# 海上輸送の経済性とエコロジー

# Economics and Ecology of Marine Transportation


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| 長谷川　和彦 | 大阪大学大学院工学研究科 |
| 石田　　憲治 | 神戸商船大学 |
| 浜　　四郎 | 鳥瞰師 |
| 濱本　　秀樹 | 大阪大学工学部 |
| Kho Shahriar Iqbal | 大阪大学工学部 |

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| Kazuhiko Hasegawa | Graduate School of Engineering, Osaka University |
| Kenji Ishida | Kobe University of Mercantile Marine |
| Shiro Hama | Aerial Photographer |
| Hideki Hamamoto | Faculty of Engineering, Osaka University |
| Kho Shahriar Iqbal | Faculty of Engineering, Osaka University |



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**ABSTRACT**

Prevention of climate change and economical development are contradictory, but important issues. Sustainable development is the word satisfying both requirements. However, it is not so easy to realize and evaluate. In this paper, marine transportation is discussed from the economical and ecological view-points compared with land transportation. For this purpose indices of life cycle assessment (LCA) are introduced to evaluate total sustainability or survivability and an idea of destruction index is described.


## 1. Introduction

Coral bleaching[1] is the phenomenon recently frequently reported in the world. Coral loses its colour and looks being bleached. It was believed that the existence of coral reef is a kind of evidence of clean ocean. However, this summer we have observed the phenomenon in Sakishima Islands, Okinawa, Japan, even if the ocean is so clean. It is said the monthly mean sea surface temperature (SST) excesses 1-2 deg. higher than the average value, the phenomenon will occur. It is also said the incomplete development of El Nino off Peru and Equador causes the distribution of so-called hotspot; area with higher SST. Bleaching, by the way, doesn't directly mean the death of coral, but under higher temperature environment it expels a microscopic organism (algae) called *zooxanthallae* (in Japanese **褐虫藻**) with which coral maintains symbiotic relationship. If it lasts long, coral will die and won't recover for decades of years. It will be spread out into various sea lives through symbiosis and food chain. The very last end of the chain is human beings. As Pecheux[2] pointed out, "mass reef bleaching is unique amongst the many alarming threats on earth ecosystems: it is the only one where the primary level of an ecosystem may collapse all over the world, and for reasons which are yet unclear, but certainly global." Who causes only 1-2 deg. elevation of SST?

Kyoto Protocol thus adopted at United Nations Climate Change Conference in Kyoto on 1-11 December, 1997 is a turning point for future economical and environmental policies

for both industrialized and developing countries. The protocol covers the reduction of three major greenhouse effect gasses; carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$) along with three lower-volume emissions of hydroflourocarbons (HFCs), perflourinated compounds (PFCs) and sulfur hexaflouride($SF_6$) that have high atmospheric lifetimes.

In the area of transportation, major causes of these emissions are by trucks and cars. Some efforts, of course, are taken to reduce air pollution and global warming in car industries and oil industries, but they are just within industries' or the nation's benefits. Global countermeasures including energy and/or modal shifts should be considered. Recently in some countries in Europe, modal shift is steadily promoted as the country's policy.

In this paper, marine transportation will be discussed under the above background, and the necessity of proposing a new index leading to destruction is stated.

## 2. Modal shift and moral in Europe

As shown in Table 1[3], the Netherlands is the unique country in Europe, where inland transportation is much than road transportation. In another resource, inland shipping shares 64.1%, while road does 30.9% and rail does 5% in tonnage base[4]. German is second largest country in term of inland transportation, although most other countries such as Italy, Spain and UK are almost relying on road transportation.

In Belgium, inland shipping is neither negligible, nor significant. The main difference between two neighbour countries is the elevation of the land level. Both countries have big rivers such as the Rhein and the Maas, as well as well-networked canals throughout the countries. The Netherlands is mostly flat country, while Belgium has moderate hills. Numerous locks and several ship-lifts are used for over 100 years, but they are at the same time bottlenecks for fast and mass transportation. To overcome this, the largest (in the world) slipway[5] and ship-lift[6] are constructed in Belgium. By these infrastructures, short-cut canal route from France to North Sea is available instead of longer trip following Maas river.

As shown in Figure 1, modal shift to inland transportation will involves economical merit to reduce fuel consumption, but also the reduction of the environmental factors.

However, to accelerate the modal shift we need to encourage the moral change towards ecological life. Brokx[7], the mayor of the city of Tilburg, the Netherlands and the chairman of the Dutch Habitat Forum, for example, quotes it as "think globally, act locally" or as the campaign of "cycle to work"[8] spread over 100 companies in the Dutch province of Zeeland. The latter movement is to encourage employees to commute in bicycle to their offices and the companies will pay certain amount of money per kilometer and they got for over four million kilometers a year, contributing to reduce the amount of $CO_2$. Besides, a third of the participating companies and organizations are contributing to a newly established Climate Fund by paying in a certain sum for each kilometer cycled. The fund is used in Bhutan, Benin and Costa Rica to help their environmental investments.

## 3. Life Cycle Assessment (LCA) and Life Cycle Impact Assessment (LCIA)

Evaluation of improving ecological aspects is still required for modal shift, as far as each company will pursuit profits or for the purpose of introducing environment tax. Life cycle assessment (LCA) standardized as ISO 14040 (Environmental management and life cycle assessment)[9] is now available for this purpose. ISO 14042 (Environmental impact assessment of products and services or rather called as Life cycle impact assessment)[10] is the tool to evaluate LCA. In LCIA, each factor to influence the environment is called impact. SEATAC-Europe[11] categorizes the impacts as in Table 2.

The weighting factors of individual impacts are defined such as 2.5 for greenhouse effect (0.1 rise every 10 years, 5% ecosystem degradation), 100 for ozone layer depletion (probability of 1 fatality per year per million inhabitants) etc. Total assessment can be done as shown in Figure 2.

In case of long-distance transportation, it will

**Table 2 Impacts defined by SEATAC-Europe [11)]**

*[A] Input related categories ("resource depletion or competition")*
- Abiotic resources (deposits, funds, flows)
- Biotic resources (funds)
- Land (Land-use)

*[B] Output related categories ("pollution")*
- Global warming
- Depletion of stratospheric ozone
- Human toxicological impacts
- Ecotoxicological impacts
- Photo-oxidant formation
- Acidification
- Eutrophication (including BOD and heat)
- Odour
- Noise
- Radiation
- Casualties

be necessary to consider the local effects. Nagata *et al.*[12)] proposed such method applicable to restricted local area.

Eco-indicator is normally used to evaluate the alternative environmental treatment such as replacing some material of the product, but in case of environmental modal shift it might be rather replaceable with destruction index which leads to the destruction of the eco-system such as coral bleaching. In this case, destruction index is SST and the critical value is 1 deg. Authors are now considering the destruction index applicable for transportation.

## 4. Conclusions

Environmental modal shift is discussed through ecological consideration. Conclusions can be drawn as follows:

1) Some examples of modal shift in Europe are reviewed.
2) Ecological consideration using LCIA is introduced.
3) Environmental modal shift using destruction index is proposed.

Future works to be done should be pointed out as follows.

4) Destruction index should be carefully investigated suitable for environmental modal shift.
5) Infrastructures necessary for inland and coastal shipping in Japan should be studied.

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Table 1 Freight Transport in Western Europe[3)] (Unit: billions of ton-kilometers)

| | Rail | | Road | | Inland Waterways | | Pipelines | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nation | 1970 | 1993 | 1970 | 1993 | 1970 | 1993 | 1970 | 1993 | 1970 | 1993 |
| Belgium | 7.9 | 7.6 | 13.1 | 35.0 | 6.7 | 5.1 | 0.3 | 1.3 | 28.0 | 48.9 |
| Danmark | 1.9 | 1.8 | 7.8 | 8.8 | – | – | ... | ... | 9.7 | 10.6 |
| Germany (West) | 70.5 | 63.8 | 78.0 | 210.0 | 48.8 | 53.0 | 15.1 | 14.3 | 212.4 | 341.1 |
| Finland | 6.3 | 9.3 | 12.4 | 24.1 | 4.4 | 3.4 | ... | ... | 23.1 | 36.7 |
| France | 67.6 | 45.9 | 66.3 | 115.3 | 12.7 | 6.0 | 28.2 | 23.9 | 174.8 | 191.0 |
| Greece | 0.7 | 0.5 | 7.0 | 9.8 | – | – | ... | ... | 7.7 | 10.3 |
| Ireland | 0.6 | 0.6 | ... | 5.5 | – | – | ... | ... | ... | 6.1 |
| Italy | 18.1 | 20.6 | 58.7 | 184.9 | 0.4 | 0.1 | 9.1 | 11.8 | 86.2 | 217.5 |
| Luxemburg | 0.8 | 0.7 | 0.1 | 0.6 | 0.3 | 0.3 | ... | ... | 1.2 | 1.6 |
| Netherlands | 3.7 | 2.7 | 12.4 | 26.0 | 30.7 | 33.0 | 4.1 | 5.5 | 50.9 | 67.2 |
| Norway | 1.5 | 1.8 | 3.2 | 7.8 | – | – | ... | 3.4 | 4.6 | 12.9 |
| Austria | 9.9 | 11.8 | 2.9 | 5.8 | 1.3 | 1.5 | 3.6 | 6.7 | 17.7 | 25.8 |
| Portugal | 0.8 | 1.8 | ... | 11.0 | – | – | ... | ... | ... | 12.8 |
| Sweden | 17.3 | 18.7 | 17.8 | 25.9 | – | – | ... | ... | 35.1 | 44.6 |
| Switzerland | 6.6 | 7.3 | 4.9 | 10.2 | 0.1 | 0.2 | 1.2 | 1.2 | 12.8 | 19.0 |
| Spain | 10.3 | 8.0 | 51.7 | 162.4 | – | – | 1.0 | 5.6 | 63.1 | 176.0 |
| United Kingdom | 24.5 | 13.6 | 85.0 | 132.3 | 0.3 | 0.2 | 2.7 | 10.7 | 112.5 | 156.6 |
| **Western Europe** | **248.7** | **216.4** | **421.2** | **975.4** | **105.8** | **102.7** | **65.2** | **84.3** | **839.6** | **1378.7** |

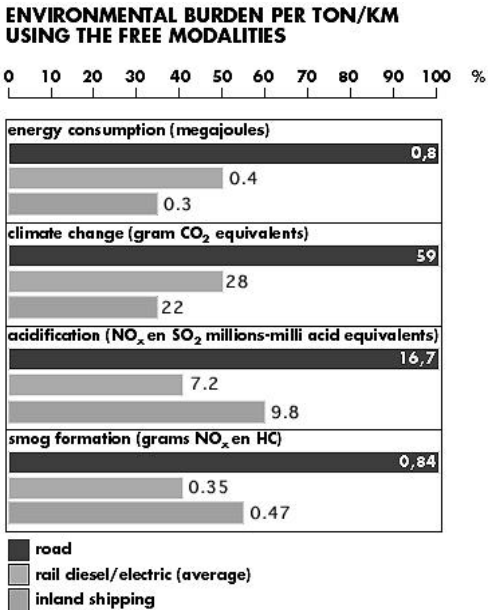


Figure 1 Comparison of Environmental Influences in Various Transportation

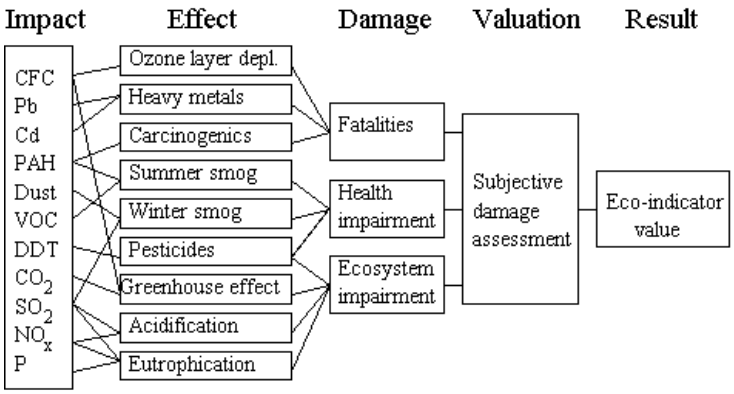


Figure 2 Eco-indicator Weighting Principle