Assessing the Natural and Socio-Economic Environments caused by Routine Maritime Activities: a New Perspective and its Applications to North Europe

Su Song [a1] **and Koi Yu Adolf Ng** [b2]

[a] *China Academy of Transportation Sciences.*
[b] *Department of Logistics,*
The Hong Kong Polytechnic University, Hong Kong.

Abstract

Environmental impacts had been well-recognized as an increasingly significant problem within contemporary maritime industry. Routine pollution, like oil spills and emissions from maritime operation, does not only generate negative externalities within the industry, but also supply chains and the surrounding environment. This problem, however, is often under-researched, mainly due to its invisibility and unnoticeable character. Understanding such deficiency, this paper proposes a new perspective in assessing the natural and social-economic costs caused by routine maritime activities and applies it to the case of Port of Rotterdam, The Netherlands. Based on the analytical results, measures for improvements will also be provided.

Keywords: Maritime pollution; Environmental impact; Social-economic; Port of Rotterdam; MARPOL 73/78

1. Introduction

Scientific knowledge on the dimension of the societal, environmental problems and external costs associated with transport has grown over the time (Button, 1999) and various tools in measuring the impacts posed by externalities have developed, with the most appropriate approaches being widely documented within the economic literature, e.g. Baumol and Oates (1988); Helm (1991); Pearce (1995); Button (1993a); INFRAS/IWW (2000), etc. As one of the most important components of the negative externality, environmental impacts had been taken high attention within the transport industry and studies which specifically targeted on evaluating the maritime-generated environmental impacts had appeared within the scientific field. However, while the introduction of evaluation methodologies specifically for accidental incidents during commercial maritime activities causing significant pollutions (such as large-scale oil spills from ship collisions) had been immense, e.g., Rawson *et al.* (1998); Etkin (2003); Garza-Gil and Prada-Blanco (2006); Liu and Wirtz (2006); Bigano and Sheehan (2006), etc., such major shipping incidental pollution, while often catching public attention due to its spectacular scale and easy visibility (Kingdon, 1995), did not necessarily make them the most important source of oil pollution at sea (Etkin 1999; Etkin *et al.*, 1999; GESAMP 2001), and incidental pollution was merely a tip of the iceberg within the maritime industry's environmental impacts as a whole. Indeed, chronic pollutions from routine maritime activities often shadowed constant threats to coastal environmental and socio-economic welfare, leading to far greater impacts over time. For example, in the European Union (EU) alone, the annual chronic oiling amounts to eight times the spills of the *Exxon Valdez* disaster, and a small amount of illegally dumped oil in a crucial seabird habitat could be far more deadly than a large, incidental oil spill elsewhere (IFAW, 2007).

Despite IFAW's efforts in providing a thorough investigation on the impacted seabirds suffered from chronic maritime oil spills, however, it had not gone any further involving other possible maritime-generated pollution sources, e.g., chemical wash water, sewage, etc., not to mention the lack

1 Corresponding author, Su Songa, China Academy of Transportation Sciences, 240 Huixinli, 100029, Beijing, China;Tel: +86 10 58278561; Fax: +86 10 6491 6266; E-mail: songsu-songsu@hotmail.com
2 Corresponding author, Koi Yu Adolf Ng, Department of Logistics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China; Tel: +852 3400 3625; Fax: +852 2330 2704; E-mail: lgtan@polyu.edu.hk

of consideration of the socio-economic impacts caused by shipping and port operations. Understanding this deficiency, the endeavour of this paper is to evaluate the chronic negative impacts on the natural and socio-economic environments caused by routine maritime activities. After this introductory section, Section 2 consists of the literature review where existing works, as well as their deficiencies, will be reviewed. This is followed by Section 3 where the authors will introduce a new perspective in assessing the natural and socio-economic impacts caused by routine maritime activities, including response and research costs. In Section 4, an empirical study on the Port of Rotterdam (PoR), The Netherlands, will be undertaken to illustrate the model's application, where a forecast for the long-term impacts on PoR will also be discussed, finally followed by the conclusions in Section 5. By shedding light on an important but under-researched issue, the authors are confident that this paper has played its role in contributing to the progress of achieving blue oceans in the foreseeable future.

2. Literature Review

A review of past literature indicated that different methodologies of evaluating the transport-related environmental impacts had been introduced. For example, the INFRAS/IWW report, entitled *External Costs of Transport: Accident, Environmental and Congestion Costs in Western Europe*, with the objective to improve the empirical basis of external costs of transport based on the actual state-of-the-art of cost estimation methodologies and identified a general approach (INFRSA/IWW, 2000), introduced a methodology to evaluate broad external costs generated by all kinds of transport modes. The broad costs categories covered not only the various environmental impact costs, e.g., nature damages, noise, air pollution, climate change, etc., but also other costs triggered by accidents and congestion within the transport sector. Here the most significant methodology was the 'resource' approach, or the so-called 'damage cost' approach, which was introduced to estimate the opportunity costs in damaged natural resources or social welfares. If one could not properly estimate the damage costs, the second best approach, called the 'prevention' approach, aiming to estimate the costs spent on avoiding the potential environmental impact, would be introduced, especially on climate change aspect (INFRAS/IWW, 2000; Daniels and Adamowicz, 2000).

Later in 2005, based on the INFRAS/IWW (2000) study, the EU updated the methodology in their research project entitled *ExternE*. Similar to the INFRAS/IWW report in 2000, this study concentrated on external costs evaluation, of which the environmental impact was one category. *ExternE* was not designed specifically for maritime transport sector, but a more general purpose to quantify all the energy-related external costs from electricity and heat production as well as transportation. It had developed an original methodology, namely the 'impact pathway' approach, which was useful especially in the quantification of the impacts by emission through providing a framework in transforming impacts, which were originally expressed in different units, into a common monetary value (European Commission, 2005). The study divided the methodology into three principal steps, namely: (i) defining the target to be studied, as well as the important pollutants and injured parties; (ii) estimating the impacts with a "dose-response function" and transformed these impact costs into monetary values; and finally (iii) assessing the uncertainties, analyzing the results and drawing conclusions. However, while the introduction of approaches could potentially measure environmental impact costs effectively, its generality was jeopardized by since the fact that the results overviewed by INFRAS/IWW (2000) were obtained only through EU research projects, e.g. TRENDS, *ExternE*, PETS and TRENEN, and similar data could be hard to obtain in regions outside the EU, thus limiting its general applicability. Furthermore, since the INFRAS/IWW (2000) study was not specifically for maritime transport sector, there had also been no detailed discussion and models on maritime-generated environmental impact evaluation being introduced.

On the other hand, Etkin (2003) provided a more straightforward methodology in evaluating oil spill impacts of shipping activities. In her work, both natural environmental and socio-economic losses were considered and she claimed that her model possessed the ability in quantifying relative damage and cost for different spill types for regulatory impact evaluation, contingency planning, as well as assessing the value of spill prevention and reduction measures (Etkin, 2003). In her paper, all the models were based on 'quantity of the pollutant' as the main variables in her formulations, and the easy-look-up tables made the models simple and handy estimation. Factors such as spill amount; oil type; response methodology and effectiveness; impacted medium; location-specific socio-economic value, freshwater vulnerability, habitat/wildlife sensitivity and location type were identified as spill-specific factors have the influences on oil-spill impact costs (Etkin, 2003). These spill-specific factors were incorporated to provide a more accurate oil spill impact assessment. Unfortunately, until recently, there had been no empirical evidence indicating that her approach could be soundly applied into the maritime industry outside the US, as the parameters in the models were highly specific to the American situation, including geographical, environmental and socio-economic conditions around and thus the methodology might be *ad hoc* to one specific country, although in theory the parameters could be adjusted in order to correspond with different situations, although Etkin herself made no attempts in generalizing the applicability of her work.

Recently, Liu and Wirtz (2006) had also developed a series of economic evaluating models in calculating the impacts of incidental oil spills. Their model consisted of two principal steps, namely: (i) measuring the lost services of injured natural resource; and (ii) integrating the lost services with a unit value of injured natural resource, which was either measured by economic valuation methods or transferred from existing valuation studies. In their paper, they introduced the 'service recovery function' into the model, and defined a broader concept of 'environmental impact cost', which covered 'natural environmental', 'social-economic', 'responding', and 'research' costs and the unit values of 'injured party' in their model accordingly. Both the natural environmental damages and socio-economic losses were deemed as the sum-up of opportunity costs in a non-market or market. For 'responding cost' evaluation, they entirely used the clean-up model introduced by Etkin (2003), of which the expenditures for natural resource damage assessment and the costs for investigating and monitoring affected areas were classified as parts of the 'research costs' of the total environmental impact cost package (Liu and Wirtz, 2006). On the other hand, Garza-Gil and Prada-Blanco (2006) introduced the similar models as Liu and Wirtz (2006). However, their work was limited to 'socio-economic losses' and 'response costs' due to accidental (rather than routine) maritime pollutions. Also, although their model was based on historical observed data analysis, they did not include a 'service recovery function' of the injured parties, thus making their model failed to forecast future path of recovery pattern, as well as the future impact costs.

Finally, IFAW (2007) concentrated their recent studies on the chronic oil pollutions from routine maritime activities along Northeast European coast, and examined the impacts to the population of seabirds. IFAW gave detailed measures and information from their "beached-bird surveys" and other monitoring methods. However, their study was only limited to the environmental impacts from maritime oil spills, i.e., MARPOL Annex I category. Impacts due to other maritime-generated pollutions (in MARPOL annex II-VI) were not considered, even although such impact might not be as significant. Similar to other European studies, the IFAW (2007) report was based on thorough pollutant data from EU projects, such as EGEMP and OCEANIDES conduced by EC Joint Research Center. Thus, IFAW's methodology might not be able to apply to other countries/regions, since such similar detailed information might not be available.

Despite the existence of the above mentioned studies in providing general environmental impact estimation concepts and methodologies within the transport sector, these studies shared common deficiencies. Firstly, most of them had only concentrated on assessing the costs of major pollution incidents within maritime operations only, where pollution from routine operations was often overlooked, despite its potential in causing even more environmental and socio-economic impacts as mentioned before. For example, the works of Hoc Panel (1997), Liu and Wirtz (2006), and Garza-Gil and Prada-Blanco (2006) put all their attentions on large-scale accidental oil spills (notably *Exxon Valdez* and *Prestige*) rather than routine minor oil spills (like spills from engine room or oily ballast water discharging in routine shipping and port activities). Indeed, large-scale of pollutants from major shipping incidents did not make them as the main source of sea pollution (Etkin, 1999; Etkin *et al*., 1999; GESAMP 2001). As an attempt to address this deficiency, Bigano and Sheehan (2006) and GESAMP (2007) calculated small and large-scale accidental oil spills separately using different models. Unfortunately, still, both studies did not extend to other maritime pollution source or providing the any further detailed evaluation of environmental impacts along the coastal areas.

Secondly, as indicated in the works by INFRAS/IWW (2000), Etkin (2003) and IFAW (2007), even when some types of generalization had taken place, it was highly restricted within a regional perspective, of which useful data (or the categories set by the studies) was usually available only within a particular region, e.g., the EU, US, etc. Finally, although a number of existing works considered the chronic environmental impact from routine shipping operations, they had not extended their work any further to a broader pollution source category, such as air emissions and chemical disposals, as characterized by the works of Bigano and Sheehan (2006), GESAMP (2007) and IFAW (2007). Clearly, further works are required to tackle this issue more comprehensively.

3. The New Perspective

Based on the literature review, here the authors introduce a new model to evaluate the environmental impacts which are specifically generated from maritime industry. Different from previous literature as discussed before, this paper's models have various specific features, namely: (i) chronic environmental impacts from routine maritime activities in seaport area, not for incidental pollutions, because incidental pollutions cannot be well-forecasted; (ii) the main variable – quantity of pollutants – is from the port's routine records which are based on MARPOL73/78 Annex[3]; a broader types of pollutants can be examined by using the model and such kind of data is comparatively easier to obtain[4]; and (iii) the concepts of 'service recovery year' and 'service recovery function' are being introduced, based on (and improved) from the existing literature; and (iv) broader costs categories are to be considered, which do not only include the costs of natural environmental damage, but also the socio-economic losses, as well as response and research costs. Before going on, however, it is noted that the proposed model here is used to assess the environmental impacts on port and coastal areas, not open oceans and seas.

3.1 The formulation

Long-term pollution from routine maritime activities, especially within the port areas, does not only impact the natural environment, but also the socio-economic welfare, with seabirds and coastal fishery being respective illustrative examples on different categories of the injured parties. The proposed model with broader costs categories can be found in the following formulation:

$$TC = \sum_{p} (N_p, S_p, R_p, x_p) - c \qquad (1)$$

where *TC* represents the total cost of maritime-related negative environmental impact; *p* represents the pollution sources found in MARPOL73/78; *N* represents the total natural environmental damages; *S* represents the total socio-economic losses directly related to *p* (such as lost in commercial fishery due to ship oil spills); *R* represents the summed costs of response (like clean-up and removal costs) and research to the pollution (which is usually a constant with little correlation with *p*); *x* represents other possible costs due to pollution impact from maritime activities; and *c* represents the coefficient costs of either combination impacts from MARPOL Annex I-VI. Note that, however, *c* is the potential overlapping costs that from some joint maritime pollutants' impacts. For example, the lost population of certain marine specie might be the result of both vessel oil-spills and chemical washed-water discharges. In practice, during data collecting and processing, breaking up such overlapping costs into independent cost data could be difficult, partly because that the majority of the data are the 'package data', on which several kinds of pollutants might have the impacts. As a consequence, in some cases, some impact costs may be double-counted, and this also implies that there are still rooms of

3 MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships) is the international treaty regulating disposal of wastes generated by normal operation of vessels. It was released in 1973 and was modified by IMO's Protocol of 1978. The Convention includes regulations aimed at preventing and minimizing pollution from ships – both accidental pollution and that from routine operations – and currently includes six technical annexes: oil spills, noxious liquid substances, harmful substances, sewage, garbage and air pollutions.

4 For example, unlike many other sources, data obtained from MARPOL 73/78 does not involve significant monetary costs or confidentiality issues.

improvements for MARPOL 73/78.

3.2 Natural environmental and socio-economic costs

Impacted by certain type of maritime-related pollution source *p*, the total natural environmental damages (*N*) can be expressed as the function of unit value and quantity of injured natural resources, as well as the years spent on recovering their lost service (or value), as expressed in the following formulation:

$$N_p = \sum_i V_N * Q_i * Y_i = \sum_i V_N * g(Q_p) * Y_i \tag{2}$$

Similarly, socio-economic loss (*S*) can be expressed in the following formulation:

$$S_p = \sum_i V_S * Q_i * Y_i = \sum_i V_S * g(Q_p) * Y_i \tag{3}$$

where *i* denotes the injured party that is impacted by pollutant *p*, which can be the injured party in either the natural environmental or socio-economic categories; *V* is the unit value of *i*; Q_i is the quantity of *i*, while Q_p is the quantity of *p*; $g(Q_p) = Q_i$ is the relation function between quantity of pollutant and quantity of injured party; *Y* is the service recovery years of *i*, or to say, the real time spent on injured party in order to let recover its lost value or service.

Here is to note that, although *V* is the unit value of *i*, V_N and V_S represent the different value of *i* on natural environmental (non-market) and socio-economic (market) aspects; the calculations of V_N and V_S, therefore, are different. Calculating V_N can be one of the most difficult steps in maritime environmental impact estimation as V_N is extracted from environmental common resources which the unit value cannot be evaluated via examining the market-driven price, it should therefore base on the approximate average 'willingness to pay' (WTP) method, through applying the Contingent Valuation Method (CVM). On the other hand, all the socio-economic goods are traded within marketplace and have their market values, estimating V_S is comparatively easier and thus during V_S's estimating process, it does not need to calculate the rough average WTP through complicated CVM (like V_N does). The only thing that should be done in estimating V_S is to examine the price in existing or future market place, e.g., the potential unit income from fishery for certain fish *i*, the potential average revenue from certain coastal tourism, etc.

3.3 Response and research costs

Response and research costs can be expressed in the following formulation:

$$R_p = \alpha * Q_p + \beta \,, \;\; Q_p > 0 \tag{4}$$

where α is the unit response cost; β is the research costs. As discussed, response cost response includes all the costs directly related to addressing maritime-related pollutants, but not the treatments to the injured parties, for instance, rescuing contaminated marine mammals. The function of *R* has two sections, in which the response cost has a linear relationship with pollutant amount while the research costs are deemed as constant. *R* has no relationship with recovery function of injured parties; but is the direct function of pollution amount Q_p. The unit response cost α, which the value is determined by current market. During a certain period, R_p has a linear function with Q_p due to the routine small-scale pollutions, the unit response cost α can be constant. However, in practice, there is hardly any maritime pollutant can be instantly 'cleaned up' within a rather short period of time, especially for the case of large-scaled illegal pollutions; some pollutant residues (like sticky vessel sewages) might require months, or even years and decades, to be completely removed, if possible at all. Therefore, all the forecasted future α should be discounted by certain discount rate, such as interest rate, to the present until the years when the discharged pollutant is fully removed, namely Q_p. For the long-term, chronic environmental impacts from routine maritime activities, research costs β does not have significant quantitative relationship with either Q_p or Q_i. Indeed, β represents the expense of a general marine environment research which considers all the pollutants in MARPOL 73/78 Annex, and thus should be regarded as a constant.

Other costs, which may cover the expenses on rescuing the contaminated animals, or on the indirect research aimed to promote technical innovations for maritime environment improvement, e.g., improving the anti-fouling components, new-tech filtering systems, etc., have little relationship with collected variables (Q_p and Q_i) and thus will be deemed as constant in equation (1).

3.4 Service recovery function

As for equations (2) and (3), only a few injured parties from maritime-related environmental impact can be fully recovered within short-time period. To evaluate the maritime environmental costs over years, it is essential to introduce the 'service recovery years' *Y* of the injured party *i*. Since the numbers of years spent on service recovery are equal to the years when partial service is lost, *Y* can be also explained as the 'lost service years' of *i*. The authors made revisions and improvements on previous literatures and introduce *Y* with more accuracy. As indicated in equations (2) and (3), the impacts can be due to natural resource's degradation and socio-economic welfare losses and, as a consequence, a decrease of the service of *i* after the maritime-related pollution took place. Figure 1 illustrates the service recovery path which is presented as the function of *Y*.

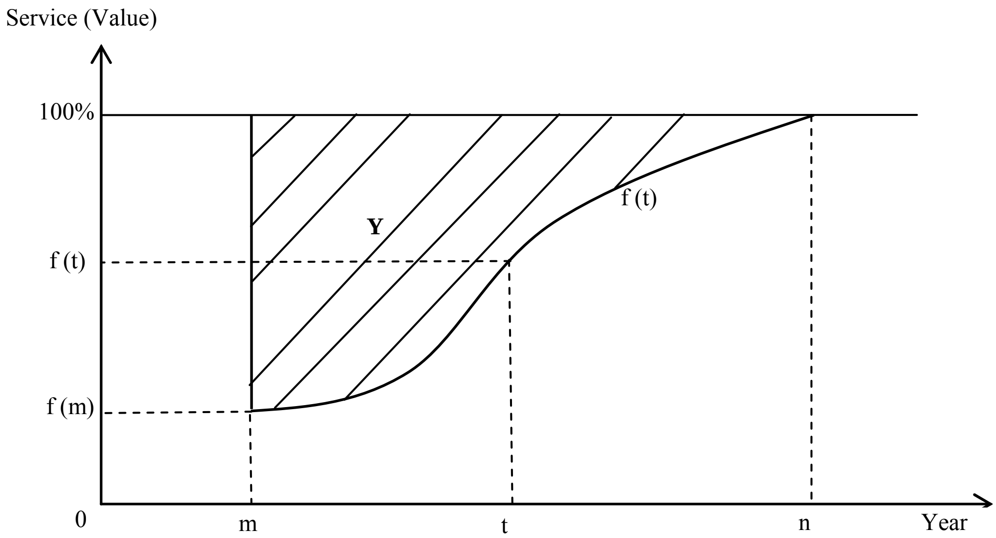


Figure 1: Service recovery function of an injured party

In Figure 1, *f(t)* is the service recovery function of the injured party *i* on year *t*, while the path of *f(t)* shows the recovery course of a unit injured party over time. *m* is year when injury begins, as years gone by, such loss will be recovered and finally reach zero, of which the service will be fully recovered, or when the recovery course has finally stopped (year *n*). Here is to note that, in some situations, *n* can be also defined as infinite (∞), or having a trend to 'permanently close' to zero losses. This is because not all the damages or losses of injured party can be fully compensated after a finite recovery time and some services (or values) might be lost forever after serious environmental impact from accidental large-scale vessel pollutions like the *Exxon Valdez* spills. However, given the focus of this paper which is on small routine maritime pollutions, it is assumed that *n* equals to zero. The service recovery years, *Y*, is illustrated in the shadowed area as indicated in Figure 1. The function between *f(t)* and area *Y* of unit *i* can be expressed in the following formulation:

$$Y_i = \int_m^n (1 - f(t_i))dt_i \,,\quad m \le t_i \le n \,,\quad 0 \le f(t_i) \le 1 \qquad (5)$$

where *f(t)* (no unit) denotes the remaining service as the percentage to the full service value which is before injured. Therefore, *(1-f(t))* is the percentage lost service at year *t*. *Y* (in years) is the integrated area of small fractions of the real service recovery years.

3.5 Social discount rate

In order to estimate the present value of the lost services over the injury years, the lost services of *i* have to be discounted into present with appropriate discount rate. When considering the discount rate, the equations (2) (3) and (5) can be combined, forming the following formulations:

$$N_p = \sum_i V_N * Q_i * Y_i = \sum_i V_N * g(Q_p) * Y_i$$
$$= \sum_i \int_m^n V_N * g(Q_p) * (1 - f(t_i)) * \left(\frac{1}{1+r}\right)^{t_i - m} dt_i \qquad (6)$$

$$S_p = \sum_i V_S * Q_i * Y_i = \sum_i V_S * g(Q_p) * Y_i$$
$$= \sum_i \int_m^n V_S * g(Q_p) * (1 - f(t_i)) * \left(\frac{1}{1+r}\right)^{t_i - m} dt_i \qquad (7)$$

where *r* is the annual discount rate. Just like *V* and $g(Q_p)$, *r* may be different in equations (6) and (7). In equation (6), which evaluates the impact costs of natural environmental damages, *r* is the 'social discount rate'. On the other hand, in equation (7), which evaluates the impact costs of socio-economic losses, *r* can be the current market interest rate (or any other suitable discount rate). With the market-based character, it is relatively easy to obtain *r* in equation (7) by examining the current and historical market. On the other hand, since equation (6) possesses a non-market character, calculating *r* is more difficult, although based on NOAA's estimation, the number of social discount rate *r* is defined as 0.03, which would also be used by this paper.

4. Case study: Port of Rotterdam, The Netherlands (PoR)

This section illustrates the model's practicality by applying it into PoR. This section is divided into two parts. Section 4.1 discusses the modeling assumptions and data collection, while Section 4.2 illustrates the results and discussions.

4.1 Data collection and assumptions

Given that The Netherlands is a member of the MAPROL 73/78, every year, Rotterdam Port Authority (RPA)[5] would prepare detailed statistics on daily pollutants being discharged into PoR's premises, and such data would be significant enough to represent the general environmental impacts to PoR and its surrounding areas caused by routine maritime activities, and so data could be found in PoR's reported pollutions published in the MARPOL 73/78's Annex providing a clear clue to track the routine small-scale pollution sources from port area's maritime activities with various categories. Thus, based on the evaluation model, the authors collected required data of Q_p from PoR. RPA recorded data regularly on the quantity of pollutants (Q_p) generated from seagoing vessels within their port area through the years. This unit of Q_p of this empirical study is in cubic meters (m^3). On the other hand, the data of quantity of injured party (Q_i) was collected from OSPAR's recent costal survey along the North

5 Since 2004, a new public corporation had been established in PoR which undertook all the major responsibilities related to the operation and management of PoR, namely Havenbedrijf Rotterdam N.V. Since then, the collection of data on maritime pollutants was carried out by the Harbour Master's office under this newly-established corporation.

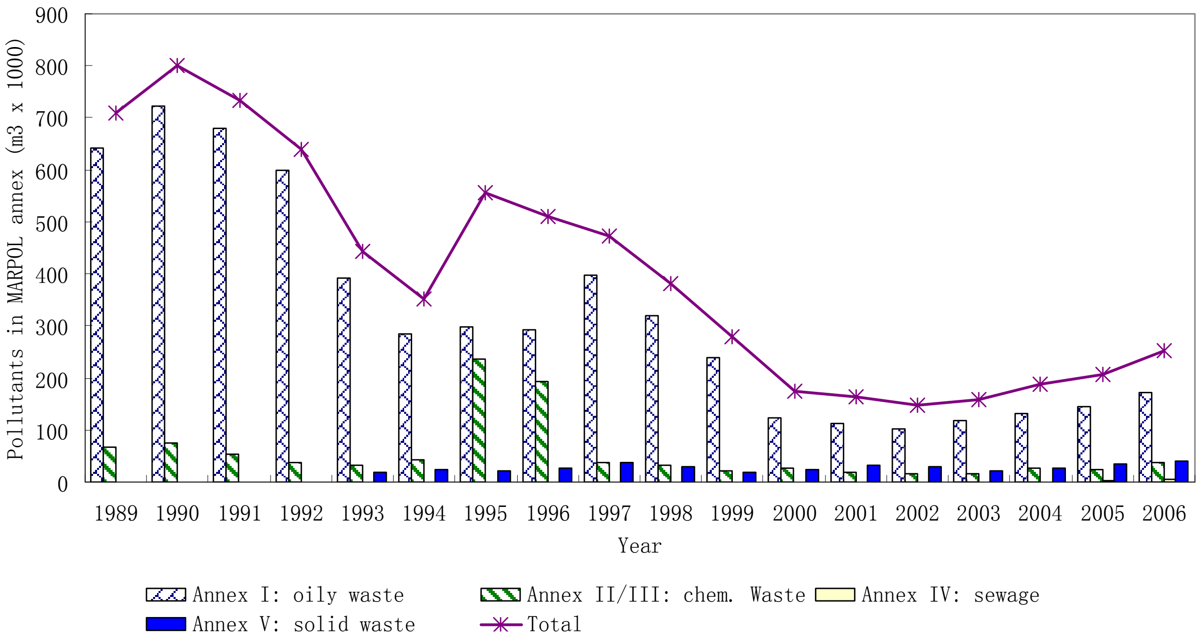
European coastal areas. The definition of the pollutants was based on MARPOL 73/78 Annex which categorized the pollution sources into five categories (Annex I-V), which can be found in Table 1.

Table 1: Maritime pollution sources based on MARPOL 73/78 Annex I-V

MARPOL 73/78 Annex	Pollution sources	Type of waste
I	Fuel oil residues (sludge)	Ship-generated
	Used engine oil (UEO)	Ship-generated
	Bilge water (BIW)	Ship-generated
	Wash water oil (WWO)	Cargo residue
	Ballast water oil (BTW)	Cargo residue
II and III	Wash water chemical 1	Cargo residue
	Others	Cargo residue
IV	Sewage	Ship-generated
V	Domestic waste	Ship-generated
	Food waste	Ship-generated
	Plastics	Ship-generated
	Dry cargo residue	Cargo residue
	Maintenance waste	Ship-generated
	Cargo associated waste	Ship-generated

Source: MARPOL 73/78 Annex; PoR (2006)

Based on the classification of Table 1, Figure 2 illustrates the maritime pollutants discharged into PoR's premises between 1989 and 2006.



Source: PoR (2006)

Figure 2: Maritime pollutants discharged into Rotterdam port area, 1989-2006

From Figure 2, it is not difficult to found that, throughout the last two decades, oily waste spills (MARPOL – Annex I) had the dominating source of maritime pollutant to PoR. However, one should note an interesting phenomenon happened, where the gap between oil waste and other pollution sources had been continuously shrinking throughout this period, especially since 2000. As a consequence, it is clear that a comprehensive consideration of all polluting categories in the MARPOL Annex is necessary in this case, as other pollutants might get more equal impacts to PoR's port community than simply to oil spills.

During the data collection process, a number of assumptions had been made. Firstly, while OSPAR (2006) reviewed 21 ecological quality objectives in their North Sea pilot project which covered major possible natural communities impacted by coastal maritime activities, the authors had chosen 'commercial fish species' (expressed in tons) and 'seabirds' (expressed in tons) as the two injured parities (i) within PoR's premises. With this assumed i, the commercial fish species represented the socio-economic category which was fixed in equation (7); while the seabirds represented the natural environmental category fixed in equation (6). The unit values (V) of both natural communities were assumed to be constant throughout the 10 years of services recovery and, based on existing information on market fishery stock and seabirds along the North West European coast, the authors assumed that the average values for commercial fish and seabirds would be 300 USD per ton 100 USD per unit respectively.

Also, although the service recovery function, $f(t)$ could be any shapes depending on the characteristics of the injured parities, after examining the recovery pattern throughout the years on different injured services, Liu and Wirtz (2006) found that the lost service estimation was not sensitive to the choice of recovery function, as long as the recovery time did not exceed one decade, of which it would be specifically useful for the chronic pollution impacts from routine maritime activities. With such understanding, it was assumed that $f(t)$ was in linear function for both injured seabirds and commercial fishery values. With the assumed linearity, the initial injured (m) and recovery-ending (n) years would be 0 and 10 respectively; For social discount rate (r), the authors followed NOAA's estimation (see last section) and the r which was equal to market-base interest rate in equation (7) was assumed to be no different to the social discount rate in equation (6). For response and research costs, the average unit response costs (α) in equation (4) was assumed to be 1.5 USD/m^3 of all kinds of MARPOL 73/78 Annex pollutants, and was also assumed as constant through the recovery years. According to anecdotal information from the industry, the research cost (β) was assumed as annual inputs for maritime environment research and pollution prevention projects. β was assumed to be constant, at 700 000 USD per year regardless of Q_p and Q_i, while the coefficient effects of research to the Q_p and total costs would not be considered. Finally, it was assumed that no other costs (c) would be triggered from other maritime-related environmental impacts.

4.2 Results and discussions

By applying the models that are discussed above with the relevant assumptions and data, the total costs (TC), natural environmental costs (N), socio-economic losses (S) and response/research costs (R) can be found in Figure 3.

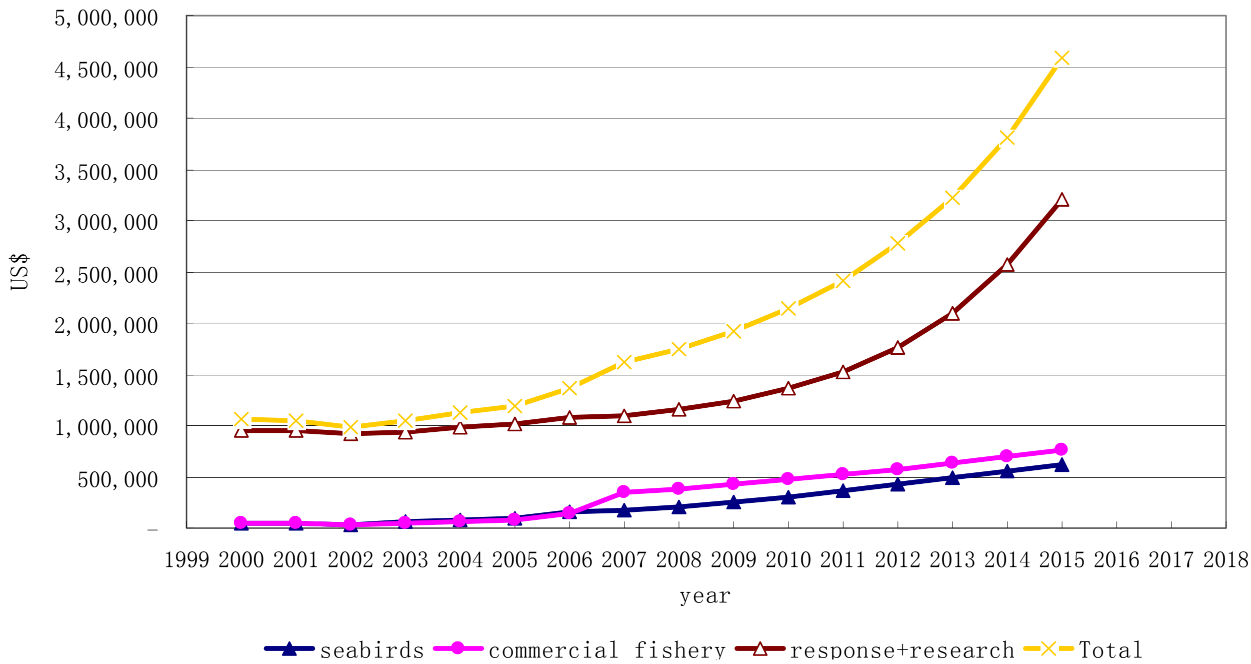


Figure 3: The projected costs of environmental impacts caused by Rotterdam port area maritime activities, 2000-2015

Figure 3 displays an increasing pattern of environmental impacts caused by maritime activities within PoR's premises, which is projected from 2007 until 2015. Through regression analysis, it was found that both the natural environmental damages (represented by injured seabirds) and socio-economic losses (represented by commercial fishery lost) would be significantly sensitive to the pollutants categorized in MARPOL Annex I, i.e., oil residues discharged from routine shipping operations, where the correlations between Annex I (oil spill) and injured parties are over 90% compared with other pollutants (Table 2).

Table 2: The correlations between different injured parties and polluting categories within PoR's premises

Category	Annex I	Annex II/III	Annex IV	Annex V
Seabirds	0.96	0.75	0.93	0.58
Commercial fish	0.92	0.80	0.71	0.38

On the other hand, however, the costs spent on response (mainly the disposal of oil spills) and researches, however, were huge (Figure 1) and they may, in the long-term, decelerate the trend of the negative impacts caused by routine maritime activities. With the consideration of long-term time span, usually over the 10 years, research may help ships to improve their cleaning technologies, controlling their residues within a reasonable range during the shipping process within the port area or along the coastal, and finally relieving the increasing impacts to the overall natural environment and social welfares. This means that the research costs should have a negative relationship with the increase rate of pollution amount (Q_p), and therefore reducing some impacts costs of maritime pollutions. Although this paper does not formulize such relationship, mainly due to the complexity in quantifying the effects of research (namely, the amount of *TC* increase rate reduced due to relevant researches results, especially the R&D of the green-technology innovation) (where further research is required), Figure 4 gives an initial readjusted estimation on the trends of the maritime environmental impacts with the consideration of coefficient effects of research.

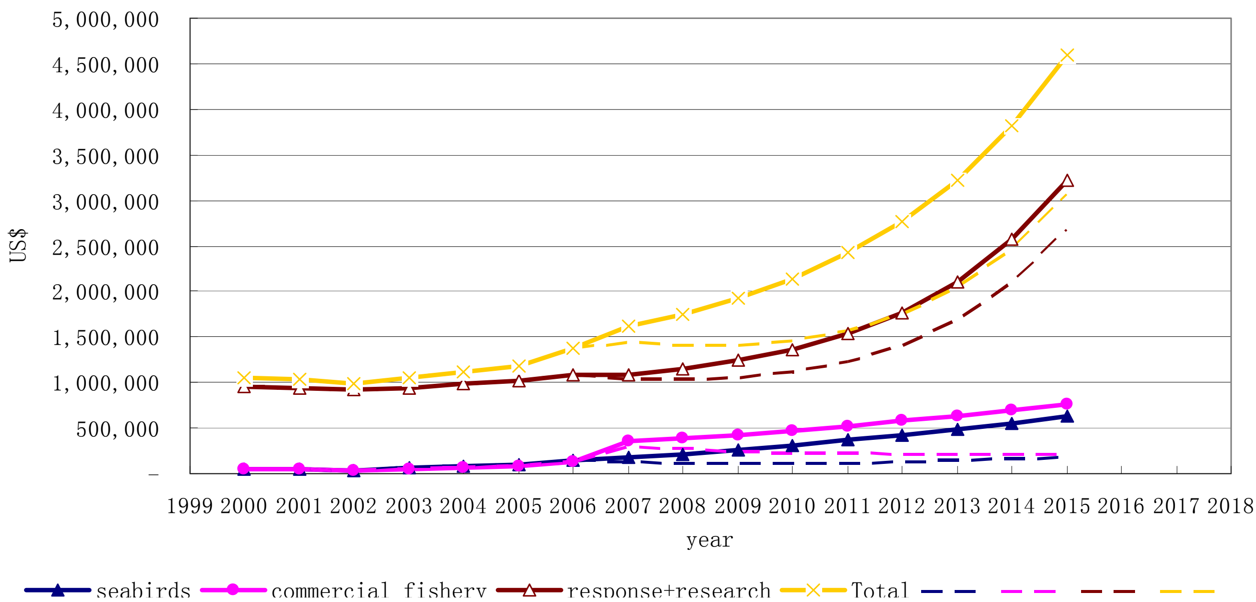


Figure 4: The projected costs of environmental impacts caused by PoR's maritime activities with the consideration of coefficient effect of researches, 2000-2015

Both Figures 3 and 4 illustrate an increasing trend of general environmental impacts from maritime activities of PoR's premises between 2000 and 2015. It should be noted that the rate of such impacts has also been increasing throughout the years. Scientific researches or actions with the aims on clean technology improvement and regular pollutions preventions in maritime industry can actually reduce the total environmental impact costs by approximately 10% to 30% in a long term context.
With the understanding that the routine oil residues (MARPOL Annex I) could have significant impacts

on PoR coastal environment and society welfare, a recommendation to PoR and other similar ports is to put their main environmental considerations on oil spills within or around port area. Based on empirical results in this paper, the authors would recommend a number of policy measures to RPA and/or similar national authorities and enforcement agencies of other states, as well as the international authorities. First of all, it is important to implement OSPAR's Ecological Quality Objectives (EcoQO) or other similar monitoring tools to injured parties in other coastal or seaport areas. Local authorities should cooperate with and support local NGOs or other institutes to conduct survey schemes of oil-contaminated parties, especially in the 'natural environmental' category. That will be very helpful to estimate the current and future environmental impact from maritime activities.

Also, although the collection of pollutant data is comparatively easy to the port authority, PoR should go on put their main concern on monitoring and recording oil residues in the MARPOL Annex I. This also requires the close cooperation between port authorities and shipping companies. To strengthen the existing legislation and measures in order to put stricter limitations on future chronic oil pollutions, port state control should be improved and makes sure all ships within their port areas would comply with the international anti-pollution standards and facilitate the use of port reception facilities. Some economic incentive policies should be applied properly to reduce shipping oil spills, e.g., discount on the purchase of fuel upon delivery of waste waters to reception facilities, smaller port access fees, etc. (IFAW, 2007). Besides, port authorities should also encourage onboard oily waste disposal, and monitor the disposal and handling procedure by using the transponders.

At an international level, the IMO should consider amending the MAROPL Annex I, where the speeding up of replacing Oil Record Book by the Electronic Oil Discharge Monitoring System (EODMS) is required and made compulsory in the MARPOL Annex I. Shipping companies and other marine stakeholders should be encouraged to facilitate this transformation process so as to comply with the MARPOL Annex I's oil discharge requirements. If possible, placing the "places of refuge" for distressed ships may minimize the risk for the impacts to seabirds and other parties. Finally, in order to make the unified database and international regulations, other port states are urged to join the MARPOL 73/78. Indeed, the proposed model in this paper can potentially develop to become a global generalized model in assessing the environmental footprints due to routine maritime activities, but this requires port states around the world to join MARPOL 73/78, as well as providing relevant and internationally comparable data and information.

5. Conclusion

Long-term chronic pollution from routine maritime activities casts a shadow to coastal natural environment and socio-economic welfare, often leading to far more negative externalities over time than large, incidental ones. However, due to various reasons, notably the lack of public attention due to their routine small dose, invisibility and thus comparatively unnoticeable character, they are always overlooked within environment shipping's research field. Compared with many existing studies, which limited to large-scale incidental maritime pollutions aspect, this paper concentrates on routine maritime-generated pollution and introduces a new simulation perspective in assessing its impacts on the natural and socio-economic environments.

Also, when compared with previous similar studies that were restricted within particular regions, this paper has provided a more general evaluation method based on easily-available database and makes the future impact trend more predictable. The calculation of maritime pollution impacts depends highly on coastal surveys on injured parities amounts and pollutants records, which are based on MARPOL 78/78 annex. As long as the port state is a member state of MARPOL 73/78, unified and stable routine pollutant records will be rather easy to obtain and the evaluation results will likely be comparatively accurate. This will also greatly help researchers to compare the coastal environmental impacts among different ports. Also, different from large incidental maritime pollution, the chronic future environmental impact from routine maritime activities can be well forecasted by applying the models in this paper, especially for the small amount pollutants discharged from vessels within or around port premises and coastal areas. While not attempting to argue that this new perspective does not need any improvements, notably further research is required to improve the make the assumptions on social discount rate and research cost more concrete, it has offered an ideal platform in creating a global, generally-accepted method in assessing the impacts of maritime activities.

The variables and the model itself can be readjusted in case of port regions' specific situations, which might be various greatly. The calculations performed in this paper provide approaches for the crucial factors should be considered in the maritime environmental protection issue. Based on the findings of this paper, reducing the routine small oil spill (in MARPOL Annex I), in the long-term, will have much significant effects for the coastal environment and society compared with other maritime pollutants. Through addressing the deficiencies of previous works and its reliance on MARPOL's data source (which is, basically, the generally-accepted international standards), the new perspective introduced in this paper can potentially become a global generalized model in assessing and benchmarking the negative impacts of routine maritime activities on port and coastal areas, especially when more port states are joining MARPOL 73/78 in the near future, thus allowing more detailed data to be collected from other impacted parties. Last but not least, by shedding light on an important, but often under-researched, issue, the authors are confident that this paper has played its role in contributing to the progress of achieving blue oceans for future generations.

References

1. Baumol, W.J. and Oates, W.E. (1998): '*The Theory of Environmental Policy (Second Edition)'*, Cambridge: Cambridge University Press.
2. Bergh, J. (1999): '*Handbook of Environmental and Resource Economics'*. Cheltenham: Edward Elgar.
3. Bigano, A. and Sheehan P. (2006): '*Assessing the Risk of Oil Spills in the Mediterranean: the Case of the Route from the Black Sea to Italy*'. Working paper no. 32.2006, Milan: FEEM.
4. Button, K. J. (1993a): '*Transport Economics'*. Cheltenham: Edward Elgar.
5. Button, K.J. (1993b): '*Transport, the Environment and Economic Policy'*. Cheltenham: Edward Elgar.
6. Button, K.J. (1999): '*Environmental Externalities and Transport Policy*'. In: Y. Hayashi, K.J. Button and P. Nijkamp, (eds.): The Environment and Transport, Cheltenham: Edward Elgar.
7. Caratti, P., Dalkmann, H., and Jiliberto, R. (eds.) (2004): '*Analyzing Strategic Environmental Assessment'*. Cheltenham: Edward Elgar.
8. Daniels, R. and Adamowicz, V. (2000): '*Environmental Valuation*'. In: D.A. Hensher and K.J. Button (eds.): Handbook of Transport Modeling, Oxford: Elsevier Science.
9. Dicks, B. (1998): '*The environmental impact of marine oil spills – effects, recovery and compensation*'. The International Seminar on Tanker Safety, Pollution Prevention, Spill Response and Compensation (6th November 1998: Rio de Janeiro, Brazil). ITOPF. London, UK: ITOPF.
10. Etkin, D.S. (1999): '*Estimating cleanup costs for oil spills*', Proceedings of the 1999 International Oil Spill Conference. Washington D.C.: American Petroleum Institute.
11. Etkin, D.S. (2003): '*Modeling oil spill response and damage costs*'. Proceedings of the 2003 International Oil Spill Conference, Washington D.C.: American Petroleum Institute.
12. European Commission (2005): *'Externalities of Energy (ExternE): Methodology 2005 Update*', Luxemburg: European Commission.
13. Fox, A.D., Desholm, M., Kahlert, J., Christensen, T.K., and Petersen, I.K. (2006): '*Information Needs to Support Environmental Impact Assessment of the Effects of European Marine Offshore Wind Farm on Birds',* (British Ornithologists' Union No. 148). British Ornithologist's Union.
14. Garza-Gil, M.D., Prada-Blanco, A. and Vazquez-Rodriguez, M.X. (2006): '*Estimating the short-term economic damages from the Prestige oil spill in the Galician fisheries and tourism*', Ecological Economics 58(4): 842-849.
15. GESAMP (2001): '*A Sea of Troubles'*, IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) and Advisory Committee on Protection of the Sea. Reports and Studies No.70, IMO, London.
16. GESAMP (2007): '*Estimates of Oil Entering the Marine Environment from Sea-based Activities'*, London: IMO.

17. Georgakaki, A., Coffey, R.A., Lock, G., and Sorenson, S.C. (2005): '*Transport and environmental database system (TRENDS): maritime air pollutant emission modeling*', Atmospheric Environment 39: 2357-2365.
18. Guo, J.C.Y. (2006): 'Overland flow model for asphalt oil spills', *Journal of Environmental Management* 78: 102-105.
19. Hanley, N. and Spash, C.L. (1993): '*Cost-Benefit Analysis and the Environment',* Cheltenham: Edward Elgar.
20. Hanley, N. Shogren, J.F. and White, B. (1997): '*Environmental Economics in Theory and Practice',* London: Macmillan.
21. Helm, D. (1991): '*Economic Policy towards the Environment',* Oxford: Blackwell.
22. Hensher, D.A. and Button, K.J. (eds.) (2003): '*Handbook of Transport and the Environment',* Amsterdam: Elsevier.
23. IFAW (2007): '*Chronic Oil Pollution in Europe',* Brussels: IFAW.
24. INFRAS/IWW (2000): '*External Costs of Transport: Accidents, Environmental and Congestion Costs of Transport in Western Europe',* Paris: INFRAS/IWW, International Union of Railways.
25. Kingdon, J.W. (1995): '*Agendas, Alternatives and Public Policies (Second Edition)',* New York: Longman.
26. Lee, N. (2006): 'Bridging the Gap between Theory and Practice in Integrated Assessment', *Environmental Impact Assessment Review*, vol. 26, pp. 57-58
27. Liu, X. and Wirtz, K.W. (2006): '*Total Oil Spill Costs and Compensations*', Maritime Policy and Management, vol. 33, No. 1, pp.
28. Maler, K. and Vincent, J.R. (eds.) (2005): '*Handbook of Environmental Economics (Volumes 1-3)',* Amsterdam: Elsevier.
29. *MARPOL 73/78 Annex*, accessible at IMO's website: http://www.imo.org.
30. Morgan, R.K. (1998): '*Environmental Impact Assessment: a Methodological Perspective',* The Netherlands: Kluwer Academic.
31. Organization for Economic Co-operation and Development (OECD) (2006): '*Cost-Benefit Analysis and the Environment – Recent Developments',* Paris: OECD.
32. Pearce, D. (1995): '*Blueprint 4: Capturing Global Environment Value'*, London: Earthscan.
33. Peris-Mora, E., Orejas, J.M., Subirats, A., Ibanez, S, and Alvarez, P. (2005): '*Development of a System of Indicators for Sustainable Port Management*', Marine Pollution Bulletin, vol. 50, pp. 1649-1660.
34. Perman, R., Ma, Y., McGilvray, J., and Common, M. (1999): '*Natural Resource and Environmental Economics',* US: Pearson Education.
35. PoR (2006): '*Waste Disposal Guide (2006)'*, Rotterdam: PoR.
36. Rawson, C., Crake, K. and Brown, A. (1998): '*Assessing the Environmental Performance of Tankers in Accidental Grounding and Collisions*', SNAME Transactions 106: 41-58.
37. Riha, S., Levitan, L., and Hutson, J. (1996): '*Environmental Impact Assessment: the Quest for a Holistic Picture*', General Session on the Economic, Environmental, Public Health and Social Impacts of IPM (February 27-March 1, 1996: Washington DC, US). USDA, Economic Research Service, Natural Resources and Environment Division. Washington DC, US: Miscellaneous Publication Number 1542.
38. Sirkar, J., Ameer, P., Brown, A., Goss, P., Michel, K., Nicastro, F., and Willis, W. (1997): '*A Framework for Assessing the Environmental Performance of Tanker in Accidental Groundings and Collisions',* (publisher unknown).
39. Vanclay, F. (2006): 'Principles for Social Impact Assessment: a Critical Comparison between the International and US Documents', *Environmental Impact Assessment Review*, vol. 26, pp. 3-14.