December 2017 Development Paper

MariEMS Learning Material - E-Navigation and Weather Routing

This is the 17th compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material extracted from the IMO TTT Courser. The material is composed from Chapter 17 of the learning material.

17. Introduction to Ports and Port-Area Emissions

17.1 Port Role and Functions

Ports are part of a wider international and national network of transport and logistics. They significantly contribute to the cargo logistic network. The success of ports in the logistics chain depends on their strengths as well as the strength of other players in that chain including shipping. A similar reasoning applies to the other maritime transport players including ship owners, port operators and the land-based transport service providers. Accordingly, the function of a port like other major maritime stakeholders (e.g. ship owner) does not depend exclusively on its own facilities and management processes but also affected by a variety of other stakeholders. Figure 17.1.1 shows a simple view of the basics of a logistic chain.

Figure 17.1.1 - A simplified schematic of a logistic chain [Voorde & Elsander]

As Figure 17.1.1 indicates, the maritime logistics chain consists of three large sections:

- The purely maritime aspects (at the centre above) that mainly relates to ship operation;
- The cargo handling and storage in the port; and
- The land-based (hinterland) transport services.

Depending on the cargo category concerned and the type of chain management applied, this structure may become more complex and possibly involve different players as well as other ports of call. Considering only the port-related activities in the above overview, one of the core and most important function of ports relate to the ships' cargo loading and unloading. Specifically focussing on ports, Figure 17.1.2 shows the main activities of a marine port in a schematic form.

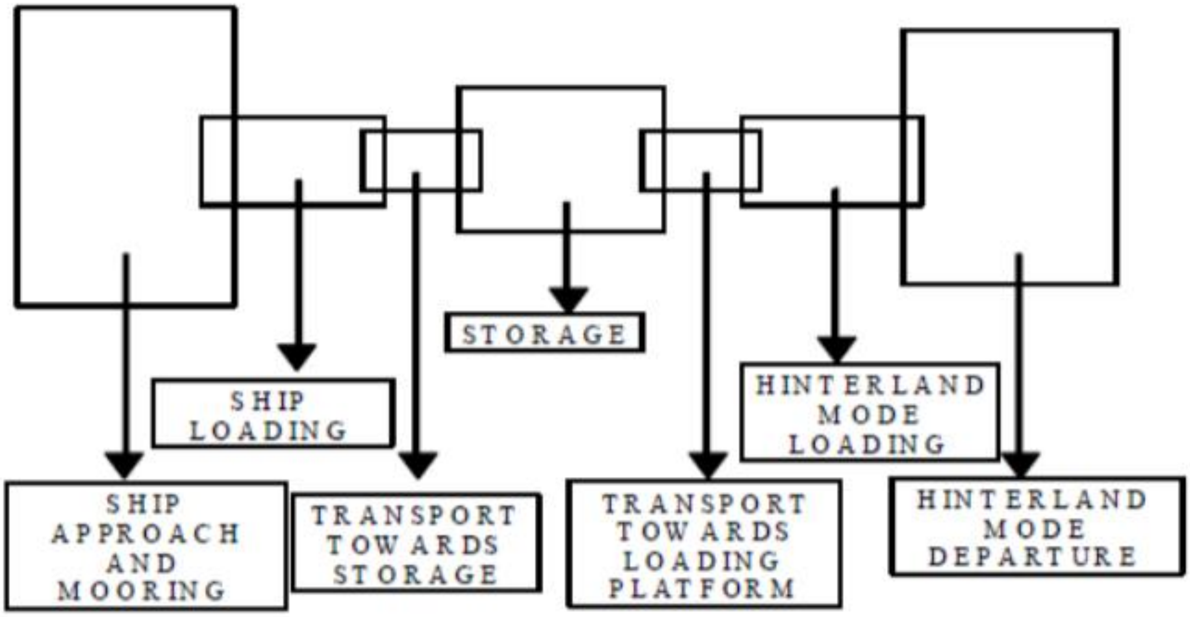

Figure 17.1.2 – The main activities of a marine port [Voorde & Elsander]

Over the time, ports have engaged in a large number of so-called value-added services in addition to cargo loading and unloading plus other core services. These could include a variety of marine services such as bunkering, to repair and real estate activities in ports as shown in Figure 17.1.3. This evolution of port activities is indicative of the increasingly complex nature of ports of modern times.

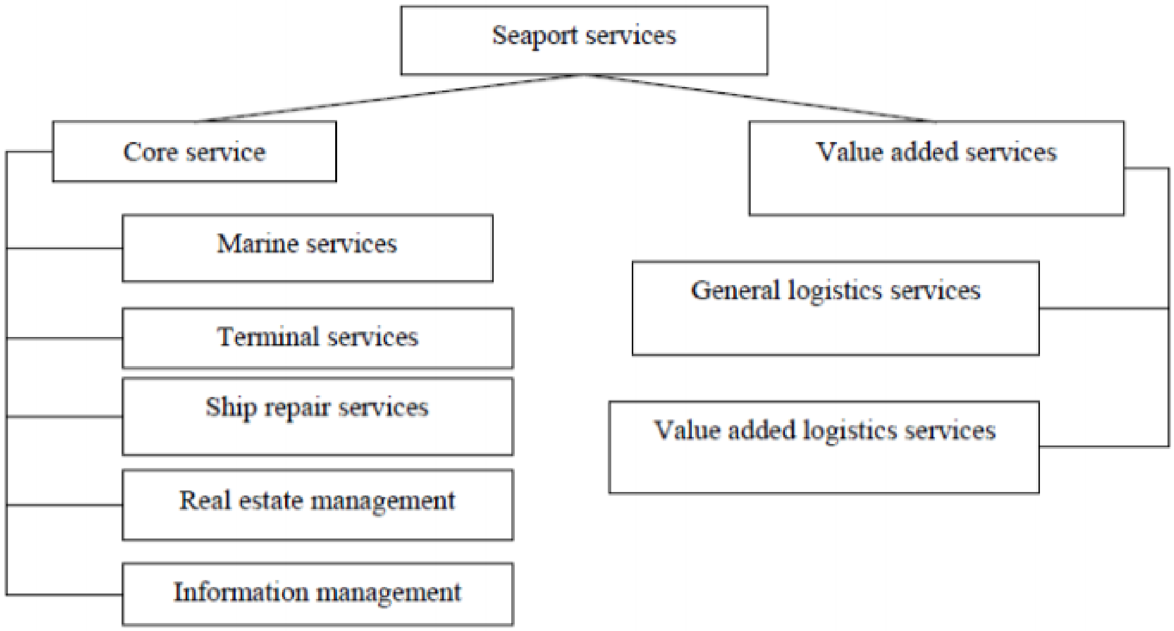

Figure 17.1.3 – Principal port activities [Voorde & Elsander]

17.2 Complexity of Port Operation

A port encompasses more than the port authority as the top governing body but also other players such as shipping companies as its principal customer and terminal operating companies as the main suppliers of services. There are numerous other, often smaller players to take into account and typical examples of such players are fuel trading and dredging. The former plays a big role in ship operations, whereas the latter has its role in the construction of shipping and port facilities. The availability of efficient fuel provision can convince a shipping company to call at the port and even make a longer stay, in both cases resulting in more cargo loading and unloading capacity. Dredging activities are an important element of capacity creation and maintenance.

From a different perspective, port management is a complex process as this is normally made up of a variety of links. Often different part of the chain are controlled or managed by different players, but some activities are also integrated across links. So, ports could have a relatively complex management and decision making structure.

No two ports are physically and economically the same. Therefore, their operations will depend on the port as a physical entity, taking into account the various activities such as facilitating the loading/unloading of vessels, freight handling and storage and access to land-based transportation. Clearly these are quite diverse activities, which combine to make port services quite diverse and complex.

Port operations involve a great many players, both at management level and at operational level. The management of ports also varies from one country to the other. The port as a physical entity is managed by a port authority in which the public authorities may or may not be a stakeholder. In addition, depending on the size of the port, any number of enterprises may be located within its perimeter. Figure 17.2.1 offers an overview of the various market players within a port, indicating who provides services to whom. The diagram confirms that shipping companies rely on services provided by third parties (e.g. pilots, towage services, ship repairers, provisioning, waste reception facilities, and bunkering companies) that are somehow but not fully associated with a port.

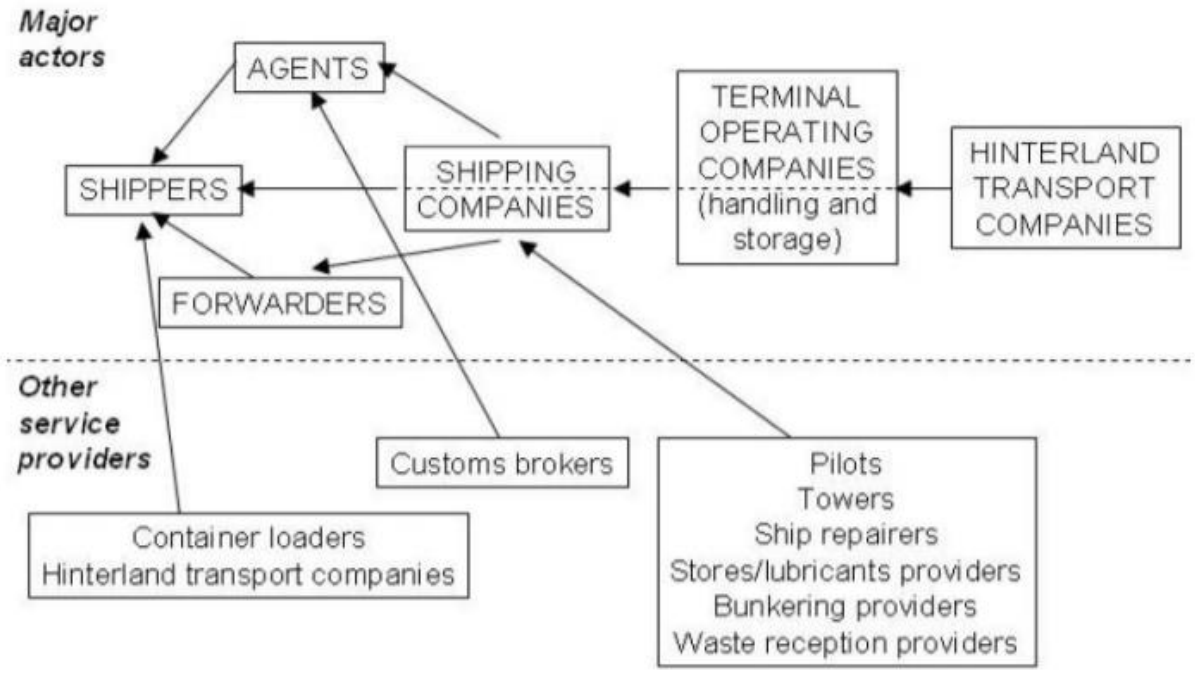

Figure 17.2.1 – Schematic of major players in port-related activities [Meersman, Van de Voorde and Vanelslander]

The large number of parties involved in port activities, each of which pursues its own objectives, gives rise to a considerable degree of diversity, both within the port and between ports. Hence, a generalised comparison between ports may not be fully possible. Moreover, the situation is further complicated by the fact that different ports often work under different economic, legal, social and tax regimes just because they are regarded as part of national entities in each country. Thus ports are to a large extent different from international shipping that is mostly regulated by IMO rather than by national-specific regulations that applies to ports [Hilde Meersman, et al].

The issues of governance, control and ownership are critical to any discussion of environmental management in ports. The vast majority of harbours are characterized by privately owned dock facilities and in these instances, control of property and operations lie with each private property owner.

17.3 Ports and Air Emissions

On the environmental side, one of the main issues that ports are facing is local air quality. This is caused due to air pollutants; rather the CO_2 emission that is the main topic of this training course. As most of activities relating to reduction of air pollutants have impacts on CO_2 emissions, in this module, the emphasis will be on all air emissions rather than simply CO_2.

In port areas, air emissions and energy consumptions are primarily due to ships. However, there are other equipment and facilities that use energy or contribute to air emissions to port areas. These are for example:

- Cargo loading and unloading devices.
- Trucks and other land-based transportation units such as locomotives.
- Buildings and energy needed for these building.
- Harbour crafts that provide additional services to port and shipping companies.

Emissions in port areas are mainly those due to diesel engines and boilers. These air emissions include:

- Nitrogen Oxides (NOx): The main sources of NOx are diesel engines both for ships and other land-based trucks.
- Particulate Matters (PM): Again diesel engines are the main source of such emissions.
- Sulphur Oxides (SOx): These are due to burning of sulphur content of fuel.
- Some carbon monoxide and unburned hydrocarbons could also be emitted from ship engines if they are not properly tuned.

The amount and level of such emissions will depend on not only technologies used but also operational aspects of ships, the time they stay in port and other energy using machinery and facilities in port itself. Emission reductions in the port area are typically focused on PM, SOx and NOx due to air quality health impacts. Controlling NOx, PM and SOx is the central focus for most national and regional regulatory agencies and therefore the same applies for ports as does to the shipping industry. GHGs emissions have recently been seriously addressed by regulatory agencies such as IMO, although in the port area, health effects and thus pollutants typically take the priority over GHG emissions.

In a discussion paper by International Transport Forum [Olaf Merk], it is claimed that shipping emissions in ports are substantial, accounting for 18 million tonnes of CO_2 emissions (this is equivalent to burning of about 6 million tonnes of fuel oil), 0.4 million tonnes of NOx, 0.2 million tonnes of SOx and 0.03 million tonnes of PM10 (PM with size of less than 10 microns) in 2011. Around 85% of emissions come from containerships and tankers. Containerships have short port stays, but high emissions during these stays.

The same paper states that most of CO_2 emissions in ports from shipping are in Asia and Europe (58%), but this share is low compared to their share of port calls (70%). European ports have much less emissions of SOx (5%) and PM (7%) than their share of port calls (22%), which can be explained by the EU regulation to use low sulphur fuels at berth. Future forecasts indicate that most of shipping emissions in ports are estimated to grow fourfold up to 2050. This would bring CO_2- emissions from ships in ports to approximately 70 million tonnes in 2050 and NOx-emissions up to 1.3 million tonnes. Asia and Africa will see the sharpest increases in emissions, due to strong port traffic growth and limited mitigation measures.

The above indicates that various initiatives are needed to combat air pollution in ports. These will be discussed in this module with specific reference on CO_2 emissions. Various ports have developed infrastructure, regulation and incentives that mitigate shipping emissions in ports. These instruments would need wider application in order for ship emissions in ports to be significantly reduced.

17.4 Method of Reduction of Port Area Emissions

Numerous and diverse measures and strategies are available to effectively reduce emissions and improve energy efficiency for ships in the port area. Experience with addressing ship emissions and implementing measures in the port area dates back to the late 1990's and is becoming more prevalent over the past decade There are initiatives underway by various stakeholders to evaluate and demonstrate emerging and innovative measures that could be effective both at-sea and in the port area.

Although the direct control of ports/terminals on ships' emissions is limited, they can have an impact on the reduction of ship emissions in the port area in a number of ways [MEPC 68/INF.16]:

- Ports/terminals can facilitate the just in time ship operations in ports that substantially reduces the ship's port time, thus emissions.
- Ports/terminals can directly or indirectly provide incentives for the ship owners to implement emission abatement measures on-board.
- Ports/terminals can facilitate port area ship emissions reductions by providing certain infrastructure themselves, like OPS facilities.

To deal with the above, one could deal with port related emissions for ship sources and non-ship sources.

17.5 Port Non-Ship Related Emissions Reduction

17.5.1 Port-land based side

If the land-based side of marine transport operations is taken into account, it would include cargo handling equipment, stationary power sources, locomotives and heavy-duty trucks operating within the port area. These are non-vessel related emissions from ports. To reduce emissions in such cases, the following may be considered [Corson et al]:

- **Clean Fuel:** Change to advanced clean diesel fuel, such as low or ultra-low sulphur diesel (LSD) (ULSD), emulsified diesel, bio-diesel, compressed natural gas, liquefied natural gas, liquefied petroleum gas (propane, which requires a dedicated engine) and so on. All of these will provide direct benefit to port air quality and at the same time some reduction in GHG emissions.
- **Technology Retrofit:** Installation of "after treatment" devices on existing diesel engines such as diesel particulate filters, oxidation catalysts, closed crankcase ventilation, selective catalytic reduction, lean NOx catalyst, exhaust gas recirculation and so on. Trucks could be retrofitted with some of these technologies.
- **New technologies:** Use of hybrid-electric technologies as replacements for pure diesel engine vehicles and equipment.
- **Operation management:** This could include a large number of measures that helps to reduce fuel consumption and emissions including:

- Implementation of policies that would reduce the idle operation of vehicles such as reduction of port congestion and start-stop technologies.
- Include incentives for emissions reduction in leases and contracts with tenants, contractors and transportation service providers;
- Expand operating hours to reduce truck queuing, idling and traffic congestion;
- Promote other aspects that would reduce port area traffic congestion and emissions.

The above include a summary of the important pollution reducing measures. For reduction of energy consumptions, port need to follow energy management system and develop energy management plan that could be applied to all aspects of port operation. ISO 50001 can be used for this purpose and energy review and audit will form a part of energy planning for the port.

17.5.2 Port harbour crafts

Apart from ships calling a port, there are a significant number of harbour crafts that provide support services to ships and port. Although not directly related to international shipping emissions, such crafts contribute to port air quality as they are mostly powered by diesel engines.

For harbour crafts and in order to save fuel and reduce pollutants to port, similar general measures as larger ships are applicable. Measures that can be applied to address emissions from harbour crafts are often adapted from those developed for on-road and non-road equipment. These measures include. Some of the measures that may apply for harbour crafts are:

- **Engine Replacement:** Replacement of a harbour craft engine is not an easy option as it normally will require all sort of different auxiliary machinery, space and fuel requirements. However, retrofit of engine can be an important consideration for harbour crafts in view of changing technologies, move to hybrid electric options as well alternative fuels. Replacing main-propulsion engines with cleaner engines will provide great emission benefits that compound over the remaining life of the equipment. For harbour craft, this can be significant because the total operating life can be up to 30-40 years. Cleaner engines are, however, costly and capital costs may be a major barrier [ICCT June 2012].

- **Clean Fuels:** The second option that may require less capital cost but will have implications on operating costs is the use of cleaner alternative fuels. The most obvious one is the use of low sulphur fuel in a similar fashion as road transport that uses ultra-low sulphur fuels these days. Additionally, other options could include emulsified diesel fuels and biodiesel. The more promising alternative fuel is natural gas in the form of LNG as LNG fuelling infrastructure is being developed. Move to LNG will require capital investments but the longer term the return could be via cheaper fuels, and a reduction of all types of air emissions. Use of biofuels, CNG or LNG would benefit the climate change as they would reduce overall discharge of CO2 to atmosphere.

- **Technology upgrade:** This option relates to retaining the engines but opting for more advanced available engine controls, fuel additives and after-treatment emission control technologies such as diesel oxidation catalyst, diesel particulate filter and selective catalytic reduction (SCR).

- **Hybrid electric systems:** The harbour crafts are good candidates for use of more advanced technologies such as hybrid technologies to include batteries and electric motor / generators in the same way that land-based vehicles are moving into hybrids domain. Also, these vessels can be connected to onshore power when at berth for on-board electrical generation for hoteling functions. Hybridization is best for harbour crafts when they are away from the berth and have fluctuating energy demands. Hybridizing for harbour crafts has become much more feasible in the past several years as several demonstration projects have illustrated the feasibility and benefits of the technology. In Long Beach, Foss tugboats retrofitted an existing tug with lithium ion batteries and advanced drives for a total project cost of $2.1 million [ICCT June 2012].

The above discussion about port-side emissions including those from cargo handling equipment, buildings, ground transportation services, etc. plus those coming from harbour craft will not be further discussed in the following sections. Instead the full attention will be on ship-port interface and ship-related emissions from now on.

17.6 Port Ship-Related Emission Sources

The emission sources directly associated with ship operations in port include those due to propulsion engines, auxiliary engines and auxiliary boilers plus Volatile Organic Compound (VOC) that is associated with bulk liquid cargos and various Ozone Depleting Substances (ODS) due to refrigeration system. From an air pollutant perspective, vessels can produce significant amount of NOx, SOx and PM from burning fuel in the propulsion engines, auxiliary engines and auxiliary boilers/steam plants. Depending on the geographical configuration of the port area and type of vessels, these three combustion systems can have varied level of emissions. It is important to know for the vessel in question, which of these plays a more important role in ports when it comes to emissions and energy efficiency reduction measures [MEPC 68/INF.16]. Most emissions from ships in ports are the result of diesel engines burning heavy fuel oil. Compared to land-based transport, the marine engines are not as strictly regulated as their land-based counterparts. National and regional regulatory authorities have limited control over international ships other than on their own flagged ships and to some extent ships visiting their ports. Reducing emissions from ship-board diesel engines is therefore one of the significant challenges and opportunities related to improving air quality in port areas. The unique challenge associated with the port area, with regard to reducing ship emissions, is how the emission sources listed above associated with various modes of ship operation in the port area. Generally a ship in port area has two general modes of operation [MEPC 68/INF.16]:

Transit and manoeuvring: During this mode, a ship is typically operating within confined channels and within the harbour approaching or departing its assigned berth. The distance associated with this mode is unique for each port and varies depending on geographical configuration of the port. During this mode of operation:

- The ship is moving at its lowest speeds, thus propulsion engines are operating at low loads.
- Auxiliary engine loads are normally at their highest compared to other modes because of the need for running additional machinery on-board, such as thrusters (for manoeuvring), air scavengers/blowers (due to low main engine load), etc.
- An additional auxiliary engine (diesel generator) is online for safety reasons in case one auxiliary engine's trip/failure does not lead to dangerous situations or blackouts.
- Auxiliary boilers are on because the economizers are not producing enough steam due to low propulsion engine loads and resultant lower engines' exhaust temperatures (this does not apply to large diesel-electric ships with central electric power generation).

In such a mode, still most of fuel consumption will happen in main propulsion engines but boilers and auxiliary engines will consume fuel more than the normal sea going levels. The other aspect is that all the above combustion systems are working off-design at part loads. This is not good as such systems tend to be less efficient and more polluting under such low-load operating conditions.

At berth or anchored: During this mode, a ship is secured and not moving. Typically under this condition:

- Propulsion engines are off.
- Auxiliary engine loads can be high if the ship is self-discharging its cargo, as with general cargo vessels, auto carriers and roll-on roll-off (RoRo) vessels and oil tankers.
- Auxiliary boilers are operated to keep the propulsion engine and fuel systems warm in case the ship is ordered to leave port on short notice and also for other purposes. In some tankers, steam is used for discharge of cargo through the use of steam turbine driven pumps.

Vessel fuel consumption can be low, medium or high for auxiliary engines and can be low, medium to very high for boilers (for example for tankers when discharging), depending on ship types and if it uses energy for cargo operations. Again, both auxiliary engines and boilers will be operating at part load with low efficiency and high specific levels of emissions.

The majority of ship owners, operators and engine manufacturers as well as the regulators to some extent focus their efforts in reducing emissions and increasing energy efficiency for normal at-sea conditions as opposed to the port area. Typically, most ships move from one port area to another and for these ships, a majority of the ship's energy consumption over the life of the ship occurs at sea. Ship emissions estimation studies show total ship carbon dioxide (CO_2) emissions in the port area range from 2% at the Port of Los Angles [Starcrest Consulting] as compared to the entire voyage of the ship, to 6% at the Port of Rotterdam [MEPC 68/INF.16] as compared to greater North Sea area. Figure 17.6 emphasizes this point by illustrating the magnitude of time and energy spent at sea versus time and energy spent during the modes.

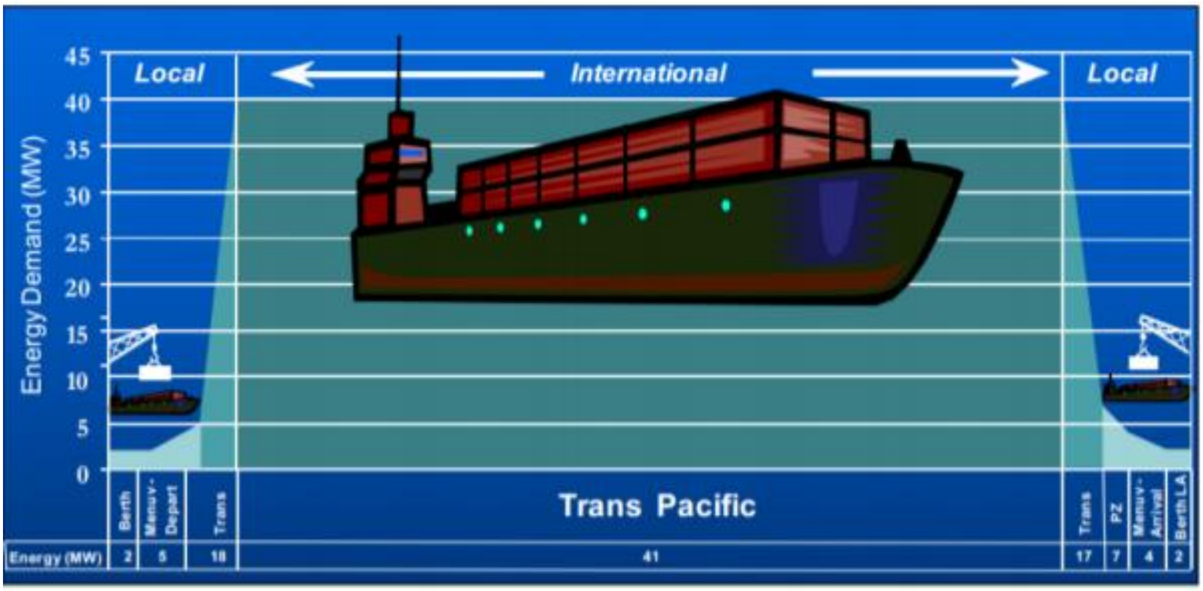

Figure 17.6 - Energy demand example: Trans Pacific transit from Shanghai to Los Angeles [Starcrest Consulting Group]

It is not uncommon for most vessels to be operating at propulsion loads below 50% in the port area and even at loads below 25% for significant portions of the time in the port area. In the transit and manoeuvring modes, the propulsion engine is operating with variable loads and is even turned off/on depending on the specific area the ship is manoeuvring through. The emission factors *(Emissions factor refers to emission produced per unit of energy produced or fuel used and for engines it is specified as g/kWh or g per kg of fuel)* of an engine will vary according to engine load and generally becomes worse (higher) at lower loads as both pollutants and CO_2 emissions factors will increase at lower loads per unit of power production. Thus in port and harbour areas, it can be stated that:

- Ship engines are operating with lower and varying loads.
- Propulsion and auxiliary engines are operating below their optimal performance loads.
- Auxiliary boilers are also for most of the time below their normal operating loads
- Various emissions factors for engines and boilers are higher than design values due to low load factor.

The main question is that whether one could avoid the above situations via use of alternative technologies, fuels and operational processes. These questions will be answered in various sections of this module.

17.7 How to Deal With Ship-Port Interface

Based on discussion about the ship-related and non-ship related emissions in port, it is clear that the emissions in port areas can be dealt with by measures to be implemented at ship level and port level via analysis of the following:

- Non-ship related air emissions
- Ship-related air emissions.

The "non-ship related air emissions from port's infrastructure, facilities, its land-based transport, and harbour crafts" and main aspects of dealing with them was introduced and summarily covered in Section 17.5. As this is not the main focus area of this course, no further discussion will be provided. The readers could refer to list of references for further information on this subject in particular the ICCT reports.

The ship-related emissions to port as indicated above can be divided to those related to ship manoeuvring and transit in port area plus those when ship is at berth. To reduce them, a number of main measures could be followed:

- **Reducing the time of ship stay / operation in port:** No matter how low or high a ship emits, the absolute total amount of exhaust emissions to the port area will be a function of total time of ship manoeuvring and stay in port area. Thus staying in ports for an extra 50% of the time is expected to increase the ship emissions to port area by approximately an extra 50%. For this reason, reducing a ship's time in port could be regarded as one major strategy for improving air quality in ports. This at the same time would help the ship save fuel significantly by running slower due to extra time in passage. This strategy can be achieved via a policy of operating just in time in port.
- **Use of alternative ship technologies and fuels:** As discussed, current diesel engines burn heavy fuel oil that is not a clean and low carbon fuel. Additionally, the conventional diesel engines technology on-board ships can be improved to more efficient engines with lower fuel consumption and pollutants. There are options to move away from these technologies and fuels to more energy efficient and clean technologies and fuels. This strategy, in particular

new and alternative technologies, may be more applicable to new ships rather than existing ships.

- **Ship in-port technical operation management:** When a ship in port at berth or at anchor, various engines, boilers and machinery still need to be operating and thereby will use energy. Off course, the way these operations take place would impact a ship's in-port fuel consumption and exhaust emissions.

- **Switching off the engines in port via shore connection:** The next strategy could be to switch of the ship-board engines when in port. This is subject to availability and supply of power from port to ship. This is an important development and requires investment both by port and ship and may result in some extra operational complexities. This policy is achieved via on-shore power supply system (cold ironing).

- **Ship loading with due consideration for ship energy efficiency:** The subjects of ship loading, trim optimisation, ballast optimisation were covered in previous modules. Some of these will not be achieved unless the cargo handling aspects of the ship are done properly. Although this may not have impact on port area fuel consumption and emissions, but is an important measure for a ship's energy efficiency that is impacted by its port operations.

- **Environmental oriented incentives:** To encourage ship-owners and operators to do their best to reduce emissions, regulations and market incentives could be used to encourage use of the above measures. IMO and regional initiatives have already regulated ships to some extent; for example with switch over to low sulphur fuel in certain areas and ports. There are financial incentives from certain ports to encourage use of environmentally friendly ships and so on. Section 6 on green port initiatives and port environmental program cover some of these aspects. Overall, there are significant opportunities for ship-port interface improvements to reduce air emissions from ships to port area and enhance overall energy efficiency of shipping. Although ports' core attention is on air quality and pollutions, nevertheless, there is a strong link between air pollutants and GHG emissions and this will be the subject of detailed discussion throughout this module.

17.8 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. "IMO train the trainer course material", developed by WMU, 2013. Viewed Nov 2016.

http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Air%20pollution/M5%20ship-port%20interface%20final.pdf

2. Eddy VAN DE Voorde and Thierry Van Elsander "Market Power and Vertical and Horizontal

Integration in the Maritime Shipping and Port Industry", Discussion Paper No. 2009-2, December 2008, University of Antwerp, Belgium. Viewed Nov 2016.

3. Hilde Meersman, Siri Pettersen Strandenes, and Eddy Van de Voorde "Port Pricing:

Principles, Structure and Models", a discussion paper, Institutt for Samfunnsøkonomi, Department Of Economics, April 2014. Viewed Nov 2016.

4. Starcrest Consulting Group "The Port of Los Angeles 2010 Expanded Greenhouse Gas

Inventory", Report published December 2011. Viewed Nov 2016.

5. ICCT June 2012, “Developing Port Clean Air Programs: A 2012 update to the International Association of Ports and Harbor’s Air Quality Toolbox”, June 2012
6. MEPC 68/INF.16, “Study of emission control and energy efficiency measures for ships in the Port area”, MEPC 68/INF.16, 4 March 2015, report prepared by Starcrest Consulting Group, LLC CE Delft and Civic Exchange. Viewed Nov 2016.
7. Olaf Merk “Shipping Emissions in Ports”, Discussion Paper No. 2014-20, International Transport Forum, December 2014. Viewed Nov 2016.