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A Green Ocean Carrier Network Design Problem: Empirical Study on Egyptian Port of Alexandria

By

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Abstract :

Port sustainability has become a main component ofthe international maritime transport. This sustainability concept should be integrated in the network design problem to reduce negative externalities for both port and sea activities and the average operational costs by using environmental indicators. The ocean carrier network design problem (OCNDP) will be solved using the triple bottom line of the port green approach to minimize operational costs. Therefore, this problem could be described as a sustainable ocean carrier network design problem (SOCNDP) and it will be solved using the software Microcity and a set of nine regional ports taking as a reference the Egyptian Port of Alexandria. The results show that a green sustainable route can be drawn among these nine ports while minimizing total shipping costs and reducing considerably gas emissions of the various ports.

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1 - Introduction

Egypt›s economic and social development plans aim at enhancing the competitiveness of the Egyptian economy, promoting exports of goods and services at an annual rate of 12 percent and encouraging private sector›s participation in economic activity, particularly in service sectors [1,2]. Recognizing that services play a key role in achieving these national objectives, the government of Egypt›s multilateral, regional and unilateral efforts to liberalize trade in services and enhance their efficiency will be discussed in the fourth section. In an effort to increase the efficiency ofports, Egypt has been attempting to deregulate its port sector. At the same time Egyptian ports are not considered noteworthy in terms of their efficiency as they are characterized by the existence of obsolete and poorly maintained equipment, hierarchical and bureaucratic management structures, weak coordination between the port trusts and users of the ports hence there is a need to study the Egyptian ports and the factor influence their efficiency in depth. Then, Egyptian ports do not take into consideration both environmental nor social indicators and still they do not think «green». Hence there is a stray justification for analyzing the factors determining the efficiency ofthe Egyptian ports sector through integrating environmental indicators in the sustainable ocean carrier network design problem. The main contribution of this paper is to define and implement a flexible mathematical model that, after a preliminary customization, can be used to recreate any marine port scenario including multiple ports. The modular architecture of the mathematical model allows the user to insert new objects easily and characterize them to create marine ports that can include multiple terminals (i.e. container terminals, car terminals, general cargo terminals, etc.). The evaluation of the environmental impacts is performed considering the environmental impacts of each object included in the simulation (i.e. vessels, forklifts, rubber tired gantries, cranes, etc.). For each object the user can set up the values of different parameters that allow defining the behavior of the object (i.e. operating modes, fuel consumption, fuel type and cost, power consumption, conversion factors, etc.) and calculating as a consequence its environmental impacts during the simulation run. We seek to provide a new insight of the traditional OCNDP by including a green approach to reach the SOCNDP.

Our objective is to provide research a new insight for conceptualizing the traditional OCNDP while including the sustainability concept through environmental indicators.

This paper is organized as follows:•-Section 2 presents an overview of Egypt›s maritime sector:-

- Section 3 solves the SOCDNP using the software of Microcity for the nine selected sets ofports.
- Section 4 focuses on discussion and analysis.
- Section 5 sets some limitations for the present study.
- Finally, Section 6 provides a conclusion and summary ofthe article with a future insight to the study.

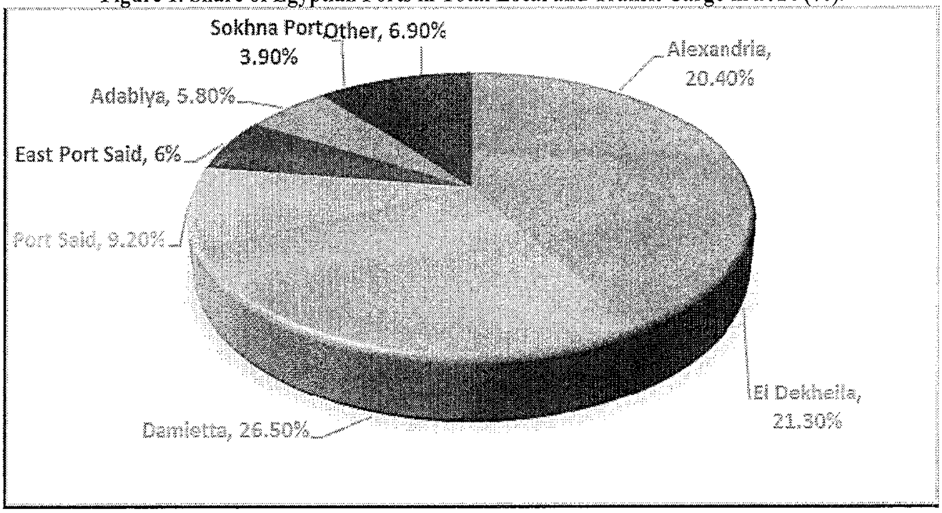
2-Overview of Egypfs Maritime Sector

Egypt›s modest commitments in the GATS reflect the conservative approach that was adopted by the government of Egypt (GoE) during the Uruguay Round. Since 1997 this approach to liberalization and reform has changed significantly with the adoption of a new investment law (Law 8/1997) which opened up several service sectors to investment (both domestic and foreign). Reform of different service sectors is ongoing at an accelerating pace through deregulation, privatization and adoption of liberal laws and regulations, reflecting the increasing importance devoted to trade in services by the GoE.

There are 82 ports in Egypt, out of which nine are main commercial ports (Alexandria, EI-Dekheila, Port Said, Safaga, East Port Said, Damietta, Adabiya, Suez and EI-Sokhna), six are general commercial ports and 67 are specialized ports. 19 There are nine dry ports, some ofwhich are not used to their full capacity.

According to the Egyptian Maritime Data Bank of the Ministry of Transport, there was a 56 percent increase in the TEUs (Twenty Feet Equivalent Units) 20 handled by all Egyptian ports,up from 435,655 TEUs in the year 1995 to 884,481 TEUs in 2014. Figure 1 shows the share of Egyptian ports in total local and transit cargo in 2014. The number of vessels visiting Egyptian ports increased from 8,799 in 1995 to 11,876 in 2014, a 35 percent increase [3,4]. Alexandria Port is considered the most important port in terms of vessels received by Egyptian ports, receiving in 2014 around 26 percent oftotal vessels.

Figure 1. Share of Egyptian Ports in Total Local and Transit Cargo in 2014 (%).



Source: Ministry of Transport, 2015a.

The capacity of Egyptian commercial ports reached 135.18 million tons in 2014.21 General cargo handled by Egypt›s ports in 2014 reached 97.5 million tons, in addition to

231.6 million tons handled by specialized ports out of which petroleum products represented 230.8 million tons [2, 5]. The number of containers handled by Egyptian ports reached 3.6 million TEUs (of which

1.2 million TEUs are imports and 2.4 million TEUs are transit). There is a relatively high Concentration in the ports› handling of trans-shipment containers, with Damietta and Port Said handling the majority of trans-shipment containers in Egypt›s main ports. Although container port traffic in Egypt has been experiencing a decline in recent years, the country remains among the largest 20 developing countries in terms of container traffic [6, 7, 8, 9, 10, 11].

3- Sustainable Ocean Carrier Network Design Problem (SOCNDP)

3.1 Literature Review

Air pollution is mostly discussed as main sustainability problem for the seaports in the Literature [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]. Because, marine vehicles emits toxic gases (C02, NOx, SOx, PM) which have negative impact on air quality ofthe port region [21, 24]. However, recent study of ESPO (European Sea Ports Organization) (2013) has showed that port characteristics could change gradually as 79 ports of 21 European Maritime States provided environmental data which presents that air quality was the most significant problem in 2013. Garbage and port waste was the second, energy consumption was the third and noise was the fourth in the same year. However in 2009, noise pollution got the first place, air quality was the second, garbage/ port waste was the third and dredging operation was the fourth. It indicates that importance of the criteria could change by time and sensitivity against the topic. This may be due to the introduced regulations, which may have started to address some of the issues. For instance, EU noise directive in residential areas which also covers the ports, passage ways started forcing the port authorities to take action in terms of design of ports as well as measures to reduce the noise emissions. Moreover, solid waste and their hazardous aspects were also the focus points of some studies such as [12, 13, 14, 15, 16, 19,20,21,22,23,25]. They all have argued that solid waste pollution contains potential threats to public health or to the environment. It has also been reported that solid waste has been a cause of water and air pollution (Lim et aI., 2013). Besides that, [12, 26, 27] say that water pollution is the vital problem for engagement in seaports. Therefore, it can be stated that reducing the volume of the solid waste is not only important for solid waste pollution but also very significant for water pollution. Moreover, [12, 16, 18, 24] discuss that the noise pollution and its prevention is very important for the green port terminals. For instance, the noise arisen from handling equipment and trucks during freight movements should be reduced in the container terminal with some operational and technological arrangement. Noise may affect health and performance of the people working in the port and well-being and quality of life for residents around the port region. Another key aspect of the green container terminal is energy related criteria which usually contains energy consumption, sustainable resource usage, and electric powered equipment usage [13, 15,20].

It is found that the energy consumption was a parameter for the green container terminals. [15] states about the importance of energy efficiency and energy transition (from fossil towards clean fossil towards renewable energy) for sustainable port concept.

Moreover, [18] consider that the main requirement of the green container terminals is to reduce energy consumption by using automated container terminal equipment.

This equipment assists to reduce the greenhouse emissions ofthe ports.

The ports not only can reduce the energy consumption, but also can be more eco-friendly by supplying the energy from sustainable resources such as solar panels and wind turbine,

and waste heat recovery [28].

Electric powered vehicles are used to reduce emissions and energy [14, 19].

Consequently, it can encourage container ports to invest in those of electric vehicles for more eco-friendly operations. Furthermore, the noise pollution in the container terminals could be reduced by using these electric vehicles [12, 16, 18].

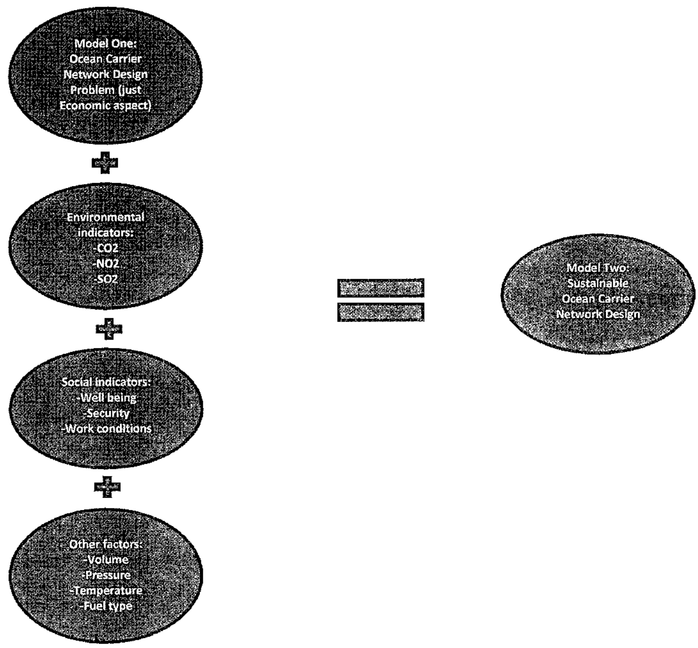
Therefore, the electric powered equipment could be beneficial for the sustainability targets. For instance, fuel cells or «cold ironing» in-ports (which provides electric supply to ships from shore sources) reduce air pollution significantly [29].

[12, 13,25] also note that seaports should take into consideration habitat deformation by investing or working on the environment quality wetland and marine habitat preservation, ecological preservation and environmental protection and training, and ballast water treatment.

3.2 Methodology

As discussed in [30], the past literature did not establish a clear relationship between port sustainability and Ocean›s Carrier Network Problem (OCNP), as the sustainability concept is a relatively recent approach in the maritime literature, and still a gap exists in this field. To address this issue, we define a mathematical model which incorporates port sustainability indicators in an OCNDP as in Figure 2.

Figure 2. Link between the traditional OCNDP and the SOCNDP



3.3 Software Application

The software tool is designed based on a simulation framework named MicroCity [32]. MicroCity is a versatile, open source, and fast GIS (Geographical Information System)•type framework for studies involving transportation topics. In addition to some fundamental GIS functions, MicroCity also has many unique libraries, including Network, Fractal, 3D, Simulation and Linear Programming Solvers, making it an ideal instrument for solving the problem addressed in this paper. Moreover, it is quite convenient to use MicroCity for accessibility analyses of transportation networks, simulation in multi-agent systems and 3D real-time demonstrations oftransportation systems [31].

Based on MicroCity, the software tool for global intermodal shipping network design is coded in c++ using object-oriented programming. The software tool uses a three-layer system structure: a database layer, a function layer and a graphical user interface (GUI). The outputs of this software tool mainly consist of the results of the GPA and the resulting pattern of liner ship routes. There are several default decision processes in Microcity; namely, Berth Allocation, Quay Crane Assignment, Quay Crane Scheduling, Container Location Assignment, Yard Crane Deployment, Yard Crane Dispatching, and Yard Truck Dispatching. Most of the decision problems in major container terminals are covered by these decision processes. Other models of container terminals can also be adapted by using Microcity as a template with slight modifications.

3.4 Choice of itineraries

The fact that the region is surrounded by several seas -Black Sea, Mediterranean Sea, Adriatic Sea, Ionian Sea, Aegean Sea, and Marmara Sea -makes maritime shipping a prime area for growth going forward (see Figure 3). Container feeder shipping lines offer critical transport connections between the hinterland of this region and global trunk shipping lines. Egypt›s ideal location in the heart of the Middle East gives its ports a competitive advantage and opportunity to develop the sustainability concept. In this regard, Egypt as stated in Section 4, has significant potential and several projects for the development of green projects. One of these projects is the construction of a green terminal in order to improve Egypt›s hub port environmental activities. In this region, the potential market areas of Alexandria as a hub port could be categorized into eight ports: 2 Port of Tartous (Syria), 3 Port of Gemlik (Turkey) 4 and 5 Ports of Rostov and Novorossiysk (Russia), 6 Port of Casablanca (Morocco), 7 Port of Antwerp (Belgium), 8 Port of Sagunto (Spain) and 9 Port of Ravenna (Italy). Based on the above figure (Figure 2), we can identify the following four itineraries on Figure 3.

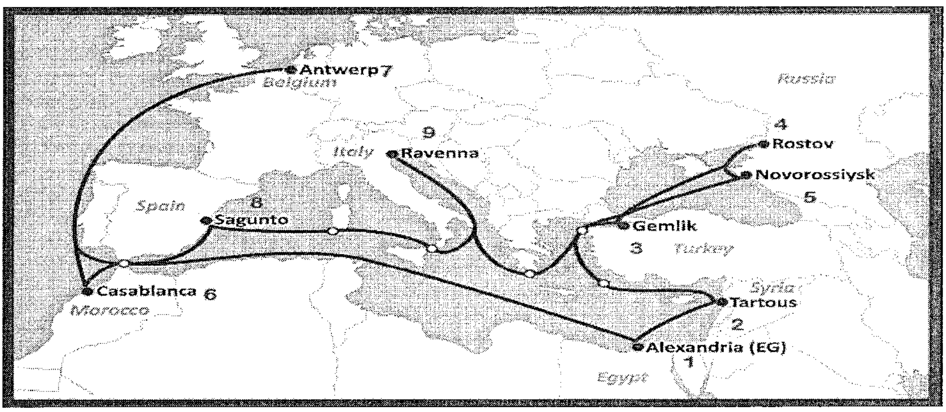


Figure 3. Maritime routes and active ports in the Mediterannean Sea and choices of itineraries

In this region, 12 container terminals at 8 feeder ports are served via a hub port for a feeder liner shipping company with 1180 TEU total daily demand and 780 TEU total daily supply amount. The feeder liner currently designs its existing feeder network with a hub port of Alexandria in North Egypt. Alexandria serves as a reference hub port to feeder ports of the region. This scenario is tested under different time deadline and service frequency conditions for a 52 week planning period. The major cost items and ship costs for three ship types are shown in Table 1.

Table 1. Model costs (in U.S. dollars) and parameters.

Parameter	Unit	Ship 1	Ship 2	Ship 3
Capacity	TEU	4300	2600	1200
Operating speed	knots	22.60	19.90	17.40
Fuel consumption (on sea)	Tons/hour	5.26	2.82	1.51
Fuel consumption (on port)	Tons/hour	0.26	0.14	0.08
Charter cost	$/day	12772.00	7579.00	5866.00
Operating cost	$/day	6000.00	5707.00	4643.00
Administration cost	$/day	552.00	3180.00	1380.00
Port charges	$/call	35000.00	29000.00	22000.00
Handling cost (feeder port)	$/lift	120.00	120.00	120.00
Handling cost (hub port)	$/lift	120.00	120.00	120.00
Lay-up duration (hub port)	Hour/call	28.80	24.00	16.80
Planning period	Days	364	364	364
Idle duration	Days	2.00	1.80	1.50

4 -Numerical Results and Data Analysis

In this section, we will discuss and analyze the different numerical results drawn from the Microcity software. Table 4 shows the total shipping costs for the hub port of Alexandria and the eight feeder ports in the region based on different service frequency and idle time.

Table 2. TotaJ shipping costs for each itinerary.

Itinerary	Hub	Feeder ports	Frequency	Idle time	Total costs ($)	Time (hour)
1	Alexandria	Tartous, Gemlik, Rostov and Novorossiysk	7	2*7	285125.22	43.77
2	Alexandria	Casablanca, Antwerp	7	3*7	286704.60	70.57
3	Alexandria	Casablanca, Sagunto, Ravenna	7	3.5*7	288057.59	40.10
4	Alexandria	Casablanca, Sagunto, Ravenna , Gemlik, Rostov and Novorossiysk	7	4*7	331503.51	96.25

In Table 2, total costs include chartering costs, operating costs, administration costs, on•sea bunker costs, on-port bunker cost and port charges for a 52 week planning period. In the first itinerary the existing hub port (Alexandria) presents minimum total operational costs of $285,125.220 with 7 days service frequency and 14 (2x7) days deadline for returning to the hub and finishing the unloading operations. The second itinerary presents minimum total operational cost of $286704.600 with 7 days service frequency and 21 (3x7) days deadline. Still, from a comparative perspective feeder shipping liners› itinerary selection is sensitive to fuel price and network distance as well gas emissions. As a conclusion, itinerary 1 has the lowest total shipping cost as the lowest emission of all types ofgas as a percentage of the total operating costs.

5 -LIMITATIONS

More effort is needed to extend the work presented in this paper by considering some of the practical features of the sustainable ocean carrier network design problem. First, in this paper the demand between each 0 (Origin) D (Destination) pair is assumed fixed, yet in practice it is affected by the total shipping charge. Thus, demand elasticity should also be addressed in future work. Second, container terminal operations such as the availability of berths [36], which affects the arrival and departure time of ships at each port of call [37, 38], may also be incorporated in modeling. Third, there are a number of uncertainties associated with liner shipping operations [39, 40]. How to consider these operational-level uncertainties in tactical planning network design models is a worthwhile research topic.

6-CONCLUSIONS

This paper has focused on the ocean carrier network design problem with sustainability approach based on environmental indicators. In view of its practical significance, a software framework was also presented, based on the proposed methodology. A large-scale application based on a real-life case of the Mediterranean network of eight feeder ports in the region taking the port of Alexandria as the hub port was then adopted to verify the model using the software ofMicro city. The numerical results showed that the network designed by the software tool was best suited for the first itinerary (Alexandria-Syria-Turkey-Russia) which minimized total shipping costs, as well as it had also the lowest emissions of C02, S02, N02, and PM. A sustainable balanced scorecard will be implemented in our future work in order to integrate the environmental and social indicators in one framework, which will be designed to help maritime ports to draw the more «green, efficient, and sustainable» network design along with the other ports ofthe region.

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