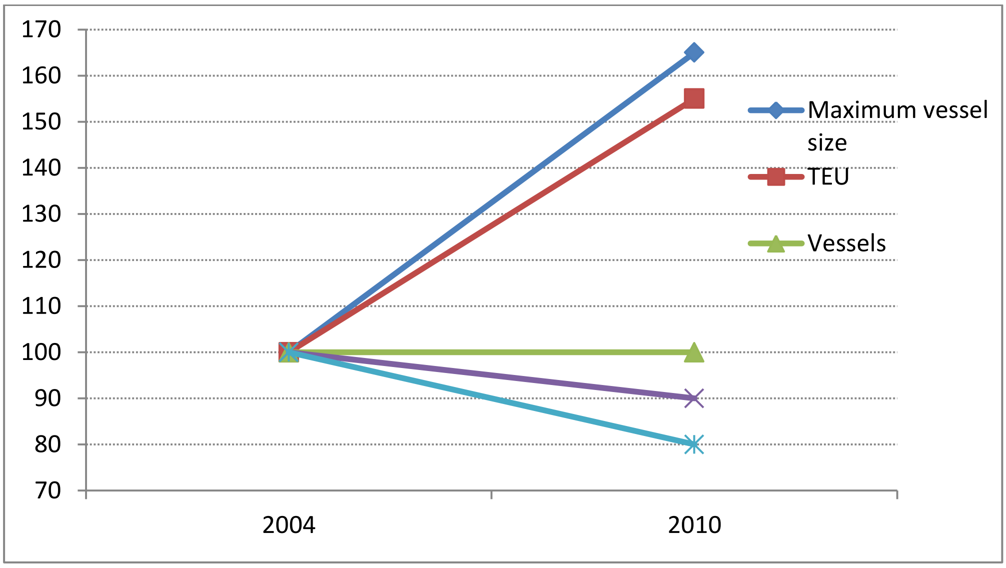


Figure 3 - Emissions of CO2 from shipping compared with global emissions from other industries (2007). Source: Buhuag et al (2009).

Another significant development impacting maritime logistics flows concerns the emergence / expansion of various shipping corridors, most notably the expansion of the Panama Canal and the opening up of the North East and North West artic passages (Economist, 2012). Corbett et al (2010) suggest that these artic routes offer distance savings of approximately 25% and 50% for certain trade flows.

Efforts by ports to reduce the carbon footprint associated with maritime freight will not be reported on in detail in this paper due to space constraints; they are reported in another paper (Gibbs, 2012). In summary, that paper concludes that emissions generated by ships during their voyages between ports are of a far greater magnitude than those generated by the port activities. Thus while reducing ports' own emissions is worthwhile, the results suggest that ports might have more impact through focusing their efforts on reducing emissions from shipping.

5. Views of experts

As part of our ongoing work on the LCS project, during summer 2012 we canvassed the views of a panel of seven UK container industry experts with respect to how they would foresee maritime container networks in 2050 and specifically in relation to: size of vessels, route networks, speed of vessels, vessel power sources, ports.

Most of the participants obviously found it difficult to predict what the UK container sector would resemble in 2050. Some commented that with various important developments ongoing at present, such as the London Gateway project, it is difficult to predict what the sector will look like in even five years from now. Vessel size was noted as a key constraint for the UK, with many ports unable to handle the larger vessels. That said, most commented that for container vessels, size is likely to be capped in their view at around 21,000 TEU. Many respondents also pointed out that feeder vessels are likely to increase in size as well. The impact of mergers among shipping lines was also noted, with less direct calls in the future being likely especially as the UK's position as a large manufacturing centre erodes. Respondents predicted that as bunker prices move upwards the speed of the vessels will move downwards, and slow steaming will be the future. They added that such slow steaming should give added schedule reliability as vessels will have the ability to speed up if required to meet berthing windows. While all panellists agreed that the shipping industry has to reduce its CO_2 impact, they were unsure which technologies would evolve, but many did highlight the importance of efficiency and related improvements in the transport chain. Finally, the respondents pointed to likely future changes in the ports sector, in particular as a result of the London Gateway development.

From this short review of the views of seven industry experts it is apparent that it is quite difficult to see ahead even five years with regard to what the UK container sector will look like. The difficulties in predicting the future in any industry are of course well known; one approach which is sometimes used to aid in this process concerns development of scenarios. The engine manufacturer Wartsila for example has suggested the following three scenarios for the future global shipping sector, each dependent upon the dominant geopolitical context (Wartsila, 2012):

Rough Seas
In the world of Rough Seas, scarcity of resources is predominant. Climate change adds further stress. Cartels and bilateral agreements have overtaken free markets. Wealth is divided unequally among nations, resulting in tension. The entire logistics chain is optimised regionally and national governments control ports.

Yellow River
In Yellow River, China dominates the global arena economically, geopolitically and in shipping. China is no longer the world's cheapest manufacturing region. Instead, labour and resource-intensive manufacturing has moved to Africa and other Asian countries. Economic growth is significantly slower in the West and climate change is tackled only on a regional level – no global agreements exist.

Open Oceans
The world of Open Oceans is a strongly globalised one. Global mega-corporations and megacities have gained power over the nation state. Governments cooperate on the governance of climate issues and free trade protocols. Climate change is perceived as an opportunity, and innovating green solutions is a lifestyle. Highly optimised and integrated large scale logistics systems support global trade.

It is of course impossible to know which of these scenarios (if any) will emerge. What is apparent however is the key role of global geopolitical influences and how these will dictate the (derived) demand for shipping and thus its associated emissions.

Our work in this consortium is ongoing with regard to building up a picture of how maritime logistics systems and networks will evolve into the future, and how they will contribute to the emissions associated with the evolving shipping technologies that will dominate the sector.

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