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Analysis of Most Important Indices in Environmental Impacts Assessment of Ports

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Abstract

Ports are the main centers of economic activities and producers of environmental pollutions on the shores and urban areas. Regarding the growth of world trade, transportation of goods through the ports has been undergoing prompt development, possibly experiencing further progress in the upcoming years. In the recent years, the destructive impacts of ports on the environment has been increasing. The type of activities and interactions carried out in the ports have speeded up such destructions. The major sources of pollutions are usually air, noise, water, soil and garbage. The objective of this study is to identify the main and sub-indices in the assessment of environmental impacts of ports (EIAP). To this end, a number of 28 case studies over the world have been analyzed. The indices of the environmental impacts of ports are categorized and evaluated according to four scales: the application and study aspects, the time, the location, as well as the quantity of occurrence of the criteria. Totally 200 main and sub-indices have been identified, within which, the first 10 have been allocated to the pollution of air, noise, water, transportation, traffic, greenhouse gases, garbage, soil, climate change and dredging, since 2000 to 2016. Finally, to better understand the subject, the conceptual framework for EIAP is presented. This study provides with port managers guidance toward identifying significant environmental aspects of ports; it is, at the same time, applicable in order for awareness and prioritization in the environmental management.

Keywords: Environmental Impacts Assessment of Ports (EIAP); Conceptual Framework; Port Managers; Environmental Management; Environmental Indicator.

1. Introduction

Instant progress of sea transportation has left significant impacts on the growth and development of international trade [1], as nearly 90% of the world trade is managed via sea transportation [2, 3]. Coastline development as well as direct and indirect job creation have been some of the favored consequences of the development of sea transport infrastructures [5]. For instance, in 2014 goods transportation through sea has experienced a 3.4% growth over the world [4]. Moreover, Asia has been remarkably expanding its role in import and export through the sea [7]. Likewise, almost half of the American population are working inside the 500-meter vicinity of coastline [10]. Nearly 13 million jobs per year have been provided related to the transport industry of the U.S port users, leading to a 1.5 million dollars annual profit [1]. Thus, ports play a vital role in the economy of a country. The expanded industrial activities for meeting humanitarian demands as well as accommodation of a vast portion of human population inside the coastal ecosystems -as nearly 44%

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of the world population are living inside the 150 km vicinity of coasts and 66% of the urban population (2.5 million people) are living in the coastal regions- show the high significance of this ecosystem [2].

Industrial revolution has ended in the expansion of human activities, deteriorating environment and human conditions. While the ports play role in the production of jobs in a region, proportionally they play a considerable role in the pollution growth and entering various types of pollutants to the environment [1]. Port activities release several destructive effects [3, 5, 8], such as air, water, noise, soil and sediments pollution as well as dredging [2-6]. Activities such as fishing, industrial facilities, storage of hazardous material, etc. could release harmful impacts on the environment [6]. Control of such damaging impacts is the main purpose of environmental management system [3]. Despite the great progress in the rail transport which had a great effort in the prevention and control of pollution, the environmental effects of the ports have been increased [1]. Any type of growth and development of the port facilities affect of the habitats [6]. If a port is located inside or in the vicinity of an urban area, then the destructive effects will be greater [11]. Ports are the main sources of air pollution, affecting the human health of the vicinity population. The major air pollutants include diesel exhaust, particulate matter (PM), volatile organic compounds (VOC), nitrogen oxide (NOx), etc [1]. Based on the report of environmental protection agency (EPA), it is anticipated that the contribution of vessels in the spread of PM and NOx being doubled until 2020 [1]. Increment of the population of coastal areas has led to the spread of plenty of pollutants to the water, affecting the coastal ecosystem. This indicates the sever exploitation of coastal sources by human, causing one of the greatest environmental threats on the earth. Some sources of the threats are namely sediment accumulation, toxic material (pesticides and pollutants), acidification and sludge formation due to human activities [10].

Over time, knowledge has been growing on the environmental aspects [9]. Considering the environmental concerns, the Ports and Maritime Organization for the first time, published the code ESPO in the 1994 which was updated then, in 2003 [5]. Environmental indices could be powerful and proper tools for upgrading public awareness about the environmental issues. The importance of various environmental issues depend on the characteristics of each port [6, 11, 12]. Regarding the current conditions of the national ports, estimation of the environmental impacts is a difficult task [4]. Some of the key environmental aspects and/or indices of the ports are the emission of greenhouse gasses to the air, discharge to the water, soil, sediment and noise pollution, production of redundant material, dredging, destruction and losing earth habitats, variation of the marine ecosystem, odor, consumption of resources, and port development [2, 6]. Evaluation of the environmental impacts of all of the megaprojects such as construction of ports and development of them are necessary; also the sustainable development of port activities is achievable only through such action [2]. Climate forecast reduces the destructive effects on cost, water resources, ecosystem and the other resources. The northern coasts of Iran (Caspian Sea) is favored from a moderate and pleasant climate. Across the southern coasts, there is environmental concern for the oil and gas industry and heavy traffic of the tankers. In order to reduce the air pollution and global warming, Iran is trying to produce lower volumes of fossil fuels. Significant reduction of greenhouse gasses emission is essential since they have some of the worst consequences on the climate change [13].

Numerous investigations have been carried out so far on the environmental Impacts assessment (EIAP). In study, by analysing previous studies two major goals are followed. Firstly, identifying and evaluation of the main and sub-indices determining the ports environmental effects. Four criteria have been used to analyze the indicators, namely 1- time criterion, 2- locative criterion, 3- the study aspects and mathematical methods introduced in the investigations, and 4- the Frequency of occurrence of index. Finally, for better understanding and application of users and managers in the environmental management sectors, the second goal i.e. the conceptual framework for assessment of the EIAP is introduced.

2. Literature Review

In the assessment of previous studies on the EIAP, it is necessary to use tools capable of measuring the extent of variations, the Frequency of using indices as well as any other kind of analysis. Thus, in this study primarily some tools were employed as analysis scales. These scales include the aspects of the study, the application of method, the time analysis, and the locative analysis [14]. In order to use these tools and analysing indices, initially, 28 case studies were reviewed and are presented Table 1. The studies are categorized based on the date, as well as main indices, sub-indices, the aspects of study and the application.

Table 1. Literature review

	Study	Main indices	Sub-indices	Study dimensions	Application type
1	Environmental impact of port activities, 2000 [15]	Air pollution, Water pollution , Soil pollution, Noise and Waste generation	Transportation, Greenhouse gas emissions, Ship's activity in the port (ship's Movement in port, Lighting, heating), Discharge and Loading, Accidental leakage of petroleum and chemical substances, Chemical waste residues, Engine fuel leaks, Oil spills from industries, Diesel and Petrol, Harmful aquatic organisms (Dinoflagellate, Pathogenic bacteria such as bacteria), Ship waste, Car traffic, Railroad, Ship repair, Towing, Propulsion machinery, Motorcycle, Propeller, Runoff, Dredging, Fuel storage, Maintenance , Retrofit, Truck, Crane	Environment	Qualitative
2	Pollution prevention at ports: clearing the air, 2004 [1]	Air pollution, Noise, Water Pollution, Soil pollution, Traffic, Pond damage, Waste generation, Light Pollution, Marine ecosystem changes	Marine traffic, Ship exhaust, Truck idle, Tow trucks, locomotives, Garbage evacuation, Runoff, Erosion, Dangerous cargo, (pulmonary, Respiratory, Asthma, Cancer and mortality)	Human & environment	Quantitative & Qualitative
3	A new methodology to assess environmental management in sea ports, 2004[6]	Water quality, Air quality, Soil quality, Noise, Dredging, Waste production, Sewage, Port development (water and land), Traffic volume, dust, Energy consumption, Habitat loss	Emissions, Fishing, Storage of hazardous materials, Hazardous cargo, Industrial facilities, Dredging, Wastewater drainage	Environment	Quantitative & Qualitative
4	Impact of ship emissions on the Mediterranean summertime pollution and Climate: A regional model study, 2005 [16]	Air pollution, Weather quality, Sedimentation	Emissions , SOx, NOx, Radical hydroxyl, Ozone tropospheric, Sediment, Dust, Soot, Ship traffic, Transportation, Airborne particles	Environment	Quantitative & Qualitative
5	A procedure for identifying significant environmental aspects in sea ports, 2005[11]	Water pollution, Air pollution, Soil contamination, Noise, Sediment and Dredging, Greenhouse gas emissions, Contamination of sediment, Destruction of habitat, Changing marine ecosystem, Odor, Consumption of resources and development of the port	Waste production, Fishing, Storage of hazardous materials, Water balancing drainage, Industrial facilities, Ship movements	Environment	Qualitative
6	Emissions from international shipping in the Belgian part of the North Sea and the Belgian seaports, 2008 [17]	Climate change, Air pollution	Transportation, Gluten Gases (CO_2, SO_2, NOx), Fuel ferries, Cruise ship, Anchor, Maneuvering, Discharge and Mooring, Sucker, Toilets, Boat	Environment	Quantitative & Qualitative
7	Modelling the effects of ship emissions on coastal air quality:A case study of southern California, 2008 [18]	Air Pollution	Emissions (NOx , SOx), Ozone, PM, VOC, NO_2 and SO_2, Ship traffic, Sulfur deposits, Tropospheric ozone, Ozone concentrations, Ship characteristics such as engine size, Fuel consumption, and Emission factors , Hourly weather parameters (Temperature, Wind and Relative humidity), Weather conditions, Wind	Environment	Quantitative & Qualitative
8	Survey on environmental monitoring requirements of European ports, 2009 [19]	(Flow, waves, tide), Water quality, Humidity, Turbidity and precipitation, Air quality, Weather parameters, Oil summit, Ecologic, Port development, Water balance control, Noise, Dust, Soil quality	Ship evacuation, Hazardous Mohamed, Garbage in port, Dredging, Transportation, Soil recycling	Environment	Quantitative & Qualitative
9	The environmental impacts of pollutants generated by routine shipping operations on ports, 2010 [9]	Oil spill, Natural damage, Air pollution, Noise, Climate change	Transportation, Oil residues, Waste disposal, Commercial fish losses, Marine bird injuries, Tourism	Environment	Quantitative & Qualitative
10	Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective, 2011 [7]	Air pollution, Noise	Transportation (Truck, Railways), Emissions (NOx, CO, SO_2, Volatile organic compounds (VOC)) vehicles, Traffic volumes, Fuel quality	Human & environment	Quantitative & Qualitative
11	Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO2 emissions ،2013 [20]	Air Pollution, Noise, Reduce transportation costs	CO_2, Rail and truck transportation, NOx , SOx , Dry port investment and maintenance operations, Diesel oil, Reduced density	Human & environment	Quantitative & Qualitative
12	Managing truck arrivals with time windows to alleviate gate congestion at container terminals, 2013 [21]	Air pollution	Freight traffic volume, Truck queue	Human & environment	Quantitative & Qualitative

13	Reducing truck emissions at container terminals in a low carbon economy: Proposal of a queueing-based bi-objective model for optimizing truck arrival pattern, 2013 [22]	Air pollution	The publication of greenhouse gardens from the truck	Human & environment	Quantitative & Qualitative
14	Identification and selection of Environmental Performance Indices for sustainable port development, 2014 [33]	Air quality, Water quality, Soil and Sediment quality, Odor, Ecosystem of habitat, Waste management of ports, Noise, Carbon effects, Dredging, Dust, Port development, Consumption of resources	Environmental education and Awareness, Critical situation planning	Environment	Quantitative & Qualitative
15	The role of sea ports in end-to-end maritime transport chain emissions, 2014 [23]	Air quality, Noise, Water quality, Dredging	The publication of greenhouse gases from trucks, Ships, Port activities, Heavy vehicles, Railways, Construction equipment, Biodiversity and Natural habitats	Environment	Quantitative & Qualitative
16	Air pollution from ships in ports: The socio-economic benefit of cold-ironing technology, 2015 [24]	Air pollution	Transportation, Chemicals	Human & environment	Quantitative & Qualitative
17	Health externalities of ship air pollution at port – Piraeus port case study, 2015 [25]	Air pollution	Transportation, Traffic, Greenhouse gas costs, Water pollution costs, Solid waste and liquid waste water, $PM_{2.5}$, PM_{10}, NOx , SOx , CO, VOC, CO_2, CH_4, HCFC, Asthma, Bronchitis, Death	Human & environment	Quantitative & Qualitative
18	Abatement of air pollution at an aegean island port utilizing shore side electricity and renewable energy ،2015 [26]	Air pollution, Air quality, Noise	Emissions , traffic congestion, General health, Lung cancer, Heart, Mortality, Particulate matter (pm), SO_2, CO, NOx , CO_2, SO_4	Human & environment	Quantitative & Qualitative
19	Environmental risk assessment of water quality in harbour areas: A new methodology applied to European ports, 2015 [12]	Water quality	Transportation, Waste, Waste products , Ship repair, Mooring, Hazardous cargo, Cargo transportation, Rail, Sewage, Construction, Traffic, Sediments, Ballast, Remaining agricultural goods	Environment	Quantitative & Qualitative
20	A Comprehensive Pattern for Environmental Impact Assessment of Ports in Iran, 2015 [2]	Water quality, Air quality, Oil pollution, Sediment, Dredging, Noise, Odor, Waste management, Traffic, Energy consumption, Fishing	Sewage and waste pollution of the ship, Brightness, Discharge and loading of hazardous materials, Deforestation, Embankment, Drilling, Labor transport, Trench digging, Insulation, Pipeline operation, Crushers maintenance, Coastal hydrology (Wave front variation, Erosion, Beach beard)	Human & environment	Qualitative
21	Marine Environmental Monitoring by employing Data Buoy Network, 2015 [13]	Climate change, Global warming, Waves, Marine and Terrestrial ecosystems	Maritime traffic and shipping, Human migration, Industrial and urban enrichment, Greenhouse gassing	Environment	Qualitative
22	Modelling of ship engine exhaust emissions in ports and extensive coastal waters based on terrestrial AIS data e An Australian case study, 2015 [27]	Climate change, Air quality, Early death, Lung cancer	Carbon dioxide (CO_2), Nitrogen oxides (NOx), Sulfur dioxide (SO_2), Particulates (PM), Carbon monoxide (CO) and Volatile organic compounds (VOCs), Transportation, Ship traffic, Maneuvering, mooring, Fuel consumption, Wind effects, Waves, Flow, Body and Impeller sediment, Clean ship, Engine conditions and Fuel quality	Human & environment	Quantitative & Qualitative
23	Current status and trends of the environmental performance in European ports ،2015 [5]	Air Pollution, Waste (Ship and Port), Energy consumption, Water pollution, Soil pollution, Noise, Dredging, Port development, Climate change, Traffic volume	Dust, Industrial effluent, Local community, Hazardous cargo, Destruction and loss of habitat, Ship evacuation	Human and environment	Quantitative & Qualitative
25	Tools for evaluating environmental performance at Brazilian public ports: Analysis and proposal, 2015[4]	Soil Pollution, Air Pollution, Marine and Terrestrial ecosystem changes	Costs (Water consumption, Waste generation, Emissions, Noise, Energy consumption, Climate change, Recycling)	Environment	Quantitative & Qualitative
25	New environmental performance baseline for inland ports: A benchmark for the European inland port sector, 2016 [28]	Air quality, Water quality, Relationship with local community, Noise, Port expansion, Energy consumption, Port and ship waste, Dangerous cargo, Sediment, Dust, Soil quality, Carbon transport effects	Soil consumption, Biodiversity, Emissions of pollutants (CO_2, NO_2, SO_2, etc.)	Environment	Quantitative & Qualitative
26	Assessing the pollution risk of a groundwater source field at western Laizhou Bay under seawater intrusion, 2016 [29]	Water quality, Climate change, Degradation of agricultural products	Industrial production, Agricultural activity, Human life, Hydrological conditions (Precipitation, Evapotranspiration, Runoff conditions, Storm increase, Climate change), Salinity and soil salinization	Environment	Quantitative & Qualitative
27	Port environmental management: Innovations in a Brazilian public port, 2016 [8]	Water pollution, Marine ecosystem, Dredging, Greenhouse gas emissions, Truck traffic	Investment, Waste and Waste, Fishing, Solid Waste Management, Port Cargo, Pipeline changes	Environment	Quantitative & Qualitative
28	Airborne noise emissions from ships: Experimental characterization of the source and propagation over land, 2016 [30]	Noise	Transport traffic, port activity (Manoeuvring, Shoveling, Unloading and loading), Crane, Ship engine, Rigging, Effects of greenhouse gases	Human & environment	Quantitative & Qualitative

2.1. Environmental Assessment of Ports in Iran

Ports in Iran are strategic places which have got important roles in oil export, public trade and country's income. Construction and operation of ports in coastal areas will cause a group of proper and inverse impacts on physiochemical, biological and social-economical environments. Mitigation and management of these impacts are only possible by considering environmental consideration in design, construction and operational phases through environmental impact assessment studies. Preparing of ports' EIA reports which is a must on the basis of Iran legislation, needs a standard pattern consists of all related resources and parameters. The environmental performance of Iranian ports could be evaluated by three group of indices:

- **Management indices:** such as the contribution of environmental budget out of the total budget; the contribution of environmental educations out of the total port educations, etc.
- **Operational indices**: such as the discharge values of wastewater, stacks, etc. in comparison with the emission standards
- **Condition indices:** such as the environmental weather quality, the environmental water, quality, etc.

The environmental performance indices of Iranian ports are presented in Table 2.

Table 2. The environmental performance of Iranian ports by comparison of three group of evaluation indices

	Indices	Sub-index
1	Management Performance Indicators	Management Performance Indicators, Environmental policy, Objectives and targets, Environmental monitoring program, Significant environmental aspects, Environmental training and awareness, Emergency planning and response, Environmental audit, Environmental legislation, Environmental complaints
2	Operational Performance Indicators	Resources consumption, Carbon Footprint, Noise, Waste Management, Port development, transportation
3	Environmental Condition Indicators	Air quality, Water quality, Sediments quality, Coastal hydrology, Ecosystems and habitats, Ecologic

Iranian port managers, according to the meetings with the environmental experts, have compiled plans including:

1- Preparation of MOU agreement with the partner organizations and systems in which the following subjects are considered:

- The availability of using hardware (vessels, bows and navigation services) and software of the port administrations for the permanent environmental monitoring
- Cooperation with the environmental protection agency (EPA) in the pollution monitoring, marine patrols, joint maritime operations using the existing protective forces
- Rescue of the maritime mammals
- Reduction of the maritime waste

2- Compilation of the environmental and sustainability indicators for the ports and piers of the country for monitoring the environmental situation of them, considering the sustainable development goals (SDGs) and conventions provisions as well as the regional and international agreements

3- Permanent report for the degree of execution of the compiled sustainable development policies and environmental sustainability indicators.

4- Presentation of the Integrated Management Plan (IMP) or any Environmental Management Plan (EMP) existing in the ports.

5- Assessment of the integrated management plans or environmental management of ports, and compilation of management plans for the ports without such plan.

6- Compilation of plans for monitoring ports and piers in order to evaluate the degree of execution of plans.

Within the environmental agreement signed up with port of Antwerp, Belgium (of high level through the world and the 2nd in Europe), integration of the environmental indicators of Iranian ports is considered; in which Shahid Rajaee Port has been the sample and pioneer of the other ports in the country. The port of Entrop is equipped with railways in order for prevention of air pollution. In addition, the method of storage of goods in it is the way to minimize the pollution; for instance, transportation of bulk sulfur is forbidden.

3. Result and Discussion

As discussed in prior sections, toward the first goal of the study, i.e. identifying the indices, former literatures were reviewed and analyzed based on four scales. These scales are namely: the study aspects, application, time analysis and locative analysis which are described separately in detail in the following.

3.1. The Application and Study Aspects

The type of application and aspects of the study are first scale which providing certain classification through the literature review. The type of application is a scale which categorizes the literatures in quantitative and qualitative groups. For this scale, the methods which are accompanied by numbers and digits and quantity - a quantitative investigation describing the characteristics and indices of a port evaluation study - is accounted as an appropriate qualitative study. The second part of this scale is the aspects of the study including two aspects, the human and/or the environment. It is absolutely clear that the studies that are focusing on two aspects of human and environmental health are the results of a precise investigation. In such investigations the indices to evaluate the EIAP, include plenty of human and environmentally risky exposures. In this regard, the results of classifying the investigations over the world using the two named scales are presented in Table 3.

Table 3: literature review based on the application type and the study aspects scale, within 2000 to 2016

Scale		Frequency (study)	Frequency (Percent)
Application type	Quantitative	0	0
	Qualitative	4	14.3
	Quantitative & Qualitative	24	85.7
Study dimensions	Human	0	0
	Environment	17	60.7
	Human & Environment	11	39.3

According to the classification presented in Table 3, for the application type criteria, most efforts have been allocated to the quantitative and qualitative (85.7%) studies, indicating the importance of both quantitative and qualitative levels in the investigations on the EIAP. For the aspects of study part, also nearly 60% of the studies have been allocated to the environmental indices and the other have focused on both the human and environment aspects. It is worth mentioning that none of the studies have been allocated solely to the indices relevant to the human health.

3.2. Time Analysis

Time is an important scale in identifying the useful and effective indices in the EIAP. To investigate the variations of utilizing indices, literatures are categorized into four time periods and presented in Table 4. According to the literatures in each of the 4 time periods, the most important indices to evaluate the environmental impacts of ports were identified, and 20 superior and useful indices were extracted. The priority of these indices vary in different time periods. This variation might imply the variation of aspects which are associated to the port permanent difficulties in terms of environment and sustainable development. Air quality is known as the first priority of the environment, and this shows the significance of this parameter as it is directly associated to the wellness of workman and life around the port. Noise management is of high priority. The sound produced by ship engines and other machinery are the potential sources of noise in the port. The noise might be suffering for the wildlife and the people who are living and working in the vicinity [31]. Waste management is also another high priority and concerning environmental issue. Some indices such as ship movements, port development, tourism, climate parameters and … are also some of the lower priority indices within the investigated time periods.

Table 4. Top 20 priority environmental indices of ports over the world by date

	2000 - 2004	2005 - 2008	2009 - 2012	2013 – 2016
1	Air pollution	Air pollution	Air pollution	Air pollution
2	Water pollution	Production of greenhouse gases	Noise	Noise
3	Soil pollution	Weather changes	Transportation	Water pollution
4	Noise	Sediment	Waste production	Transportation
5	Waste production	Transportation	Oil summit	The traffic
6	Traffic	Traffic	Water pollution	Production of greenhouse gardens
7	Smooth cargo	Dredging	Traffic volume	Waste production
8	Emissions	Ship fuel	Soil pollution	Soil pollution
9	Wastewater	Water pollution	Dredging	Dredging
10	Runoff	Soil pollution	Weather changes	Weather changes
11	Brightness	Noise	Sediment	Sediment
12	Tow	Port development	Port development	Dust
13	Transportation	Smell	Dust	Changes in the ecosystem
14	Dust	Dust	Emission of pollutants	Energy consumption

15	Port development	Resource consumption	Fuel quality	Waste management
16	Energy consumption	Environmental degradation	Loading and unloading	Dangerous cargo
17	Fishing	Changes in the ecosystem	Vehicles	Mooring
18	Loading and unloading	Water drain	Tourism	Maneuver the ship
19	Ship repairs	Mooring	Dangerous cargo	Port development
20	Moving the ship	Storage of hazardous materials	Meteorological parameters	Odor

3.3. Locative Analysis

The indices employed in the prior literatures on the EIAP in three continents of America, Asia and Europe, cloud be analyzed by the locative criterion. Regarding the differences in the geographic, social and economic situation of the three objective continents, a novel prioritization of indicators is carried out to evaluate the environmental impacts of ports. Keeping this in mind, 15 of the useful indices by continent were extracted, prioritized and listed in table 5. According to the table, air pollution was identified as the most useful indicator by owning the first priority within the three continents. This indicator is of high priority, possibly due to the direct relationship with the wellness of the ports vicinity people. Efficient measures have been taken in lots of regions around the world -especially in the objective regions- to reduce the air pollution of ports; for instance, the methods Cold Ironing and Onshore Generation [3, 24, 26]. Although the water pollution has also been used as one of the other useful indices within the three continents, this indicator has been ranked in the third priority in the two continents Asia and Europe, while in America, it has been of the first priority and importance. In the recent years, by taking proper measures such as the reduction of oil and ship fuel leakage and/or collection of ship waste from the port, huge steps have been taken towards the reduction of such pollutions [15]. Among the 15 identified useful indices within the three continent, 8 indices namely air pollution, transportation, water pollution, traffic, soil pollution, climate change and dredging have been utilized commonly in every three continents, as it shows the high significance of these indices.

Table 5. Top 15 EIAP in different continents were based on studies that had a case study

	Europe	**Asia**	**America**
1	Air pollution	Air pollution	Air pollution
2	Transportation	Noise	Water pollution
3	Water pollution	Water pollution	Traffic
4	Waste production	Transportation	Greenhouse gas emissions
5	Dangerous cargo	The traffic	Waste production
6	Noise	Weather changes	Soil pollution
7	Traffic	Mooring	Changes in the ecosystem
8	Soil pollution	Wrestling maneuver	Noise
9	Weather changes	Fuel quality	Weather changes
10	Dredging	Soil pollution	Dredging
11	Emissions	Dredging	Energy consumption
12	Port development	Sediment	Waste management
13	Mooring	Wastewater	Dangerous cargo
14	Drain the ship	Oil pollution	Wastewater
15	Sediment	Fishing	Fishing

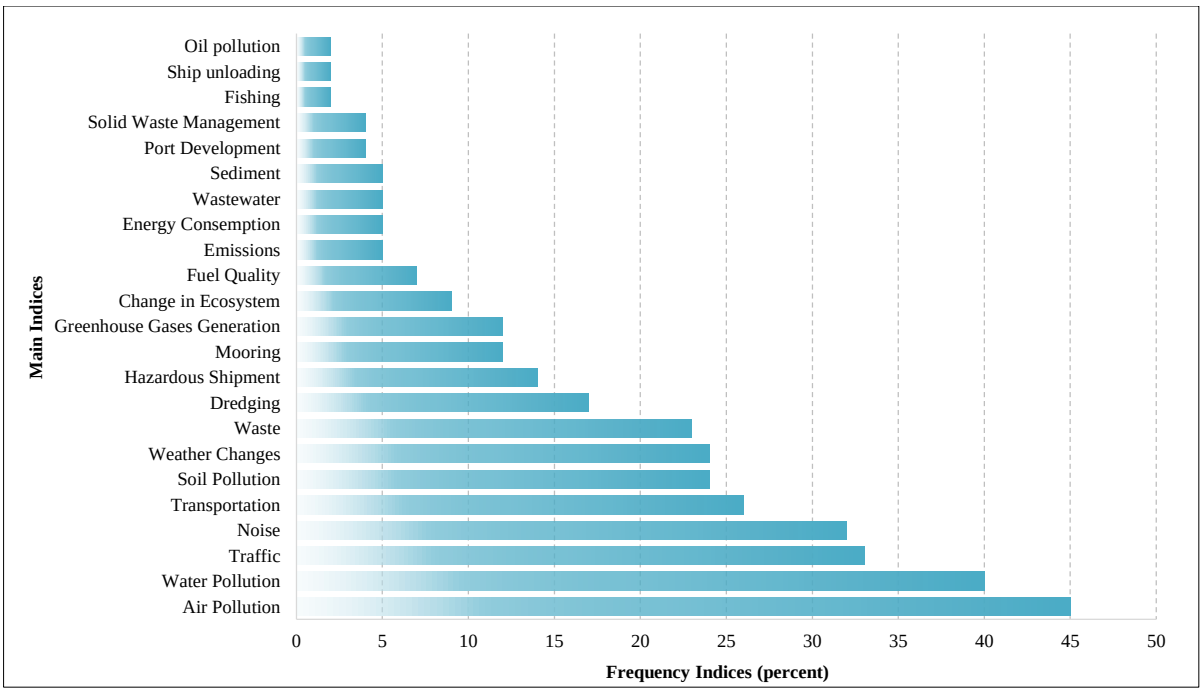

Figure 1. Frequency & priority of each top 15 indicators in three continents

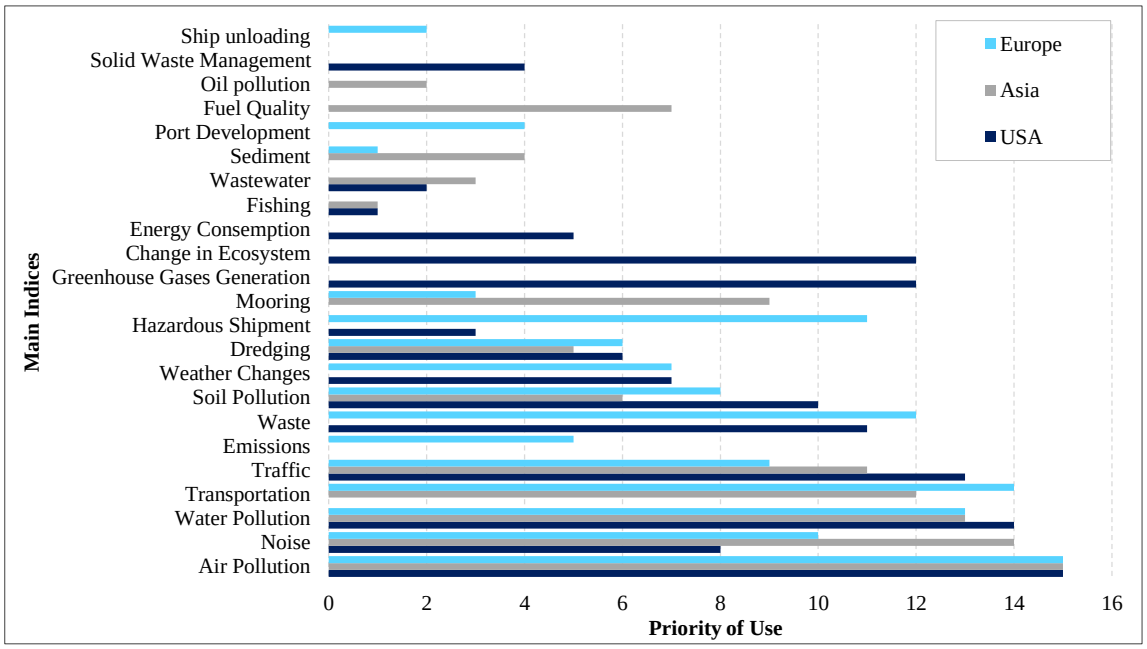

Figure 2. Priority of use of each 15 indices Europe, Asia & USA continents

Figure 1. Iillustrates the total frequency of the use of indices in the three continents and Figure 2. shows the priority of using these indices in Asia, Europe and the United States separately.

3.4. Frequency of Occurrence of Index

The fourth scale in categorizing and analysis of the previous literatures is the Frequency of occurrence of index. This scale would give noticeable results by neglecting the indices importance in the EIAP. Finally, the Frequency of occurrence of each indicator in the previous literatures and case studies were analyzed and the results are presented in table 6. In addition to the main indices in the table, the sub-indices are introduced and ranked. The air pollution has owned the highest percentage between all other environmental indices, indicating the great impact of this type of pollution on the ports environment. Transportation, traffic, greenhouse gasses and dust have also owned a considerable portion of pollution, where essential measures has to be taken in order to reduce and/or prevent them. Noise pollution also same as the air pollution has been responsible for a considerable portion. The drivers of this type of pollution are usually transportation, traffic and vessel berthing. Water pollution was also a repetitive indicator. The main indices contributing in water pollution are transportation, traffic, waste production, greenhouse gasses and dredging. Transportation and traffic, waste generation and greenhouse gasses have been secondary indices which have been

usually mentioned in the previous related studies.

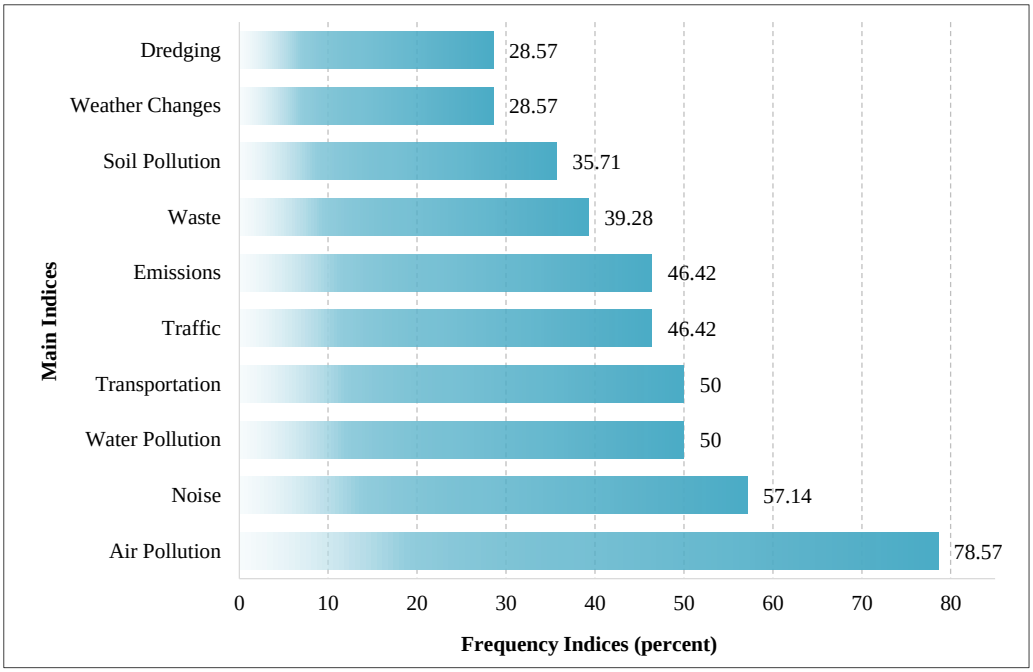

Figure 3. Top 10 priority of main indices based on frequency of occurrence scale

Figure 1. shows the 10 first primary indices based on the quantity. It is clear that the air pollution indicator with 87.5%, has owned the maximum quantity, and the dredging indicator with 28.5%, has owned the minimum quantity in comparison to the other indices.

Table 6. Top 10 priority of indices based on frequency of occurrence scale

No.	Main Indices	Sub-Indices	Frequency Sub-Indices (Percent)	Frequency Indices (Percent)
1	Air Pollution	Dust*	21.42	78.57
		Traffic*	46.42	
		Loading and unloading	7.14	
		Transportation*	50	
		Mooring*	14.28	
		Emissions*	46.42	
		Heavy vehicles	10.71	
		Port Activity	7.14	
		Truck queues	3.5	
		Fuel quality	7.14	
2	Noise	Traffic	46.42	57.14
		Transportation*	50	
		Heavy vehicles	10.71	
		Loading and unloading	7.14	
		Ship movements	7.14	
		Port Activity	7.14	
		Truck queues	3.5	
		Mooring*	14.28	
3	Water Pollution	Fuel quality	7.14	50
		Dust*	21.42	
		Runoff	10.71	
		Mooring*	14.28	
		Emissions*	46.42	
		Transportation*	50	
		Loading and unloading	7.14	
		Dredging*	28.57	

		Sediment*	21.42	
		Port Development*	17.85	
		Port Activity	7.14	
		Waste*	39.28	
		Wastewater*	14.28	
		Dangerous Cargo*	21.42	
		Fishing*	17.85	
		Tiff	3.5	
		Oil summit	7.14	
		Ship Activity	3.5	
		Pipeline operations	3.5	
		Oil pollution	3.5	
		Hydrology beach	3.5	
		Ballast Water Control	7.14	
4	Transportation*	Transport trucks	7.14	50
		Rail transport	7.14	
		Maritime Transportation	3.5	
5	Traffic*	Truck traffic	7.14	46.42
		Truck queues	3.5	
		Marine heavy traffic	7.14	
		Ship traffic	7.14	
		Traffic vehicles	21.42	
6	Emissions*	CO_2	21.42	46.42
		CO	14.28	
		SO_2	21.42	
		NO_X	28.57	
		SO_X	14.28	
		VOC	14.28	
		PM	14.28	
		$PM_{2.5}$	3.5	
		PM_{10}	3.5	
		CH_4	3.5	
		Ozone	3.5	
		HCFC	3.5	
7	Waste*	Wastewater discharge	3.5	39.28
		Waste production	10.71	
		Oily waste	3.5	
		Wastewater*	14.28	
		The remaining oil residue	3.5	
		Ship repair	7.14	
		Waste management	10.71	
8	Soil Pollution	Dredging*	28.57	35.71
		Dangerous Cargo*	21.42	
		Dust*	21.42	
		Changes in the earth's ecosystem	10.71	
		Storage of hazardous materials	7.14	
		Oily waste	3.5	
		Soil consumption	3.5	
		Traffic*	46.42	
		Repair and maintenance	3.5	
		Port Activity	7.14	
		Waste*	39.28	
9	Weather Changes	The meteorological	3.5	28.57

		parameters		
		Hydrology conditions	3.5	
		Emissions*	46.42	
		Deforestation	3.5	
10	Dredging*	Lai suction machine	3.5	28.57

* Indices that in some cases are a sub-indicator and in some cases are the main indicator

3.5. Conceptual Framework for Evaluation of EIAP

Exact study and analysis of a scientific subject the prerequisite of identifying the indices. To use these indices for the future studies and properly combine them, an obvious solution is required. Conceptual framework as an analytic tool, is used to conceptually separate and organize the ideas. In the following, to achieve the second goal of the study, various aspects in the evaluation of environmental impacts of ports according to the previous studies were analyzed; and the conceptual framework using the presented elements are shown in Figure 4.

The presented conceptual framework is in the form of a sphere in which the main and sub elements are revolving. In this framework, there is a main core (EIAP), and all of the main and sub elements are in a sequential relationship according to the center of the sphere and they finally result in the center. Initially, using criteria such as study aspects (human and environment) and the application (quantitative - qualitative), time and locative criteria and the Frequency of occurrence of index, the main and sub-indices were determined and discussed separately. As presented in the results, the main and sub-indices are different in terms of priority based on the time and locative criteria. Therefore, there is need to use a Multi-Criterion Decision Making Method considering the Decision Making Units. In addition, decision making units are used due to the difference in the local regulations and port structures in the economic and environmental affairs. Thus, use of experts would give a remarkable aid toward the optimization or optimum weight of each indicator as well as the priority of determining them in the EIAP [32].

Finally, main and sub-indices are ready to be used in a port for EIAP, based on the application priority. In this conceptual framework, regarding the overlap of time and locative criteria as well as the Frequency of occurrence of indices, a number of 10 indices have been considered as the main indices; namely: air pollution, noise, water pollution, transportation, traffic, production of greenhouse gasses, waste generation, soil pollution, climate change and dredging. Use of these 10 indices is an important part of a plan of EIAP. Regarding the sensitivity of the issue, some other main and/or sub-indices might be employed. Hence, making use of a precise analysis and a clear framework in the EIAP is a substantial step towards the awareness about the beneficial and harmful impacts of construction and operation of ports.

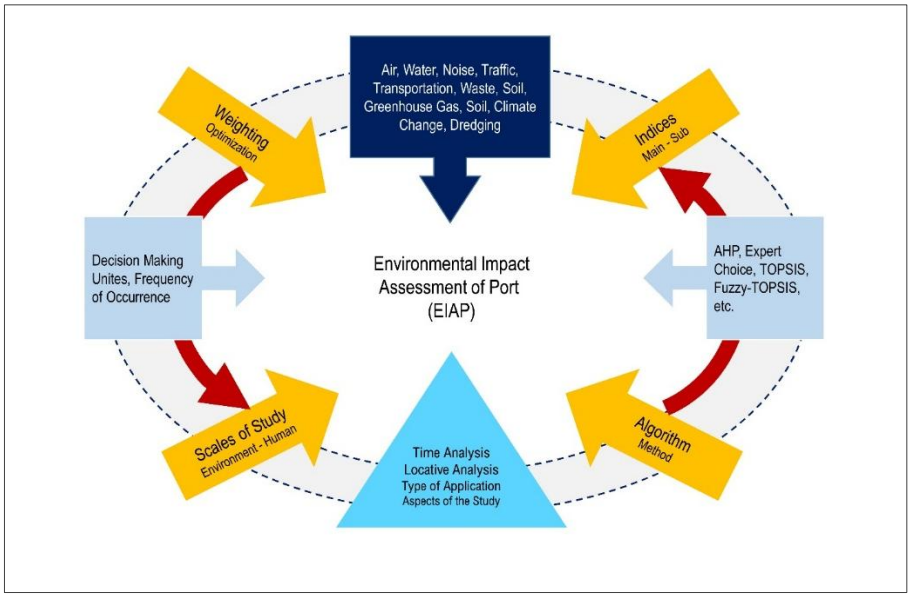

Figure 4. Conceptual framework for the EIAP

4. Conclusion

Environmental impacts assessment is a determining goal in order to reduce the pollution in ports. This is achieved by investigation and analysis through the former literatures. This study is aimed at gaining two major purposes. Firstly, identifying the main and sub-indices which determine the EIAP. Towards this, four useful scales were utilized; namely: the study aspects and application, time analysis, analysis of the location, and the Frequency of occurrence of indices. The indices for EIAP in the prior studies were applied and analyzed separately based on these four scales. In this process, totally 200 main and sub-indices were identified. Air, noise, transportation, traffic, greenhouse gasses generation, waste, soil, climate change and dredging pollutions were the 10 first determining indices. The second purpose of the study

intended in the presentation of a conceptual framework resulted from analysis of the indices in EIAP. This framework, not only sheds light to the proper EIAP for further investigations, but also upgrades the knowledge of managers and experts of ports for betterment of decision-making over the environmental plans. Furthermore, the analyses presented in this study and the corresponding results could be an appropriate reference for EIAP in Iran.

5. References

[1] Bailey, Diane, and Gina Solomon. "Pollution prevention at ports: clearing the air." Environmental Impact Assessment Review 24, no. 7 (2004): 749-774.

[2] F. Zahed, "A Comprehensive Pattern for Environmental Impact Assessment of Ports in Iran," no. December, pp. 22–25, 2015.

[3] Ballini, Fabio, and Riccardo Bozzo. "Air pollution from ships in ports: The socio-economic benefit of cold-ironing technology." Research in Transportation Business & Management 17 (2015): 92-98.

[4] Roos, Erica Caetano, and Francisco José Kliemann Neto. "Tools for evaluating environmental performance at Brazilian public ports: Analysis and proposal." Marine pollution bulletin 115, no. 1 (2017): 211-216.

[5] Puig, Martí, Chris Wooldridge, Antonis Michail, and Rosa Mari Darbra. "Current status and trends of the environmental performance in European ports." Environmental Science & Policy 48 (2015): 57-66.

[6] Darbra, R. M., Ronza, A., Casal, J., Stojanovic, T. A., & Wooldridge, C., The Self Diagnosis Method: A new methodology to assess environmental management in sea ports. Marine Pollution Bulletin, 48(5), (2004): 420-428.

[7] Hanaoka, S., & Regmi, M. B., Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective. IATSS Research, 35(1), (2011): 16-23.

[8] Quintana, C. G., Olea, P. M., Abdallah, P. R., & Quintana, A. C., Port environmental management: Innovations in a Brazilian public port. RAI Revista de Administração e Inovação, 13(4), (2016): 261-273.

[9] Ng, A. K., & Song, S., The environmental impacts of pollutants generated by routine shipping operations on ports. Ocean & Coastal Management, 53(5), (2010): 301-311.

[10] Tiquio, M. G. J. P., Marmier, N., & Francour, P., Management frameworks for coastal and marine pollution in the European and South East Asian regions. Ocean & Coastal Management, 135, (2017): 65-78.

[11] Darbra, R. M., Ronza, A., Stojanovic, T. A., Wooldridge, C., & Casal, J., A procedure for identifying significant environmental aspects in sea ports. Marine Pollution Bulletin, 50(8), (2005): 866-874.

[12] Gómez, A. G., Ondiviela, B., Puente, A., & Juanes, J. A., Environmental risk assessment of water quality in harbor areas: A new methodology applied to European ports. Journal of environmental management, 155, (2015): 77-88.

[13] B. Network, "Marine Environmental Monitoring by employing Data Buoy Network," vol. 2010, no. Icopmas, pp. 1–8, 2010

[14] Pourahmadi, A., Ebadi, T., & Nikazar, M., Development a Conceptual Framework for Industrial and Hazardous Wastes Rating Systems. Civil Engineering Journal, 2(4), (2016): 140-149.

[15] Trozzi, C., & Vaccaro, R., Environmental impact of port activities. WIT Transactions on The Built Environment, (2000). 51.

[16] Marmer, E., & Langmann, B., Impact of ship emissions on the Mediterranean summertime pollution and climate: A regional model study. Atmospheric Environment, 39(26), (2005): 4659-4669.

[17] De Meyer, P., Maes, F., & Volckaert, A., Emissions from international shipping in the Belgian part of the North Sea and the Belgian seaports. Atmospheric Environment, 42(1), (2008): 196-206.

[18] Vutukuru, S., & Dabdub, D., Modeling the effects of ship emissions on coastal air quality: A case study of southern California. Atmospheric Environment, 42(16), (2008): 3751-3764.

[19] Darbra, R. M., Pittam, N., Royston, K. A., Darbra, J. P., & Journee, H., Survey on environmental monitoring requirements of European ports. Journal of Environmental management, 90(3), (2009): 1396-1403.

[20]- Lättilä, L., Henttu, V., & Hilmola, O. P., Hinterland operations of sea ports do matter: dry port usage effects on transportation costs and CO 2 emissions. Transportation Research Part E: Logistics and Transportation Review, 55, (2013): 23-42.

[21] Chen, G., Govindan, K., & Yang, Z., Managing truck arrivals with time windows to alleviate gate congestion at container terminals. International Journal of Production Economics, 141(1), (2013): 179-188.

[22] Chen, G., Govindan, K., & Golias, M. M., Reducing truck emissions at container terminals in a low carbon economy: proposal of a queueing-based bi-objective model for optimizing truck arrival pattern. Transportation Research Part E: Logistics and Transportation Review, 55, (2013): 3-22.

[23] Gibbs, D., Rigot-Muller, P., Mangan, J., & Lalwani, C., The role of sea ports in end-to-end maritime transport chain

emissions. Energy Policy, 64, (2014): 337-348.

[24] Ballini, F., & Bozzo, R., Air pollution from ships in ports: The socio-economic benefit of cold-ironing technology. Research in Transportation Business & Management, 17, (2015): 92-98.

[25] Chatzinikolaou, S. D., Oikonomou, S. D., & Ventikos, N. P., Health externalities of ship air pollution at port–Piraeus port case study. Transportation Research Part D: Transport and Environment, 40, (2015): 155-165.

[26] Kotrikla, A. M., Lilas, T., & Nikitakos, N., Abatement of air pollution at an aegean island port utilizing shore side electricity and renewable energy. Marine Policy, 75, (2017): 238-248.

[27] Goldsworthy, L., & Goldsworthy, B., Modelling of ship engine exhaust emissions in ports and extensive coastal waters based on terrestrial AIS data–An Australian case study. Environmental Modelling & Software, 63, (2015): 45-60.

[28] Seguí, X., Puig, M., Quintieri, E., Wooldridge, C., & Darbra, R. M., New environmental performance baseline for inland ports: a benchmark for the European inland port sector. Environmental Science & Policy, 58, (2016): 29-40.

[29] Zeng, X., Wu, J., Wang, D., & Zhu, X., Assessing the pollution risk of a groundwater source field at western Laizhou Bay under seawater intrusion. Environmental research, 148, (2016): 586-594.

[30] Badino, A., Borelli, D., Gaggero, T., Rizzuto, E., & Schenone, C., Airborne noise emissions from ships: Experimental characterization of the source and propagation over land. Applied Acoustics, 104, (2016): 158-171.

[31] Cox, P., & Palou, J., Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 Relating to the Assessment and Management of Environmental Noise-Declaration by the Commission in the Conciliation Committee on the Directive Relating to the Assessment and Management of Environmental Noise (END). Annex I, OJ, 189(18.7), 2002

[32] Pourahmadi, A., Ebadi, T., & Nikazar, M., Industrial Wastes Risk Ranking with TOPSIS, Multi Criteria Decision Making Method. Civil Engineering Journal, 3(6), (2017): 372-381.

[33] Puig, M., Wooldridge, C., & Darbra, R. M., Identification and selection of environmental performance indicators for sustainable port development. Marine pollution bulletin, 81(1), (2014): 124-130.