MARINE PORTS ENVIRONMENTAL SUSTAINABILITY: A STATE OF THE ART OVERVIEW

Agostino Bruzzone [(a)], Letizia Nicoletti[(b)], Alessandro Chiurco[(c)], Rafael Diaz[(d)], Emanuela Palaia[(e)]

[(a)]MITIM-DIME, University of Genoa, Italy
[(b),(c),(e)]MSC-LES, University of Calabria, Italy
[(d)]Old Dominium University, USA

[(a)]agostino@itim.unige.it, [(b)]letizia@msc-les.org, [(c)]a.chiurco@unical.it, [(d)]rdiaz@odu.edu, [(e)]e.palaia@msc-les.org

ABSTRACT

In recent years sustainable development has become a problem of primary importance. This article focuses on the currently marine ports situation, offering a perspective through some relevant research works, from the past until today. In the second part of the paper a simulation based-tool for measuring the environmental impacts in marine ports area is briefly presented. The simulator is able to consider the impact of the main factors affecting the sustainability of port processes and operations such as CO_2 emission, ship air emissions, air quality, ship discharge, etc.

Keywords: marine port sustainability, emissions, sustainable development, M&S-based approaches

1. INTRODUCTION

Heightened sensitivity of social communities along with environmental protection laws (enacted in many Countries and mainly from the European Community), have made sustainability a key factor in many application fields.

The most common and recognized definition of sustainability can be found in the Brundtland report : "meet the needs of the present without compromising the ability of future generations to meet their own needs" (OCI, 1987). Therefore sustainability implies the capability of setting up growth processes avoiding either overexploitation of resources or damages for future generations. As a consequence, resources preservation and efficiency are basic requirements to achieve sustainability and in this perspective technical, social and environmental aspects have to be considered simultaneously.

In its historical perspective, sustainability can be dated back to the 1970s when the oil crisis propelled the first studies on natural resources depletion. In 1972, the report "Limits of Development" (Meadows et al.,1972), stated that productivity growth would have exhausted all the natural resources in a few decades. In the same year the United Nations Conference on the Human Environment, which was held in Stockholm, laid down the foundations for the strategic path toward sustainable development. Thereafter market pressures and regulations have drawn business attention to environmental issues: customers and suppliers are increasingly demanding minimal negative impact on the natural environment (Karakosta et al., 2009, Golusin et al., 2011). As a result the so-called 'green management', has emerged as a key factor for firms, see Shrivastava, (1995), Klassen and Whybark, (1999), Lun, (2011), and many others. In this scenario waste elimination, recycling, waste treatment and final disposal are crucial aspects (Crittenden and Koloczkowski, 1995); in particular energy consumption and wastes can be very high in manufacturing industries therefore proactive tools to investigate current and alternative practices are required. On this purpose Mani et al. (2011) propose an approach based on Discrete Event Simulation (DES) and Life Cycle Assessment (LCA) to tackle sustainability issues in manufacturing industries. Similarly Lee at al. (2012) suggest a simulation-based prototype for sustainability analysis of manufacturing system. Moreover a three-dimensional approach for sustainable production, which considers technology, energy and materials, was proposed in Yuan et al. (2012).

The "triple bottom line" approach has emerged as a tool to measure corporate performances including environmental and social dimensions (Elkington and Trisoglio, 1996). Based on this approach Azapagic and Perdan, (2000) propose a general framework with a comprehensive set of indicators for assessing the level of sustainability in industry and identifying more sustainable options for the future. Moreover the need for assessing and evaluating sustainability interested many authors, to name a few Labuschagne et al.(2003); Gasparatos et al.(2007), Lee and Saen (2011), Basurko and Meshabi (2012), Joung et al. (2012), etc. However, environmental impacts affect all the stages of products/services lifecycle therefore sustainability has to be considered along the entire supply chain, starting from row material procurement up to products disposal.

The extension of the traditional supply chain to include activities taking into account environmental impacts, brought out the concept of "Green supply chain (Beamon, 1999). Needless to say that the sustainability of the chain depends on the sustainability of every firm of which it is made up (Hart, 1995). For this reason Neto et al. (2007) proposed a multi-objective programming (MOP) approach to support sustainable design in logistics networks. Furthermore in the last few years the current sustainable approaches were extended to the inventory management (Nikolopoulou and Ierapetritou, 2012).

The state of the art analysis allows pointing out that sustainability cannot be neglected; it is an imperative both in logistics and industry.

Moreover, considering that marine ports are important nodes in intermodal transport networks (note that sea-trade is more than 90% of the world trade), this research work aims at facing the issue of sustainability in seaports.

This paper examines the environmental situation in marine ports relating to sustainability issues. It identifies four main areas of interest. In the section 3 the most common air pollutants are considered and discussed. In the section 4 the paper provides an overview of the port operations impact on water quality and energy consumption. In the section 5 M&S is proposed as a powerful and successful approach to evaluate sustainability in ports. In the section 6 a brief description of sustainable technologies in the port area is provided. Finally the paper briefly presents a simulation based solution developed by authors to evaluate port processes and operations sustainability.

2. ENVIRONMENTAL SUSTAINABILITY IN PORTS

Market and governmental pressures make sustainable development a critical issue in ports management and control. Considering some aspects like greenhouse gas emissions and energy consumption it is evident that the environmental impact of port activities cannot be neglected. To this end “Agenda 21” is recognized as the first initiative toward environmental efficiency within harbours: the concept of "Greenport" has been introduced and since then the quest for environmental friendly measures and technologies being able to minimize wastes, has never stopped (Langeweg, 1998).

As matter of fact, a great deal of effort has been made to improve energy efficiency, renewable sources exploitation and storm water collection and reuse. Moreover to cope with sustainability issues, the main areas of interest have been detected and classified as follows:

- Air quality: it includes the quest and development of less polluting equipments for cargo handling and the use of alternative fuels for vehicles.
- Climate change: it includes the intervention aiming at reducing some chemical agents that are responsible for the climate change.
- Water quality: to deal with this problem more stringent discharge limits on storm water runoff were introduced.
- Energy conservation & Renewable energies: many port areas are inquiring about the possibility of buying green or renewable energy.

Therefore the main actions toward sustainability can be ascribed to the areas above mentioned. As stated before this research work is intended to analyze the eco-friendly initiatives within marine ports and to propose a simulation-based approach in order to foster environmentally acceptable operational and management processes. To achieve these research goals the main issues related to sustainability in seaport areas have been considered and analyzed. As a result a state-of-art overview is proposed in the sequel (section 3 and 5).

3. CLIMATE CHANGE AND AIR POLLUTION: A CHECK ABOUT EMISSIONS

Greenhouse gas emissions contribute both to climate change and air pollution, for this reason it is important to quantify and monitor emission levels. In addition, considering that ports are vital nodes of transport infrastructures, it is worth assessing the typology and the quantities of emissions that are released into the atmosphere as a result of port processes (Howitt et al. , 2011). To this end, several studies on different worldwide ports have been carried out, i.e. Gupta et al. (2002), Saxe and Larsen (2004), Lucialli et al. (2007), Joseph et al. (2009), Villalba and Gemechu (2011), and many others. From these studies it is possible to notice that the most common air pollutants include diesel exhaust, particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), ozone, sulfur oxides (SOx), carbon monoxide (CO), carbon dioxide (CO_2) formaldehyde, heavy metals, dioxins, and pesticides (often used to disinfect products). Among them, CO2 can be recognized as the main responsible for global warming, therefore there is a great deal of works that propose emission-based models for assessing CO2 emissions within marine terminals, i.e. Berechman and Tseng (2012), Geerlings and Duin (2011), Voet (2008), and many others. However, to estimate emissions and set up management policies against air pollution the main pollutant sources have to be identified; these sources include marine vessels, trucks, locomotives, and off-road equipment used for moving cargo (Bailey and Solomon, 2004). Air pollutants and pollution sources are capital aspects to control and minimize the emissions whose effects can lead to far-reaching consequences on air quality affecting large geographical areas (Streets et al., 2000). In literature emissions have been divided into two main classes: sea-based and land-based emissions. The former are related to ships arrivals, departures, hoteling and manoeuvring whereas the latter depend on port activities and include electricity consumption, fuel, heating and generation of waste (Villalba and Gemechub, 2011).

Although sea-based emissions make up a small percentage of the overall ship emissions (Whall et al., 2002, Dalsoren et al., 2009), in-port traffics are growing noticeably therefore the overall ports workload keeps growing and as a consequence emissions of NOx, PM and SOx cannot be ignored. To this purpose some assessment methodologies can be found in Trozzi (1996), ENTEC (2002), Gupta et al. (2002) , Peng et al. (2005), Tzannatos (2010), Villalba and Gemechu (2011), and many others.

In addition, emission control effectiveness is related to the ability to develop detailed and accurate emission inventories for ports (Gupta et al., 2002; Joseph et al., 2009). Current methodologies and best practices for preparing port emission inventories were proposed by the US EPA (Iovanna and Griffiths, 2006).

Many city seaports have done emission inventories to name a few: Los Angeles, Rotterdam, Oslo, and New York, (Den Boer and Verbraak, 2010). In addition De Meyer et al. (2008) estimates the atmospheric emissions by international merchant shipping in the four Belgian seaports: Antwerp, Ghent, Ostend and Zeebrugge.

The impact of such emissions on air quality and environmental health is significant, as many research studies on this matter are have shown: Isakson et al (2001), Saxe and Larsen, (2004), Gariazzo et al., (2007), Lucialli et al., (2007), Lonati et al. (2010) and many others. Moreover Peris-Mora et al. (2005) propose a system of environmental indicators for the analysis of environmental impacts whereas Hartman and Hartman and Clott (2012) developed a model in order to control costs and emissions of the trucks within ports.

All these works allow pointing out the need for enforcing strict measures in order to curb environmental damages. The approaches that can be undertaken may rely on low-cost initiatives or more significant investments, for instance restrictions on truck idling, use of low-sulfur diesel fuels, shore-side power for docked ships, alternative fuels, etc.

4. WATER QUALITY AND ENERGY CONSUMPTION

Besides air quality and climate change, water quality and energy consumption are two key issues related to sustainable management of ports. Ports operations, in fact, impact on water quality and require high energy consumption.

Water quality may be affected from waste discharged by marine vessels, oil spills, dredging, etc. In addition contaminants and sediments can be disseminated by the tides therefore marine zones adjacent to harbours could be polluted by the waters coming from the harbours (Hart et al, 1986; Cornelissen et al., 2008). In this context, researching and developing tools to enable an efficient environmental management of harbour waters is particularly interesting for scientists and engineers (Grifoll et al, 2010). As a matter of fact, starting from Cotter (1985) that proposed a statistical method for surveying water quality, many research works have been published, i.e. Ondiviela et al. (2012) developed a methodological standard to provide port authorities with procedures for investigating the influence of port activities on the quality of water bodies. Valuable contributions can be found also in Kantardgi et al. (1995), Fabiano et al., 2002, Ronza et al., 2006, Eide et al., 2007, Palani et a. (2008), Ross and Shrestha (2008), Neacsu et al. (2009), De La Lanza et. al (2010), Wu et al (2010), Giurco and et al. (2011) and many others.

Energy consumption is another key aspect in dealing with sustainability. International seaports are striving to address energy challenges like save energy and maximize energy efficiency. To this end, Port Authorities are committed to support a more efficient and effective energy management in different ways, namely by using renewable energy sources (i.e. sun, wind, etc), installing biodiesel or biofuel systems and assessing available technologies. These initiatives drew the attentions of many researchers that have sought to develop new approaches for assessing energy requirements, monitoring energy consumptions, detecting new solutions for energy saving and new techniques for the exploitation of renewable energy sources with a lower environmental impact. To name a few: Birol et al. (1997), Todd (1997), Jesuleyea et al. (2007), Mohamed and Lee (2006), Kadiri et al. (2012) and many others.

5. MODELING AND SIMULATION-BASED APPROACHES FOR SUSTAINABILITY

To achieve sustainability all the aspects analyzed in the previous sections should be considered simultaneously. Therefore it is evident that in sustainability analysis many factors, which interact each other, have to be considered. The nonlinear nature of this kind of systems highlights its intrinsic and high complexity and consequently the need for integrating tools able to handle sustainability goals. To this end, M&S has proved to be a powerful and successful approach to cope with complex systems analysis and management.

In fact, M&S allows recreating and analyzing the operational processes taking place within marine ports in terms of their environmental impacts. However, past related works analysis show that M&S applications for sustainability are still limited to specific aspects whereas comprehensive and integrated tools, providing global impacts evaluations coupled with economical analyzes, are still missing. In other words, many attempts have been done to investigate (through simulation) specific sustainability-related issues but a comprehensive model where all this issues and their interactions are simultaneously considered, is not available currently. Some of the most representative works on M&S applied to sustainability are summarized in the remaining part of this section.

Johnson et al. (2006) worked out a simulation model to evaluate energy consumption and emissions in a terminal. Saxe and Larsen proposed a meteorological simulation model to assess the urban dispersion of air pollutants in three Danish ports. Roso (2007) presented a simulation-based approach to examine the dry port concept and the emission levels. Kim et al. analyzed the influence of ship emissions on ozone concentrations in a coastal area, by using two simulation scenarios.

Therefore these works on M&S aim to point out the effects of the major pollutants evaluate alternative and environmental-friendly strategies and solutions (Molders et al., 2010).

Analyzing in detail the simulation studies above mentioned it is possible to ascertain that the main modeled elements are:

- Port waste: garbage, sludge and waste materials resulting from industrial and commercial operations.
- Noise pollution: loading and unloading operations and movement of ships in water influence the local sound.
- Emissions to air: CO2, NOx, CO, SO2 and PM10 are the major.
- Hazardous cargo: in reference to the transport of potentially flammable, corrosive, reactive or toxic materials.

Moreover in many simulation models meteorological conditions are a key input since they influence pollutants concentrations in the air. In fact the wind is responsible for pollutants transport and dispersion whereas the intensity of solar radiations affects kinetic and thermodynamic conditions of reactions and lastly water distribution is responsible for sediments deposit (Marmer and Langmann, 2005). In addition, in a simulation study on ports sustainability, physical and chemical conditions of the environment have to be modelled carefully. In fact, for instance, it has been shown that sulphate aerosols decrease as altitude increases whereas NOx decreases when pressure drops.

6. SUSTAINABLE TECHNOLOGIES IN THE PORT AREA

As mentioned above, environmental sustainability in seaports is a very important issue given the rapid increase of ship traffic. For this reason, sustainability agendas are challenging port authorities that are required to use cleaner technologies and port assets more efficiently (Daamen and Vries, 2012). A brief description of the main environmental-friendly initiatives currently available is provided below.

6.1 Cold-ironing

When ships are berthed, they rely on onboard diesel auxiliary engines to power the equipments needed during loading and unloading operations, i.e. lights, ventilation and pump systems, cranes, etc. However, these auxiliary engines (that usually use low quality fuels) emit significant quantities of pollutants and green house gases (Hall, 2008). In this framework, cold-ironing (also known as Alternative Maritime Power (AMP)) can be seen as an alternative to onboard power generation systems. Renewable energy sources or onshore power systems can be used to power ships equipments during the port operational processes. In this way, emissions can be substantially reduced; in fact it has been proved that a 20 MW AMP can lead to a 52.7% reduction of CO2 emissions and a 39.4% reduction of PM

6.2 Electrical vehicles

Nowadays innovation is leading to more sustainable applications also in the automotive industry. In fact replacing traditional engines with electrical vehicles allows reducing emission and saving energy (40% energy saving).

6.3 Liquefied Natural Gas (LNG)

Typical LNG fuels are methane and ethane. It has been proved that LNG allows a 20% reduction of carbon dioxide emissions and also a reduction of sulphur emissions.

6.4 Onsite energy production from renewable sources

Photovoltaic systems can be used to power both port equipments and ship equipments. Currently photovoltaic panels are being installed also on roofs of cruise ships.

Seaport areas are generally exposed to the wind (Solari et al., 2012) therefore are considered suitable sites for wind turbines installation.

Furthermore, biomass is gaining an increasingly importance as source of energy, in fact it offers the possibility to reduce greenhouse gas emissions by 20%, in line with the target imposed by Kyoto Protocol. (Heinimo and Junginger, 2009). For this reason biomass power station installations are increasing within port areas.

7. CASE STUDY

After having considered the issues related to sustainability in seaports, the attention has been focused on the development of a simulation-based tool to be used for the evaluation of the sustainability of marine ports processes and operations. To this end, the GreenLog simulator (Green Logistics simulator) was the starting point of this research work (Bruzzone et al. 2009-a; Bruzzone et al. 2009-b). Actually the authors have a remarkable experience in developing advanced simulation models in Supply Chains and Industry (see for instance Bruzzone et al. 2000; Bruzzone, 2002; Bruzzone, 2004; Bruzzone et al., 2007; Longo et al. 2012).

GreenLog is part of the “Italian Green Logistics Initiative” that involved Industry, Academy and Governmental Institutions. In detail, GreenLog is a Web Based Simulator implemented by using Java™ technology. It has been developed in order to provide a decisions support tool for measuring the environmental impacts of supply chain nodes considering factors such as: air emissions, waste disposals (i.e. rubber due to tire trucks consumption) terrain degradation, noise, spills, dusts etc.

In particular for the Port Impacts environmental Model development, several factors have been considered:

- Garbage & Port Waste;
- Dredging;
- Dust;
- Noise;
- Ship Air Emissions;
- Air Quality;
- Hazardous cargo;
- Bunkering;
- Ship Discharge.

In addition, it is important to note that when environmental impacts are evaluated often, just the impacts related to the "on going" state are taken into consideration; sometime this is a wrong approach because it is necessary to consider the whole port life cycle to avoid mistakes. In fact, all the activities required to build and set up all the port facilities have non negligible environmental impacts. In other words, the EI model has been developed in order to include the environmental impacts of all the activities that have been carried when the port was built (i.e., emissions, fuel consumption, pollutants released to the environment, waste, etc). Moreover a correct assessment of these impacts binds to spread them out over the entire port life-cycle. Needless to say that this approach results in a more precise estimate of the environmental cost of port processes and operations.

7.1 The GreeLog Simulator

The authors developed an object oriented simulators for analyzing complex supply chain nodes scenarios in term of overall efficiency and sustainability (Arnold 2006). This simulator it is named GreenLog (Green Logistics simulator) and it is based on web technologies for guaranteeing easy access and distributed use. In fact GreenLog is part of a project for supporting environmental impact mitigation in Italian Logistics; this initiative involve Agencies (i.e. Assologistica Cultura e Formazione), Networks (i.e. Simulation Team), Institutions (i.e. MITIM-DIME Genoa University) and Companies (i.e. Campari, CRAI, MARS, Sony, etc.); Green Logistics initiative (Gifford 1997) it is lead by MISS DIPTEM from technical point of view and it is based on a web portal (http://st.itim.unige.it/greenlogistics) where it is possible to access to several services:

- Company Qualitative and Quantitative Questionnaire
- Self Measure of the Company Logistics Green Level based on automated configuration of the specific simulation model
- Supply Chain Simulation for measuring impacts and performances.

The model is based on the following main objects devoted to reproduce infrastructures, processes and performances; among the others it is possible to list the following objects:

- Logistics Nodes
- Logistics Link
- Vectors
- Logistics Flows
- Environmental Impact

The most interesting part is that the Green Log simulator can be used for both building the simulation model of an entire supply chain (the standard configuration of the software is a three echelon supply chain) and the simulation model of a specific logistic node (such as a marine port). In this last case all the objects provided within the software can be used to model the main port operations and processes, such as vessels arrivals, vessels entrance in the port area (supported by tugboats), vessels docking operations, loading and unloading operations, vessels departure, etc. The main idea is to recreate - by using the objects provided by the software - the complexity of the marine port scenarios and to consider all the factors (i.e. CO2 emissions, garbage and port waste, oil and fuel leakages, noise, etc.) that may have a significant impact on the sustainability of the port operations. To this end the green log simulator is able to evaluate the environmental impact (EI); EI can be attributed to each of the object included in the simulation model (i.e. vectors such as straddle carriers or tugboats, logistic flows such as container movements, etc.) and corresponds to emissions, disposals, consumption etc. In fact each EI is related to a specific variable connected with the object responsible of the environmental impact and therefore it is possible to module the EI based on the dynamic evolution of the simulation and based on relations that may involve different other variables such as constants, distances, times, flow volumes, flow masses, costs, flow types, etc.

Due to the user nature, the authors designed GreenLog in order to allow graphical construction of the simulation model as proposed in figure 1.

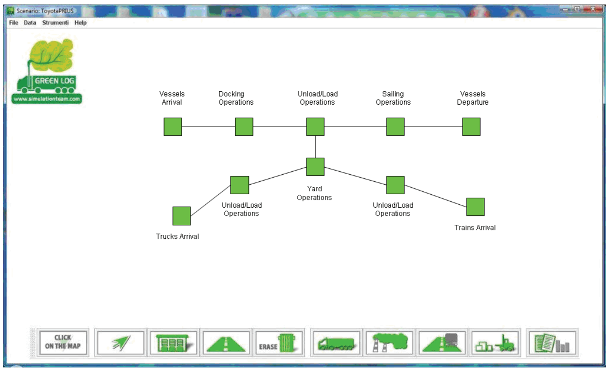

Figure 1: Green Log simulator GUI

The simulator provides easy GUI for all object creation and configuration as well as automated reporting capabilities in figures; another important feature it is the capability to present the results graphically issues directly over the logical network in order to identify critical component.

The nature of the environmental phenomena and the uncertainty on major aspects may strongly affect the reliability of the results: i.e. comparing environmental impact of different compound emissions and estimation of their social costs. Due to these reasons it is critical to proceed since the beginning in Verification, Validation process with extensive test; even if the green log simulator has been extensively verified and validated, this has been done specifically for supply chain scenarios. In this case the GreenLog simulator has been opportunely customized to be used also within the marine ports area, therefore this still requires an additional verification and validation effort that will be carried out as future research activities.

8. CONCLUSIONS

This paper proposes a survey of the state of the art on the sustainability of marine ports processes and operations. The article clearly highlights that sustainable design and development have become critical issues for major marine ports (this is particularly true when the marine port is located within an urban context, as the case of some major Italian and European ports). In the second part of the paper, the authors present the customization of the Green Log simulator and how it can be used within the marine ports area. The Green Log simulator is able to recreate the main processes and operations that usually take place within the port area and measuring the environmental impact associated to each operation. Further research activities are still ongoing in terms of verification and validation of the Green Log simulator when applied to marine ports operations.

REFERENCES

Arnold O. (2006) "Efficiency of Battery Channel", Technical Report French Ministry of Environment, Parisa.

Azapagic, A., Perdan, S., 2000. Indicators of sustainable development for industry: a general framework. *Trans. IChemE (Proc. Saf. Environ. Prot) Part B 78 (B4),*243–261.

Bailey, D, Solomon, G., 2004, Pollution prevention at ports: clearing the air, *Environmental Impact Assessment Review*, 24(7-8), 749-774.

Basurko, O., C., Mesbahi, E., 2012, Methodology for the sustainability assessment of marine technologies, *Journal of Cleaner Production*, In press.

Beamon, B., M., 1999, Designing the green supply chain. *Logistics Information Management*; 12(4), 332–42.

Berechman, J., Tseng, P., 2012, Estimating The Environmental Costs Of Port Related Emissions: The Case Of Kaohsiung; *Transportation Research Part D: Transport and Environment*, 17(1), 35-38

Birol, F., Okogu, B. E., 1997, Purchasing-Power-Parity (PPP) approach to energy-efficiency measurement: Implications for energy and environmental policy, *Energy*, 22(1), 7–16.

Bruzzone A.G., Mosca R., Revetria R., Rapallo S., (2000). Risk Analysis in Harbour Environments Using Simulation. Safety Science, vol. 35, p. 75-86.

Bruzzone A.G. (2002). Introduction to the Special Issue on Simulation in Supply Chain Management. Simulation, vol. 78, p. 284-286.

Bruzzone A.G. (2004). Preface to modeling and simulation methodologies for logistics and manufacturing optimization. Simulation, vol. 80, pp. 119-120.

Bruzzone A.G., Briano A., Bocca E., Massei M. (2007). Evaluation of the impact of different human factor models on industrial and business processes". Simulation Modeling Practice and Theory, vol. 15, p. 199-218

Bruzzone A.G., Massei M., Tarone F., Longo F. (2009-a). Sustainable Car Industry Based On Green Logistics Simulation Models. In: The International Conference on Harbor, Maritime & Multimodal Logistics Modeling and simulation (HMS20. Tenerife, Spain, September 2009, p. 201-207.

Bruzzone A.G., Cianci R., Tremori A., Massei M., Tarone F. (2009-b). Modeling Green Logistics. In: ASM2009. Bandung and Kuta (Indonesia), maggio 2009, p. 27-31.

Cornelissen, G., Pettersen, A., Nesse, E., Eek, E., Helland, A., Breedveld, G.D., 2008. The contribution of urban runoff to organic contaminant levels in harbour sediments near two Norwegian cities. *Marine Pollution Bulletin*, 56, 565–573.

Cotter, A., J., R., 1985, Water quality surveys: A statistical method based on determinism, quantiles and the binomial distribution, *Water Research*, 19(9), 1179-1189

Cox A., 1999. Power, value and supply chain management. International Journal of Supply Chain Management, 4(4), pp. 167-75.

Crittenden, B., Kolaczkowski, S., 1995, *Waste minimization. A practical guide*. UK: IChemE.

Daamen, T., A., Vries, I., 2012, Governing the European port–city interface: institutional impacts on spatial projects between city and port, *Journal of Transport Geography*, In Press.

Dalsoren, S., B., Eide, S., B. Endresen, O., Mjelde, A., Gravir, G. Isaksen (2009), Update on emissions and environmental impacts from the international fleet of ships: the contribution from major ship types and ports, *Atmospheric Chemistry and Physics*, 9, 2171–2194

De La Lanza, E.,G., Penié Rodríguez, I., Czitrom, S., P., R., 2010, Water quality of a port in NW Mexico and its rehabilitation with swell energy, *Mar Pollut Bull.*, 60(1), 123-130.

De Meyer, P., Maes, F., Volckaer, A., 2008, Emissions from international shipping in the Belgian part of the North Sea and the Belgian seaports, *Atmospheric Environment*, 42, 196–206.

Den Boer, E., Verbraak, G., 2010. Environmental impacts of international shipping: a case study of the Port of Rotterdam. Report prepared for the Organisation for Economic Co-operation and Development (OECD) as part of the project "Environmental Impacts of International Shipping: The Role of Ports", Ref. No. ENV/EPOC/WPNEP/T(2009)6/FINAL.

Eide, M.S., Endersen, Ø., Breivik, Ø., Brude, O.W., Ellingsen, I.H., Røang, K., Hauge, J.,Brett, P.O., 2007. Prevention oil spill from shipping by modelling of dynamic risk. *Marine Pollution Bulletin,* .54, 1619–1633.

Elkington, J., Trisoglio, A., 1996, Developing realistic scenarios for the environment: Lessons from Brent Spar, *Long Range Planning*, 29(6), pp. 762-769.

ENTEC UK Ltd, 2002, Quantification of emissions from ships associated with ship movements between ports in the European Community; Final Report (2002).

Fabiano, B., Currò, F., Pastorino, R., Del Borghi, M., 2002. Oil Spills: from statistical analysis to quantitative risk assessment, *Oil and Hydrocarbon Spills III: Modelling, Analysis and Control*, pp. 429–441.

Gariazzo, C., Papaleo, V., Pelliccioni, A., Calori, G., Radice, P., Tinarelli, G., 2007, Application of a Lagrangian particle model to assess the impact of harbour, industrial and urban activities on air quality in the Taranto area, Italy, *Atmos Environ*, 41, 6432–6444

Gasparatos, A., El-Haram, M., Horner, M. 2007, A critical review of reductionist approaches for assessing the progress towards sustainability, *Environmental Impact Assessment*, 28(4–5), 286–311.

Geerlings, H., Duin, R., 2011, A new method for assessing CO2-emissions from container terminals: a promising approach applied in Rotterdam, *Journal of Cleaner Production*, 19(6-7), 657-666.

Giurco, D., Bossilkov, A., Patterson, J., Kazaglis, A., 2011, Developing industrial water reuse synergies in Port Melbourne: cost effectiveness, barriers and opportunities, *Journal of Cleaner Production*, 19(8), 867-876.

Golusin, M., Ivanovic, O., M., Teodorovic, N. 2011, The review of the achieved degree of sustainable development in South Eastern Europe—The use of linear regression method, *Renewable and Sustainable Energy Reviews*, 15(1), 766–772.

Grifoll, M., Jordà, G., Borja, A., Espino, M., 2010, A new risk assessment method for water quality degradation in harbour domains, using hydrodynamic models, *Marine Pollution Bulletin*, 60(1), 69–78.

Gupta, A., K., Patil, R.S., Gupta, S., K., 2002, Emissions of gaseous and particulate pollutants in a port and harbour region in India, *Environmental Monitoring and Assessment*, 80(2), 187-205.

Hall, W., J., 2008, Assessment of CO2 and priority pollutant reduction by installation of shoreside power, *Resources, Conservation and Recycling*, 54(7), 462–467.

Hart, D. R., McKee, P. M., Burt, A. J., Goffin, M., J., 1986, Benthic Community and Sediment Quality Assessment of Port Hope Harbour, *Journal of Great Lakes Research*, 12(3), 206–220.

Hart, S., L., 1995, A natural-resource-based view of the firm. *Academy of Management Review*, Vol. 20(4), 986-1014.

Hartman, B., C., Clott, C., B., 2012, An economic model for sustainable harbour trucking, *Transportation Research Part D: Transport and Environment*, 17(5), 354–360.

Heinimo, J. , Junginger, M., 2009, Production and trading of biomass for energy – An overview of the global status, *Biomass and Bioenergy*, 33(9), 1310–1320.

Howitt, O., J., A., Carruthers, M., A., Smith, I., J., Rodger, C., J., 2011, Carbon dioxide emissions from international air freight, *Atmospheric Environment*, 45(39), 7036–7045.

Isakson, J. , Persson, T.A., Selin Lindgren, E., 2001, Identification and assessment of ship emissions and their effects in the harbour of Göteborg, Sweden; *Atmos Environ*, 35, 3659–3666

Jesuleyea O. A., Siyanbola W.O., Sanni S.A., Ilori M. O., 2007, Energy demand analysis of Port-Harcourt refinery, Nigeria and its policy implications, *Energy Policy*, 35 (2), 1338-1345.

Johnson R., Bustin R., M., 2006, Coal dust dispersal around a marine coal terminal (1977–1999), British Columbia: The fate of coal dust in the marine environment, *International Journal of Coal Geology*, 68(1-2), pp. 57-69.

Joseph, J., Patil, R., S., Gupta, S., K., 2009, Estimation of air pollutant emission loads from construction and operational activities of a port and harbour in Mumbai, India, *Environmental Monitoring and Assessment*, 159(1-4), 85-98.

Joung, C. B., Carrell, J., Sarkara, P. Feng, S., C., 2012, Categorization of indicators for sustainable manufacturing, *Ecological Indicators*, 24, 148-157.

Kadiri, M., Ahmadian, R., Bockelmann-Evans, B., Rauen, W., Falconer, R., 2012, A review of the potential water quality impacts of tidal renewable energy systems, *Renewable and Sustainable Energy Reviews,* 16, pp. 329-341.

Kantardgi, I., Mairanovsky, F., Sapova, N., 1995, Water exchange and water quality in the coastal zone in the presence of structures, *Coastal Engineering*, 26(3-4), 207-223.

Karakosta, C., Doukas, H., Psarras, J., 2009, Directing clean development mechanism towards developing countries sustainable development priorities, *Energy for Sustainable Development*, 13(2), 77–84.

Klassen, R.D., Whybark, C.D., (1999) The impact of environmental technologies on manufacturing performance, *Academy of Management Journal*, 42(6), 599–615.

Labuschagne, C., Brent, A., C., van Erck, R., P.,G., 2003, Assessing the sustainability performances of industries, *Journal of Cleaner Production*, 13(4), 373-385.

Langeweg, F. (1998), The implementation of Agenda 21 our common failure?, *Science of The Total Environment*, 218(2-3), 227–238.

Lee, J., Y., Kang, H., S., Noh, S., D., 2012, Simulation-based Analysis for Sustainability of Manufacturing System, *International Journal Of Precision Engineering And Manufacturing*, 13(7), 1221-1230 .

Lee, K., Saen, R., F., 2011, Measuring corporate sustainability management: A data envelopment analysis approach, *International Journal of Production Economics*, 140(1), 219–226.

Lonati, G., Cernuschia, S., Sidib, S., 2010, Air quality impact assessment of at berth ship emissions: Case-study for the project of a new freight port, *Science of The Total Environment*, 409(1), 191-200.

Longo F., Massei M., Nicoletti L., (2012). An application of modeling and simulation to support industrial plants design, 2012, International Journal of Modeling, Simulation, and Scientific Computing, Vol 3(1), art. No. 1240001

Lucialli, P., Ugolini, P., Pollini, E., 2007, Harbour of Ravenna: the contribution of harbour traffic to air quality, *Atmos Environ*, 41 (3), 6421–6431.

Lun, Y.,H., 2011, Green management practices and firm performance: A case of container terminal operations, *Resources, Conservation and Recycling*, 55(6), 559–566.

Mani, M., Lyons, K. W.; Muroyama, A. P.; Johansson, J., 2011, Simulation and Analysis for Sustainability in Manufacturing Processes, NIST Interagency/Internal Report (NISTIR) – 7790.

Marmer, E. and Langmann, B., 2005. Impact of ship emissions on the Mediterranean summertime pollution and climate: A regional model study, *Atmospheric Environment*, 39(26), pp. 4609-4816.

Meadows D., H., Meadows, D., Randers, J., Behrens, W.,W., 1972. The Limits to Growth: A Report to The Club of Rome. Abstract established by Eduard Pestel.

Mohamed, A., R., Lee, K.,T., 2006, Energy for sustainable development in Malaysia: Energy policy and alternative energy, *Energy Policy*, 34(15), 2388–2397

Mölders, N.,, Porter, S., E., Tran, T., T., Cahill, C., F., 2010. Influence of ship emissions on air quality and input of contaminants in southern Alaska national parks and wilderness areas during the 2006 tourist season. *Atmospheric Environment,* 44, 1400-1413.

Neacsu, G. ; Ilias, N. ; Cretu, V. ; Tudoroiu, E., R., 2009, The neural simulator of the pollution factors impact on the quality of the water inside the Romanian harbour of Black Sea, *Proc. Of the International Multiconference on Computer Science and Information Technology*, 2009. IMCSIT '09, pp. 531- 539

Neto, , J., Q., F., Bloemhof-Ruwaard, J. ,M., van Nunen, J., A., E., E., van Heck, E., 2007, Designing and evaluating sustainable logistics networks, *International Journal of Production Economics*, 111(2), 195–208.

Nikolopoulou, A., Ierapetritou, M., G., 2012, Hybrid simulation based optimization approach for supply chain management, *Computers & Chemical Engineering*, In Press.

OCI, 1987, Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987. Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment August 2, 1987. Retrieved, 2007.11.14

Ondiviela, B., Juanes, J., A., Gómez, A., G., Sámano, M., L., Revilla, J., A., 2012, Methodological procedure for water quality management in port areas at the EU level, *Ecological Indicators*, 13(1), 117-128.

Palani, S., Liong, S., Tkalich, P.,2008, An ANN application for water quality forecasting, *Marine Pollution Bulletin*, 56(9), 1586-1597.

Peng, C. , Lin, C., Jong, T., 2005, Emissions of particulate and gaseous pollutants within the Keelung harbour region of Taiwan. *Environ Monit Assess*, 109, 37–56.

Peris-Mora E, Diez Orejas JM, Subirats A, Ibáñez S, Alvarez, P., 2005, Development of a system of indicators for sustainable port management, *Mar Pollut Bull.*, 50(12), 1649-60.

Iovanna, R., Griffiths, C., 2006, Clean water, ecological benefits, and benefits transfer: A work in progress at the U.S. EPA, 60, 473-482.

Ronza, A., Carol, S., Espejo, V., Vílchez, J.A., Arnaldos, J., 2006, A quantitative risk analysis approach to port hydrocarbon logistics, *Journal of Hazardous Materials*, 128, 10–24.

Roso, V., (2007), Evaluation of the dryport concept from an environmental perspective: A note, Transportation Research Part D: Transport and Environment, 12(7),pp. 523–527.

Ross, H., Shrestha, K.,K., 2008, A common-pool resource approach for water quality management: An Australian case study, *Ecological Economics*, 68(1–2), 461-471.

Saxe, H. , Larsen, T., 2004, Air pollution from ships in three Danish ports, *Atmos Environ*, 38 (24), 4057–4067.

Shrivastava, P., 1995, Environmental technologies and competitive advantage, *Strategic Management Journal*, 6(1), 183–200.

Solari, G., Repetto, M.,P., Burlando, M., De Gaetano, p., Pizzo, M., Tizzi, M., Parodi, M., 2012, The wind forecast for safety management of port areas, *Journal of Wind Engineering and Industrial Aerodynamics*, 104–106, 266–277.

Streets, D. G., Guttikunda, S. K. and Carmichael, G., R., 2000, The growing contribution of sulphur emissions from ships in asian waters, 1988–1995, *Atmosph. Environ.,* 34, 4425–4439.

Todd, D. (1997), China's energy needs, coal transfers and the ports sector, *Geoforum*, 28(1), 39-53.

Trozzi, C., Vaccaro, R., Crocetti, S., 1996, Speed frequency distribution in air pollutants' emissions estimate from road traffic, *The Science of the Total Environment*, 189/190, 181- 185.

Tzannatos, E., 2010, Ship emissions and their externalities for the port of Piraeus – Greece, *Atmospheric Environment*, 44(3), 400-407.

Villalba, G., Gemechu, E., D., 2011, Estimating GHG emissions of marine ports—the case of Barcelona, *Energy Policy*, 39(3), 1363-1368.

Voet, M. van der, 2008. CO2-emissions by container transshipment processes in the Rotterdam port. A method for CO2-emissions from transshipment processes in the port of Rotterdam in identifying and impact of proposed policies and knowledge to make (in Dutch), Master thesis Delft: Delft University of Technology.

Whall, C., Cooper, D., Archer, K., Twigger, L. Thurston, N., Ockwell, D. , McIntyre, A., Ritchie, A. 2002, Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report 0617702121 Entec UK Limited, Norwich, UK (2002)

Wu, M., Wang, Y., Sun, C., Wang, H., Dong, J., Yin, J., Han, S., 2010, Identification of coastal water quality by statistical analysis methods in Daya Bay, South China Sea, *Marine Pollution Bulletin*, 60(6), 852-860.

Yuan, C., Zhai, Q., Dornfeld, D., 2012, A three dimensional system approach for environmentally sustainable manufacturing, *CIRP Annals - Manufacturing Technology*, 61(1), 39-42.