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Impacts of climate change on maritime industries

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IMPACTS OF CLIMATE CHANGE ON MARITIME INDUSTRIES

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The content of this dissertation reflect my own personal views, and are not necessarily by the University.

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ABSTRACT

Impacts of climate change on maritime industry were studied based on the secondary sources. The study was done using a qualitative approach applying Causal Loop Diagram (CLD) of System Analysis. The study found that climate change will affect the maritime industries in a number of ways both negative and positive. Climate change driven sea level rise, increase in sea surface temperature and increasing frequency of extreme weather events will impact the growth of shipping industries. Emission control regulations will also add operational cost to the industry. On the other hand, climate change induced ice melting will seasonally turn the Arctic into a navigational sea and will create new shipping routes through the Arctic Sea. Ice melting will also create a positive condition for oil and gas production in the Arctic. Increased ship traffic and offshore oil drilling will lead pollution of the Arctic ecosystem. Climate change driven change in agricultural patterns will also change the ship movements. The industry should take necessary steps for adaptation to be better prepared to meet the new situation. In addition the maritime sector should forcefully adopt minimum emission practices in order to try to mitigate global warming.

KEYWORDS: **Climate Change, Maritime Industries, Impacts, Causal Loop Diagram (CLD), The Arctic.**

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LIST OF ABBREVIATIONS

ANWR : Arctic National Wildlife Refuge
BWE : Back Water Effect
CCS : Carbon Capture and Storage
CO_2 : Carbon Dioxide
CLD : Causal Loop Diagram
dwt : deadweight tonnage
EC : European Commission
EEA : European Environment Agency
EST : Earth's Surface Temperature
GHG : Greenhouse Gases
GHGE : Greenhouse Gases Emissions
gt : gross tonnage
GW : Global Warming
gw : Giga Watt
IMO : International Maritime Organization
MEPC : Marine Environment Protection Committee
MW : Mega Watt
NWP : Northweast Passage
ppm : Parts Per Million
PSSA : Particularly Sensitive Sea Area
SLR : Sea Level Rise
SST : Sea Surface Temperature
SD : System Dynamics
Secas : SO_x emission control areas
TEU : Twenty-feet Equivalent Unit
USA : United States of America
USD : United State Dollar
WWEA : World Wind Energy Association

1. Introduction

1.1 Introduction

Nations across the world are competing for development. One of the fundamental components of development is energy, mainly derived from fossil fuels. Growing use of fossil fuel is releasing carbon dioxide (CO_2) to the atmosphere. Miller (2004) states that, 75% of CO_2 emissions caused by humans since 1980 are due to the burning of fossil fuels with the remainder resulting from deforestation, agriculture, and other changes in the land use. Plants use CO_2 in the photosynthetic process. Human demands for food and land, to build houses, roads or agricultural spaces have also causing deforestation. Low forest cover is using less CO_2 from the atmosphere. So, CO_2 emitted as a result of human activities are accumulated in the atmosphere. One of the main functions of CO_2 is to absorb heat. The gas accumulated at the lower part of the atmosphere forms a CO_2 blanket that protects solar energy to reflect from the earth surface. The ultimate result is rising of the temperature of the earth surface which is known as global warming or climate change.

Rising temperature in the atmosphere causes sea level rise and affects low lying coastal areas and deltas of the world, which leads to flooding of the coastal infrastructure, like ports. Ports facilitate the shipping industry, which is one of the most ancient industries, has grown in demand for trade and transportation. Climate change, which can ultimately cause flooding of these ports, will dramatically affect shipping industries. Erosion and accretion caused by sea level rise and ice melting in the Polar Regions will change present shipping routes. Ice melting will also open up the possibility of oil exploration in the Polar Regions. When the Kyoto Protocol will be enforced, oil production and transportation pattern will also be changed. Change in shipping routes, change in export-import pattern and change in oil transportation will all potentially affect shipping industries.

Intergovernmental Panel on Climate Change (IPCC, 2001a) studied the climate change impacts on different sectors. To the best of the author's knowledge, there are no mentionable studies that evaluate the potential impacts of climate change specifically on the maritime industries The intention of this study is to analyze the impacts of climate change on maritime industries.

1.2 Objectives of the Study

As mentioned earlier, climate change is a very wide issue. Studies of these impacts are even broader. To evaluate the impacts of climate change on maritime industries, a group of objectives were set up:

- to identify the impacts of climate change on world's maritime industries
    - to identify the impacts of climate change on maritime routes;
    - to identify the change in oil production and oil transportation, due to climate change phenomena and its subsequent impacts on maritime transport;
    - to identify the change in agricultural production, due to climate change and its subsequent impacts on maritime transport;
    - to identify the role of sea level rise (as a climate change issue) on erosion/ accretion along the coastal zone and its impacts on maritime industries;
- to identify the remedial measures of the potential threats of climate change to the maritime industries;

And finally-

- to find out the research needs of the issue.

1.3 Methodology

The study was done on the basis of available secondary resources that include books, regional reports, international reports, scientific journals, news articles and Internet sources highlighting climate change related maritime issues. The study will try to look for qualitative impacts of climate change on maritime industries and also will try to find out some solutions that would help maritime sectors to adapt to the problems. System Analysis was used to see the broader link of climate change and maritime industries. Causal Loop Diagram (CLD) was drawn to express the 'big picture' of climate change and maritime industries relationship link (for more about CLD, please see Haraldsson, 2004).

1.4 Scope and Limitations

In the study, attention was put on assessing the impacts of climate change on maritime industries only. It did not take part in any climate change debate. The study did not do any cost analysis that is involved in adaptation and mitigation process. As a Causal Loop Diagram methodology was used to see the climate change impacts on the industry, it was done only by the qualitative approach. No quantitative study was taken. Time allocation for the study was two months.

1.5 Structure of the Report

A brief background of the study is presented in chapter 2 of this report following this introduction. In that chapter, a background of climate change and its outcome in terms of sea level rise, maritime industries and system analysis (especially Causal Loop Diagram) are presented to the readers. Chapter 3 describes the potential impacts of climate change on maritime industries with the help of CLD. The next chapter (chapter 4) traces out the possible response of maritime industries to climate change. Finally, chapter 5 concludes the report with recommendations and research needs identification.

2. Background

Climate change is going to affect almost all sectors of human needs. Maritime business is one of the most ancient industries having importance in global economics and trade. Before looking at the climate change impacts on maritime industries, this chapter presents a brief overview of these two topics. As the study was done with the help of system analysis, this chapter will also show the behavioral pattern of CLD, a strong tool of system analysis.

2.1 Climate Change

Human activities have led to deposit greenhouse gases (GHG) in the atmosphere (Wigley et al., 1997). Most human activities imply an emission of GHG to the atmosphere. These gases protect the heat coming from the sun to the earth surface to go back. Heat trapped by GHGs causes an increase in the temperature in the earth surface. Global Earth's surface temperature has increased ~ 0.5˚C in the last century (Hansen & Sato, 2004; Hansen et al., 2000). This rise was observed during 1910-1945, and temperature decreased by ~ 0.2˚C during 1945 through 1975, and since then temperature increased by ~ 0.3˚C (Khandekar et al., 2005).

Temperature has increased by ~ 0.4˚C over past 30-35 years, the period that is treated as reliable data collection period. In the last century high temperature was observed before 1940 and after mid 70s. The Intergovernmental Panel on Climate Change (IPCC, 2001b; p.3) has shown the global earth's surface temperature (EST) for the last 140 years (1860-2000) in figure 1. The figure also shows the dramatic rise in temperature after mid 70s. Rise in the temperature will be continuing in the coming years.

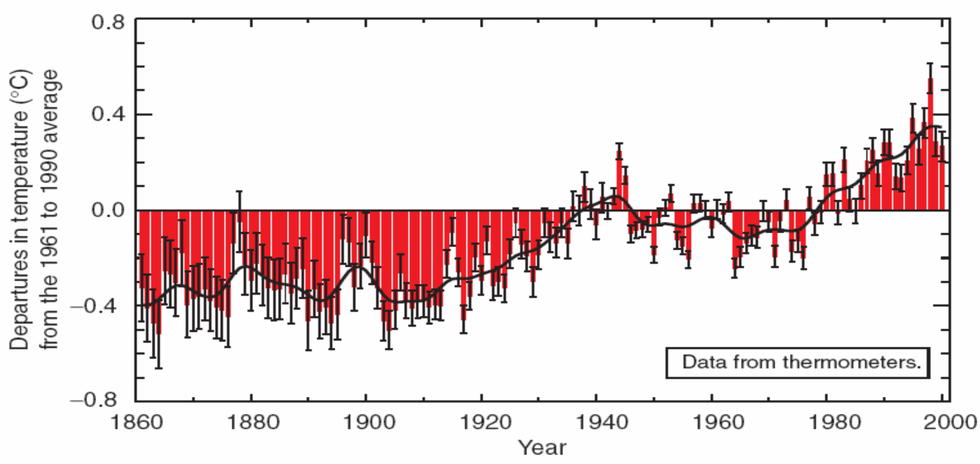


Figure1: Global earth's surface temperature (Source: IPCC, 2001c)

Mann (1999) also showed the similar pattern of temperature change (Figure 2). In the history of temperature rise, the year 1998 was the warmer year ever (Saunders, 1999). This is also visible in the figure 1 & 2. The figures show that temperature was risen by 0.6˚C in the year 1998 comparative to 1990.

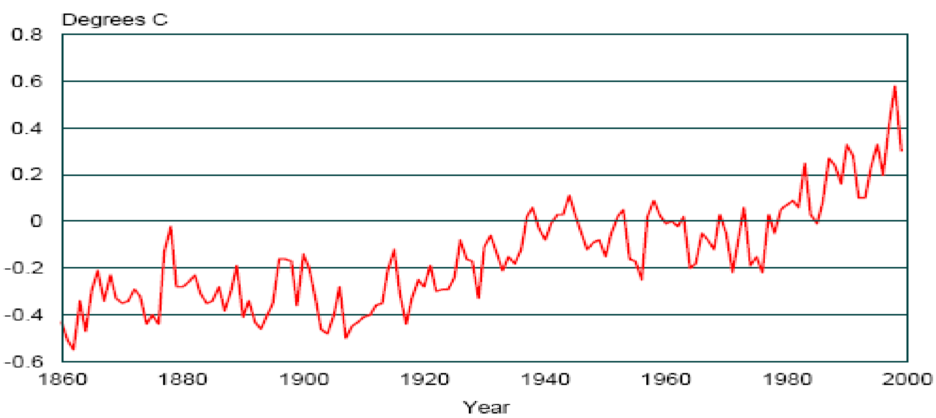


Figure 2: Global temperature change during 1860-1999 (Source: Mann et al., 1999)

Mann et al. (1998, 1999) concluded that the 20th century is likely to be the warmest century ever in the Northern Hemisphere and the 1900s were the warmest decades including 1998 as the warmest year in the last 1000 years.

This rise in temperature was observed on the terrestrial area. Sea surface temperature (SST) displays a somewhat similar pattern. Schiermeier (2003) concludes that global sea surface temperatures were increasing by about 0.5–1.0˚C every million years at the time of ancient warming, known as the palaeocene/ eocene thermal maximum (PETM). Sea surface temperature rise, observed by IPCC over 1950 and 1993 was about half of mean land surface air temperature (IPCC, 2001b)

Temperature rise is expected to be continued in coming years at an even higher rate. Schiermeier (2006) estimates that global temperatures are likely to rise by 2.5–4.0˚C by 2100. However, IPCC (2001b) estimated a surface temperature increase by 1.4 to 5.8˚C over the period of 1990 to 2100 (Figure 3)

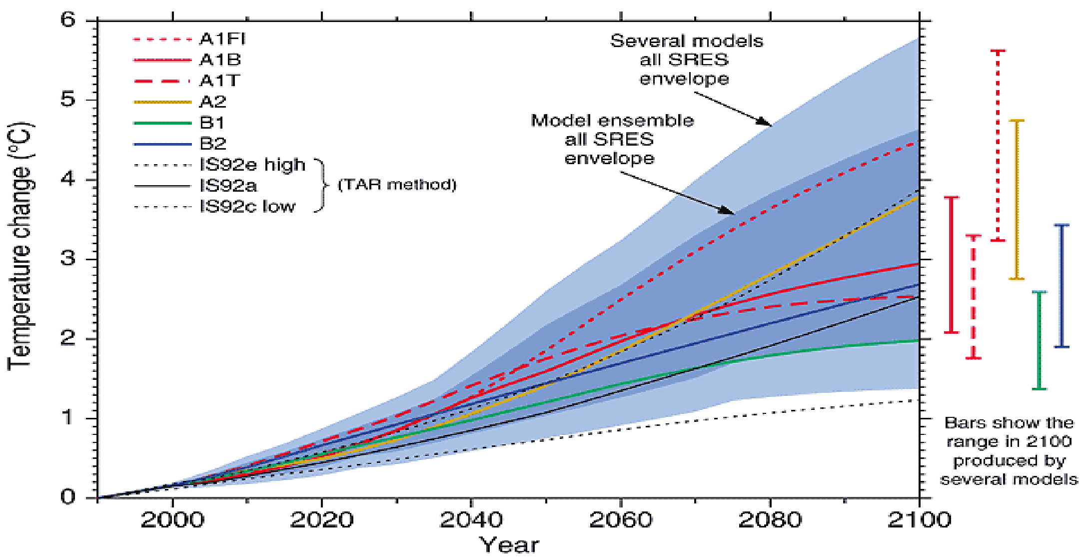


Figure 3: Temperature rise by 2100 comparative to 1990 (Source IPCC, 2001b)

There are numerous studies that show the rise in temperature of the earth surface, is because of global warming. Environment Canada (2001) also shows a global temperature rise of ~5.0˚C by 2100 comparative to the base year of 1990 (Figure 4).

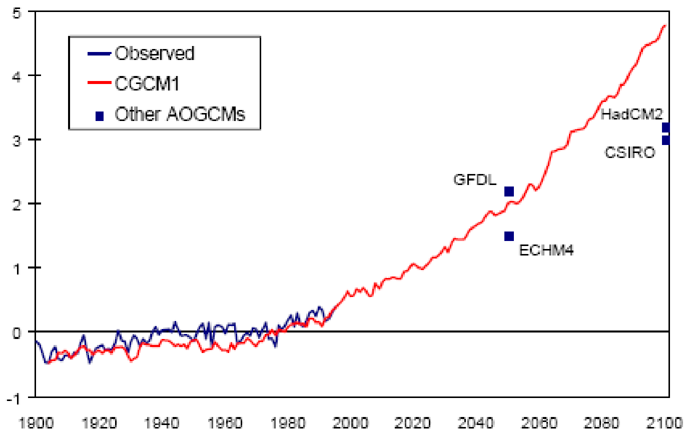


Figure 4: Observed and Modelled Global Temperature Change (Source: Environment Canada, 2001)

Scientists expect that the average global surface temperature could rise 0.6-2.5°C in the next fifty years and 1.4-5.8°C in the next century, with significant regional variation (EPA, 2006).

2.1.1 Sea Level Rise

A rise in temperature will contribute to global sea level rise (SLR). Climate change contributes to sea level rise mainly in two ways: thermal expansion of water and melting of glacial and mountain ice. Firstly, penetration of heat into the ocean's water causes thermal expansion of the ocean or sea that cause rise in sea level. Secondly, large volumes of ice in the polar region are melting due to rise in temperature, which is also another cause of sea level rise. Besides climate change, there are a few other factors that could contribute to local sea level change. The factors include land accretion, regional uplifting, soil compaction, wind and pressure patterns, ocean circulation and water density. However, climate induced causes, such as ice melting and thermal expansion of water, are the main cause of global sea level rise.

A study by Wigley and Raper (1987) estimated that the greenhouse gas induced thermal expansion, caused a sea level rise of 2-5 cm during 1880 and 1985. They again estimated a greenhouse gas induced global warming of 0.6-1.0°C for the period of 1985-2025 and the resulting concomitant oceanic thermal expansion would raise sea level by 4-8 cm. IPCC estimated that sea level rise would be 66 cm under business-as-usual conditions by 2100 with a range of uncertainty of 13 to 110 cm (Table 1).

Table 1: World's Global Warming (GW) and SLR Scenario

Model Assumption	**GW Scenario by year (^{0}C)**				**SLR Scenario by year (cm)**			
	2010	***2030***	***2050***	***2100***	***2010***	***2030***	***2050***	***2100***
Low	0.3	0.7	1.2	2.2	4	8	15	31
Business-as-usual	0.5	1.1	1.7	3.3	8	18	30	66
High	0.7	1.5	2.5	4.9	13	29	48	110
Source	Bretherton et al., 1990 (Cited in Warrick et al., 1993)				Warrick and Oerlemans, 1990 (Cited in Warrick et al., 1993)			

(Source: Sarwar, 2005)

Sea level rose by ~160 mm through the 20th century (Church et al., 2006). Another study by Church et al. (2004, 2005) found a sea level rise of 1.8±0.3 mm per year over 51 year period (1950-2000). Church & White (2006) estimates sea level rise from January 1870 to December 2004 of 195 mm, a 20th century rate of sea level rise of 1.7±0.3 mm per year and a significant acceleration of sea level rise of 0.013±0.006 mm per year. With constant rate of acceleration, sea level rise from 1990 to 2100 would range from 280 to 340 mm. Tide gauge data show that global average sea level rose between 0.1 and 0.2 metres during the 20th century (IPCC, 2001b). Gornitz (1995) concluded that future sea level is expected to rise by similar to one metre.

2.2 Maritime Industries

Seventy percent of the earth's surface is made up of the oceans and seas. This large area of earth's surface is used by humans, mainly for fishing and transportation. Maritime industries are a group of business sectors that are involved in maritime transport. The sector could include industries such as: shippers, brokers, ship builders, port authority, banks, insurance authority, maritime court, ship breaking companies, and survey and classification companies. However, shipping transport and infrastructures that are facilitating shipping transport (e.g. port) are defined as maritime industries in this report.

Shipping is the transfer of goods produced in one country, which are then taken to another country where those goods are in demand. Sea transportation is responsible for the movement of 90% of world's trade (Ma, 2005; p.11) in terms of volume. Trade and commerce reinforce the economy of a country. By carrying the lion share of the international trade, sea transport is playing the most important role for the growth of the world's economy.

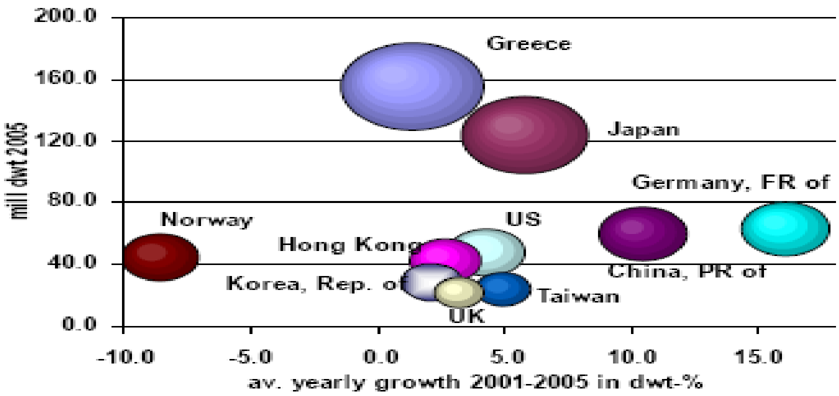


Figure 5: Controlled fleet of major shipping nations in 2005 and their yearly tonnage growth in 2001-2005 (Source: ISL, 2005)

Total numbers of world's merchant ships that are 300gt or more are 39,932 and carried 880 million dwt and 9.4 million TEU (ISL, 2005). Compared with 2004, growth rate was 3.3%, for total dwt tonnage. Growth rate of world's top ten shipping nations are showed in figure 5 that indicate the growths of China and Germany are 10 and 15% respectively. However, average growth rate of maritime industry is 3% with a possible decrease of much as 10-20 percent (Ma, 2005; p.17).

Maritime industries contribute significantly to the economy of some counties. For example, this sector contributes 7% of Singapore's GDP and provides 120,000 jobs (Hua, 2004). Dependency on maritime transport varies from country to country. Some countries depend on maritime transport largely for their growth and development. Ma (2005) calculated Maritime Dependence factor (MDF[1]) for 30 selected countries and found that Malaysia's MDF is 74%. MDF of Norway, Saudi Arabia, Australia and Japan are 54, 43, 25 and 20% respectively.

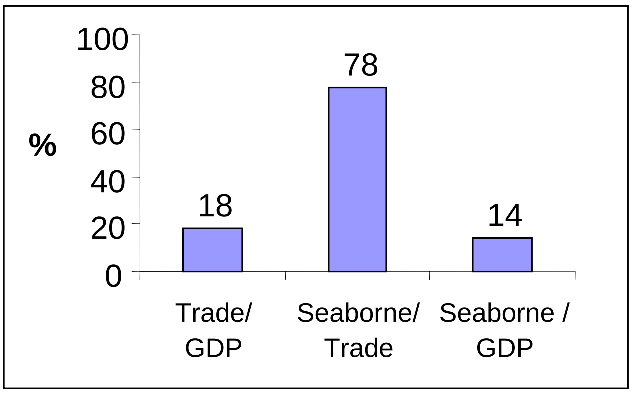


Figure 6: Global trade and seaborne trade dependence of 30 major trading nations (Adapted from Ma, 2005)

Transport is very important factor for the growth and development of a nation. Seaborne transport is the most relevance transport media that serves the significant part of transportation. Figure 5 shows that percentage of global seaborne trade over global trade is 78 and that over World's GDP is 14. For growth and development, dependency on trade is increasing day by day.

[1] MDF = Seaborne Trade in Value/ GDP * 100%

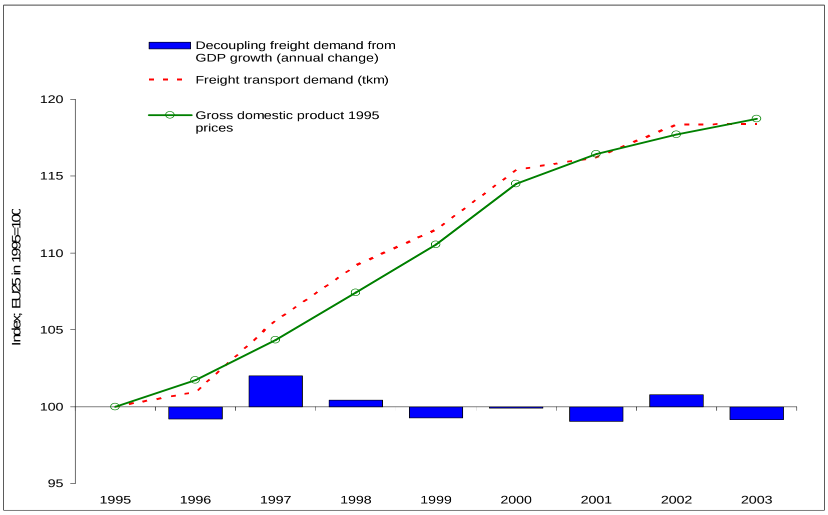


Figure 7: Freight transport demand of Europe (source: EEA, 2006)

The world's industrial production is increasing with growth of populations. Increased production demands more transportation, which is done largely by maritime sector. In figure 7, GDP and freight transport demand in Europe are increasing proportionally.

2.2.1 Emission by Maritime Industries

As the shipping industry is using fossil fuels for energy, and even if those from road and air transport overshadow its emissions, it is still releasing a significant volume of GHG to the atmosphere. GHG emitted from ship is mainly CO_2. Global emissions from ships are showing an increasing trend. Figure 8 shows that GHG emissions by international transport sector of 25 member states of the European Union have grown 86.1% between 1990 and 2004, having a growth rate of 4.5% per annum. The emissions from international maritime transport in the same region have increased 44.6% since 1990 (2.7% per annum), with an increase of 5.6% between 2003 and 2004 (T&E, 2006).

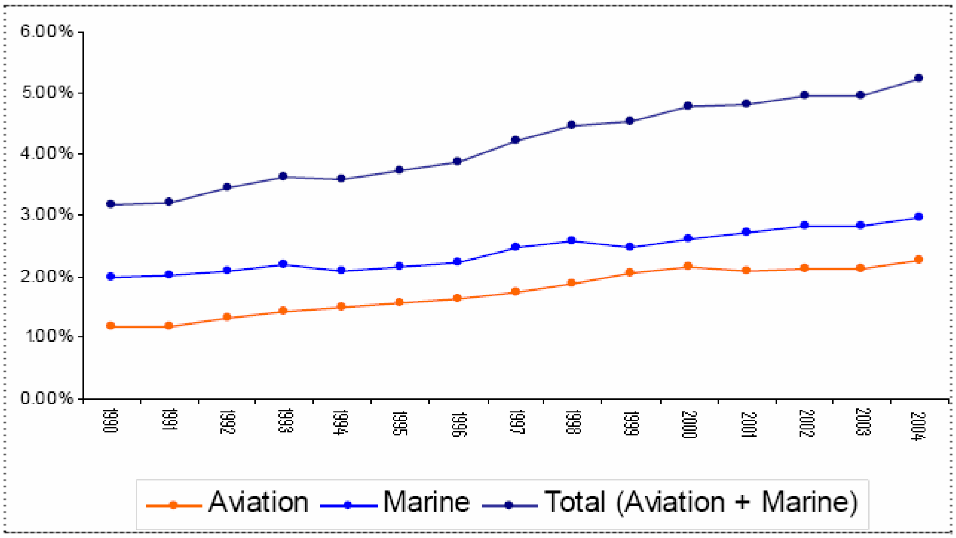


Figure 8: Contribution of international transportation to EU 25 GHG emission (adapted from T&E, 2006).

However, carbon dioxide emitted by shipping sector is very minor when compared to other modes of transportation. A report by Adidas (2006) suggests that sea freight transportation contributes only 17.5 grams carbon dioxide per kilometer each ton travels (grams CO_2/km t). The figures for road and airfreight transportation are 147 and 903 grams CO_2/km t, which are 8.4 and 51.6 times higher than the same value for sea transportation (Figure 9).

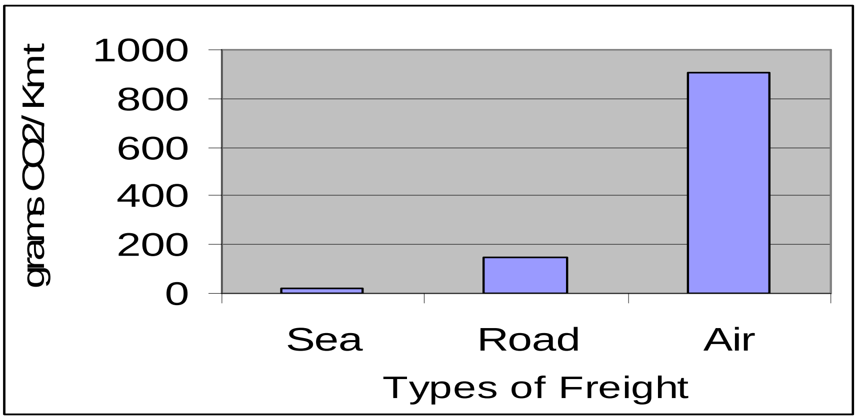


Figure 9: Proportional CO2 emissions by different modes of transport (Data source: Adidas, 2006).

Carbon dioxide emissions from ships are minor in comparison with the emissions of other gasses from ship. Emissions from ship are mainly crucial in case of gasses of Nitrogen and Sulphur. But the mentioned pair of gasses is not GHG. The only GHG emitted by shipping sector is carbon dioxide, which is only 2 % (table 2).

Table 2: Annual emission from ship

Gas emitted from the burning of fossil fuel	% of total emission
NO_x	14
SO_x	16
CO_2	2

(Data source: Corbett & Fischbeck, 1997)

Whatever the amount is, shipping sector is emitting CO_2 which is contributing to global warming. With the increased demand of sea transportation, the volume of CO_2 emission from ships will also be increased.

2.3 System Dynamics and Causal Loop Diagram

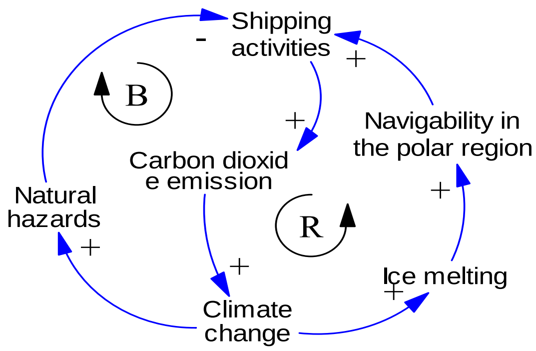
This paper identifies the impacts of climate change on maritime industries using system analysis or system dynamics (SD), which was developed by Professor J.W. Forrester in the 1950s at the Massachusetts Institute of Technology (Lin et al., 2006; Gong et al., 2004). SD is a methodology for exploring, interpreting and managing complex feedback system (Wallman, 2004). It helps to see the 'big picture' of a complex system. One of the most important parts of SD is causal loop diagram (CLD) or mental model (for more about CLD please see Kim 2006; Lin et al, 2006; Shouping et al., 2005; Tesfamariam & Lindberg, 2005; Cavana & Mares 2004; Haraldsson, 2004; Wallman, 2004 and Haraldsson & Olafsdottir, 2003).

In formulating a CLD, factors involved in the system are identified first and then cause-impacts of the factors are arranged in the mental model logically. In drawing a

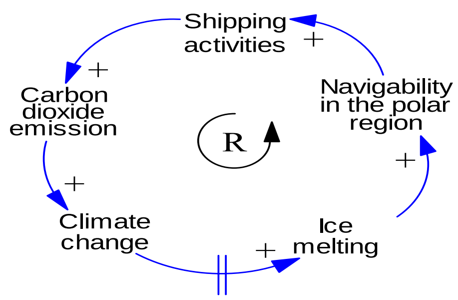
CLD, arrow heads (→), plus signs (+) and minus signs (–) are used to express the relationship of the factors. Plus signs indicate that factors of head and tail of the arrow head goes to the same direction. If the factor of the tail increases, then the factor of the head also increases. Again, when, the factor of the tail decreases, then the factor of the head also decreases. A minus sign indicates that the factors of head and tail of the arrow head goes to opposite direction. In other words, if the factor of the tail increases, then the factor of the head also decreases, or vice-versa[2].

A complete cycle of factors makes a loop. Balancing (B) and reinforcing (R) are two types of loops in a CLD, which are categorized by observing plus or minus sign or number of minus sign in a loop. If there is odd number of minus sign in a loop, then it is a balancing loop (B). If all the signs in a loop are plus, or, if the number of minus signs in a loop is even number, then it is a reinforcing loop (R).

Figure 10a is a simplified CLD that shows relationship between climate change and shipping activities with existence of both balancing and reinforcing loop. Figure10b shows a reinforcing loop and figure 10c shows a balancing loop. In a reinforcing loop all the factors in the loop reinforce each other and increase over time. In a balancing loop, the factors of the loop balance each other. To show long term effect of



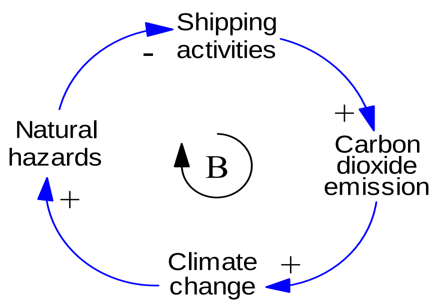
a. Combined loop



2 Some authors use ‘S’ (to indicate same direction) or ‘O’ (to indicate opposite direction) to formulate a CLD.

one factor, a delay mark is put using a pair of line (‖), which is shown in figure 10b.

b. Reinforcing loop



c. Balancing loop

Figure 10: CLD showing relationship of climate change and shipping activities.

3. Impacts of Climate Change on Maritime Industries

3.1 Cause Impact Relationships of Climate Change and Maritime Industries

As mentioned earlier, we will see the impacts of climate change on maritime industries, with the help of CLD. Initially, small loops of cause-impacts relationships will be discussed and finally all the loops will be combined to have the overall understanding of the system.

3.1.1 Balancing Loop

As outlined in previous chapters, most evidences indicate that climate change will cause sea level rise in many of the major coastal zones of the world. Rising sea level will cause over flow of seawater through the coastal region, which may wash out the topsoil of the area. Kont et al. (1997) concluded that the most vulnerable shore types to sea level rise are shoaly, sandy and silty shore, being prone to erosion. Vellinga (1988; cited in SDNP, 2004) reported that sea level rise of 1.0 metre will cause an erosion of a sandy shore in the order of 100-500m. Another cause of coastal soil erosion is back water effect (BWE), which is also positively influenced by sea level rise. Sea level rise will increase morphological activities in the coastal rivers, which will increase tidal flow in the coastal zone. Accelerated river flow will increase riverbank erosion (Alam 2003, p.13), mainly in the coastal area. Sea level rise will also accelerate salinity intrusion in the coastal area that will cause destruction of mangrove forest of the areas. Decreased mangrove will increase soil erosion, because mangroves act as soil stabilizer in the coastal area (Hossain, 2001).

Erosion in the coastal zone will increase siltation. Because soil particles washed out by sea level rise are carried out by currents from one area to another and deposited there. A continuous deposition of silt to one place will form accretion of new land in the area, which will decrease water depth. Decreased water depth causes hindrance to normal movement of ships, and gives restrictions in terms of ship sizes. Shallow water in the coastal area affects the normal activities of a sea port that minimize port performance. Erosion also may hinder port performance by removing port infrastructures. Decreased port performance also decreases the shipping activities.

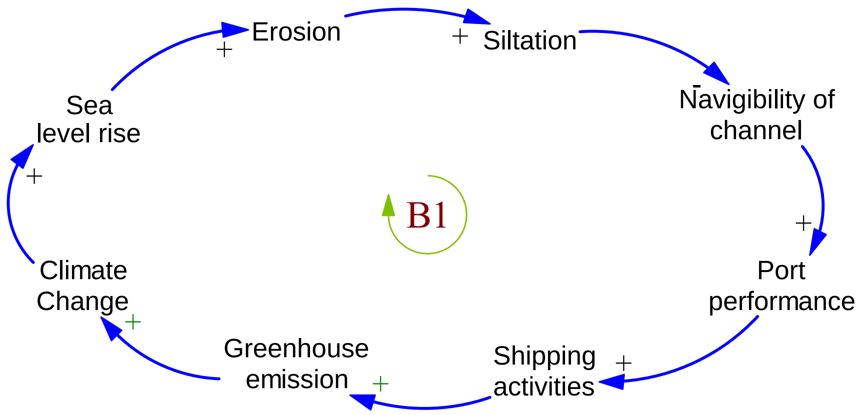


Figure 11: CLD showing the relationships among shipping activities, climate change, sea level rise and other factors (balancing loop B1)

In 1996, about 1.8% of world total carbon dioxide was emitted by shipping sector (IMO, 2000). Though the figure is not big in percentage, it is still significant in terms of volume, and shows that shipping activities contribute to climate change by emitting greenhouse gases. Thus, 'climate change – sea level rise – erosion – siltation – navigability of channels – port performance – shipping activities – greenhouse gas emission' chain makes a balancing loop B1 that is shown in figure 11.

Climate change will also cause a rise in sea surface temperature (SST). IPCC (1990, cited in Khan et al., 2004) estimated that SST will rise about 0.2 to 2.5°C by the middle of this century. Increased SST will increase cyclone frequency and its damage intensity. Sea level rise is also likely to increase the frequency of extreme weather events such as cyclones, which may imply significant damage, as illustrated during the past few years. A World Bank (2000) forecast suggests that 25 cm rise in sea level will increase 10% cyclone intensity in Bangladesh. The scenario is similar at a global scale too. With the increase in cyclone intensity, its degree of damage by cyclone will also be increased.

Flooding is also affected by climate change induced sea level rise. Again, in the case of Bangladesh, Miller (2004) and Bennett et al. (1991) concluded that rise in sea level would flood agricultural lowlands and deltas in parts of the country. Hence, sea level rise induced floods and cyclones are natural hazards that will decrease maritime security. The common issues of maritime security discuss mainly operational security of ships and physical security of seafarers, especially from pirates or terrorist attack (Bermen, 2006; Wade, 2005; Richardson, 2006). But security is a broad issue that ensures safety of an entire sector. According to Barnett (2003), security in a general sense is the condition of being protected from or not exposed to danger. Consequently, natural hazards, by imposing danger to maritime industries, cause a security threat to the sector.

Decreased maritime security will reduce shipping activities. The widely discussed devastating catastrophe, the tsunami of the 26th December 2004 destroyed 28 lighthouses out of 30 in the Andaman and Nicobar islands. It is estimated that an amount of US$ 65,446,716. (3.04 billion Indian Rupees) will be required to restore the damage to the shipping sector in the Islands (WHO, 2005).

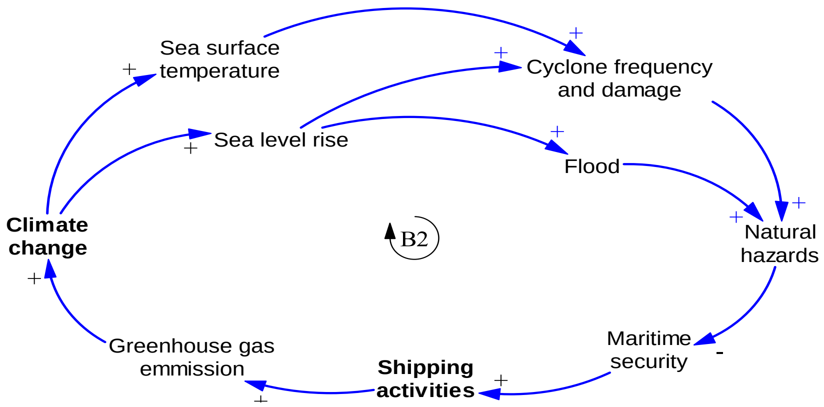


Figure 12: CLD showing relationships among climate change, natural hazards and shipping activities (balancing loop B2).

Thus, natural disasters could be an important reason for the loss of maritime security, leading to loss of lives and assets. Again, shipping sector emit greenhouse gasses that contribute to climate change. Thus, 'climate change – sea surface temperature – cyclone frequency and damage – (sea level rise - flood) – natural hazards – maritime security – shipping activities – greenhouse gas emissions' make a balancing loop (B2), figure 12.

If climate change driven natural hazards are considered, whatever the form is, a loop of a different bias is revealed. In this scenario, costs within the shipping sectors have gone up in terms of insurance premiums, as an effect of the implications of natural hazards.

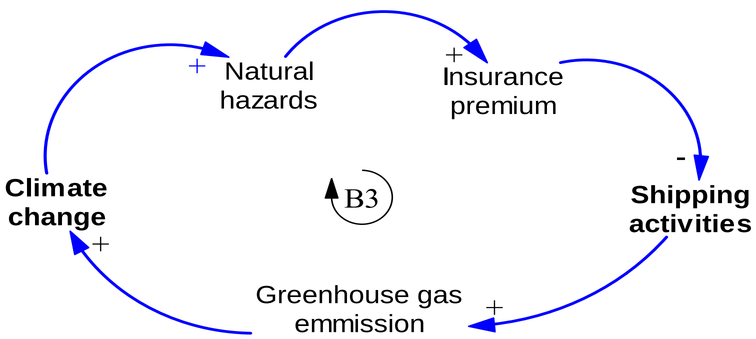


Figure 13: CLD showing the relationships of climate change, natural hazards, insurance, and shipping activities (balancing loop B3)

Since 1990, worldwide losses by natural hazards were over $40 billion each year with few exceptions losses were as high as $167 billion in 1995 alone (Freeman & Kunreuther, 2006). Most of the natural hazards, including storm surge, hurricane, typhoon, and tsunami are initiated from the sea. The shipping sector is likely to be more exposed to these hazards than other industries. Increasing losses in the shipping sector by natural hazards is responsible to raise insurance premiums in shipping business. To pay more insurance premiums for the compensation of losses by natural disasters, shipping industry needs to spare its money from different sub-sectors for insurance, which leads to decreased shipping activities. As mentioned earlier, shipping industries are responsible for greenhouse gas emission that leads to climate change. Thus, 'climate change –natural hazards – insurance premium – shipping activities – greenhouse gas emissions' make another balancing loop (B3), which is shown in figure 13.

Shipping industry, as a single business sector, contributes to greenhouse gas emission (GHGE). Increased GHGE has drawn attention of international communities in mid 80s. In response to this issue, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988 (UNFCCC, 2002; p.9) to assess scientific, technical and socio- economic information relevant for the understanding of climate change. In 1992, United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature and entered into force on 21 March 1994 (UNFCCC, 2002; p.9) to respond to emissions.

In 1997, International Maritime Organization (IMO) adopted a resolution on CO_2 emissions from ships. This resolution invites the Marine Environment Protection Committee (MEPC) to consider what CO_2 reduction strategies would be feasible for ships. IMO Assembly further adopted resolution A.963(23) on IMO policies and practices related to the reduction of greenhouse gas emissions from ships, which requests the MEPC to develop a greenhouse gas emission index for ships, and guidelines for application of that index (IMO, 2005a).

The IMO guideline is voluntary. But it could become compulsory with increasing growth of GHGE. Emissions control regulation by IMO, other international or national organizations will force the shipping sector to take initiatives for the control of GHG and it will certainly increase the operational cost of the industry. Excess investment for the control of GHG will decrease shipping activities.

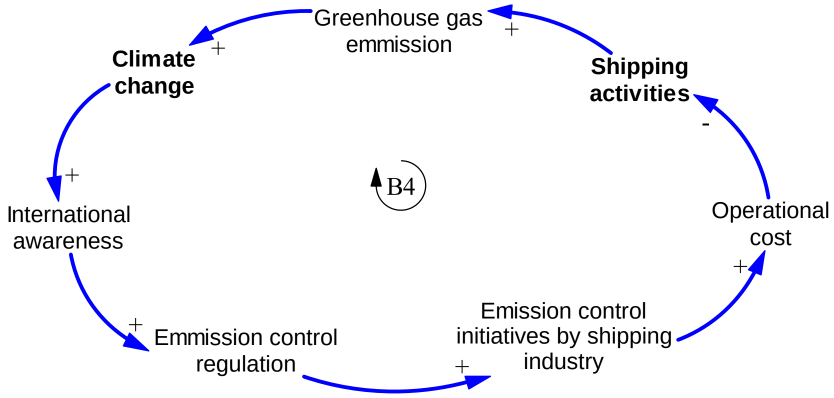


Figure 14: CLD showing relationships among climate change, shipping activities and its emission (balancing loop B4)

Thus, 'Climate change – International awareness – Emission control regulation – emission control initiatives by shipping industry – ship operational cost – shipping activities – Greenhouse gas emission' chain form another balancing loop B4 (figure 14).

All the loops, discussed above in this chapter are balancing loops. The balancing loops indicated that climate change somehow pulled back the maritime industries on its growth. Let us now find out the reinforcing loops to see, how the industry is going to be benefited by climate change.

3.1.2 Reinforcing Loop

Climate change, by warming the globe will cause ice melting of polar ice cap and glacial mountain. The temperature of the Arctic is increasing at a double rate of the global temperature rise (CBC, 2006; IISD, 2004) and 95 per cent of the Alpine glacier mass could disappear by 2100 (IPCC, 1997). Melting polar ice will create new route for shipping. If the present warming trend continues, sea ice in the Canadian Arctic will no longer exist in the summer months, by 2050 and upwards (CBC News, 2006; Wilson et al., 2004). Number of summer days in the Arctic is decreasing slowly.

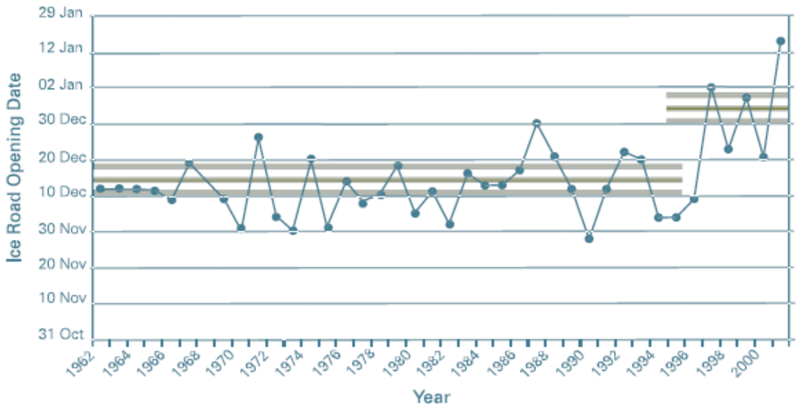


Figure 15: Average opening date of Mackenzie River ice road for light traffic (Source: DoT, 2002)

A study by the Department of Transport (DoT, 2002) of Canadian Northwest Territories found that the average opening date of Mackenzie River ice road for light traffic has shifted from 12 December to 4 January since 2004 (Figure 15). About 70,000 sq. km. of ice of Canadian Arctic is shrinking every year and this part of the Arctic has shrunk by 30-40% since the mid of the last century (IISD, 2004; CBC News, 2006). Shrinking of ice is opening the possibility of shipping route through the Norwest Passage (NWP).

The NWP of the Canadian part of the Arctic connects the North Atlantic and the North Pacific. The distance of shipping route between Europe (London) and Asia (Tokyo) through Panama canal is 23,000 km. Using the passage, the same distance is 16,000 km, which is 7,000 km shorter than the previous option (CBC News, 2006). Wilson et al. (2004) mentioned that NWP shortens Europe and Asia by 9,000km compare to Panama Canal route and 17,000km compare to Cape Horne route. So, navigation through NWP would open a potential route for connecting Asia and Europe in a shorter way that will save fuel, manning and other resources.

By 2070-2090, there is a strong possibility that the Arctic Ocean will be ice free in the summer that will allow the shipping of goods through the Canadian Arctic archipelago (IISD, 2004). NWP will facilitate the business of the Northern countries as well as other countries of the globe. Japan has special interest on this route, as it will save time, and subsequently fuel and crew cost to transport oil from Mexico and Venezuela to Japan.

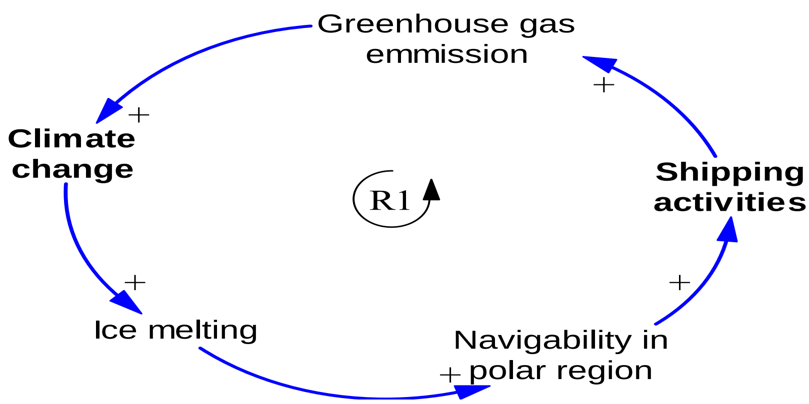


Figure 16: CLD showing relationships among shipping activities, climate change, ice melting and navigation (reinforcing loop R1)

Climate change induced ice melting is opening the navigation possibility through the polar region. Navigation through Arctic will increase shipping activities, which is responsible for a part of GHG emission. This is illustrated in Figure 16. Here, 'Climate change – Ice melting – Navigability in the polar region – Shipping activities

– Greenhouse gas emission' forms a reinforcing loop that indicates that each factor of the loop is pushed up by the previous factor and the cyclic increase will go on. In this case, climate change has a positive contribution to shipping activities.

Some prognoses indicate that oil demand will be increased by 60% by 2030 (Madslien, 2005), an increase that will need to be met by the oil production industry. Ice melting in the arctic will open the potentiality for the exploration of oil, which will be able to help to meet this demand. Northern sea route is expected to increase to about 120 days from the current 20-30 days (Doggett, 2004). Increased temperature is going to convert the ice covered polar region into a seasonal sea that will create favorable condition for oil exploration.

A 1998 US Geological Survey assessment (cited in AP, 2005) confirmed that 5.6 billion barrels of recoverable oils are deposited at the Alaska's Arctic National Wildlife Refuge (ANWR). The same report concluded that the reserve could be as high as 16 billion barrels. Another report by U S Energy Information Administration concluded that potential ANWR recoverable oil would have a value equivalent to USD 125-350 billion.

The oil reserve scenario in the Arctic region is similar for other countries of the Arctic including Canada, Greenland, Norway and Russia. *Snow White*, a liquidified natural gas processing plant at Hammerfest, Norway, the northernmost town in the world, is estimated to earn USD 63.8 billion (400 billion Norwegian Kroners) in 30 years. The Shtokman field in Russia, 320 Km from the North Pole and the largest offshore gas reservoir in the world is believed to have a reserve of ten times than that of the Snow White (Macintyre, 2006). The huge stock of natural oil and gas reserves in the Arctic are left almost untouched because of adverse environmental conditions, preventing economically viable production.

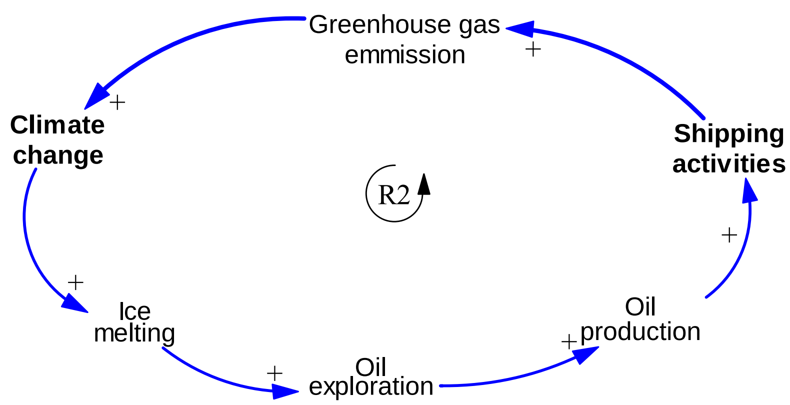


Figure 17: CLD showing the relationships among climate change, shipping activities and oil exploration (reinforcing loop R2)

Adverse weather condition in the Arctic is the main obstacle to explore oil and gasses of the region. A warmer, less iced condition would offer to break that obstacle. In figure 17, we can see that climate change is acting positively on ice melting. Ice free seasonal sea will create favorable condition for oil exploration. Effective oil explorations will increase oil production in the Arctic, which in turn will increase shipping activities. At the same time, shipping activities are contributing to climate change by GHG emission. Thus, 'Climate Change – Ice melting – Oil exploration – Oil production – Shipping activities – Greenhouse gas emission' form another reinforcing loop which indicates that climate change is acting positively on shipping activities.

If we assemble all the loops discussed previously in this chapter, we can have an overall picture of impacts of climate change on shipping activities. It is interesting to notice that one climate change phenomenon – ice melting is conducive to a growing maritime industry. All other climatic events like sea surface temperature rise, sea level rise and climate change policy or emission control regulations will have negative impacts on shipping activities (figure 18).

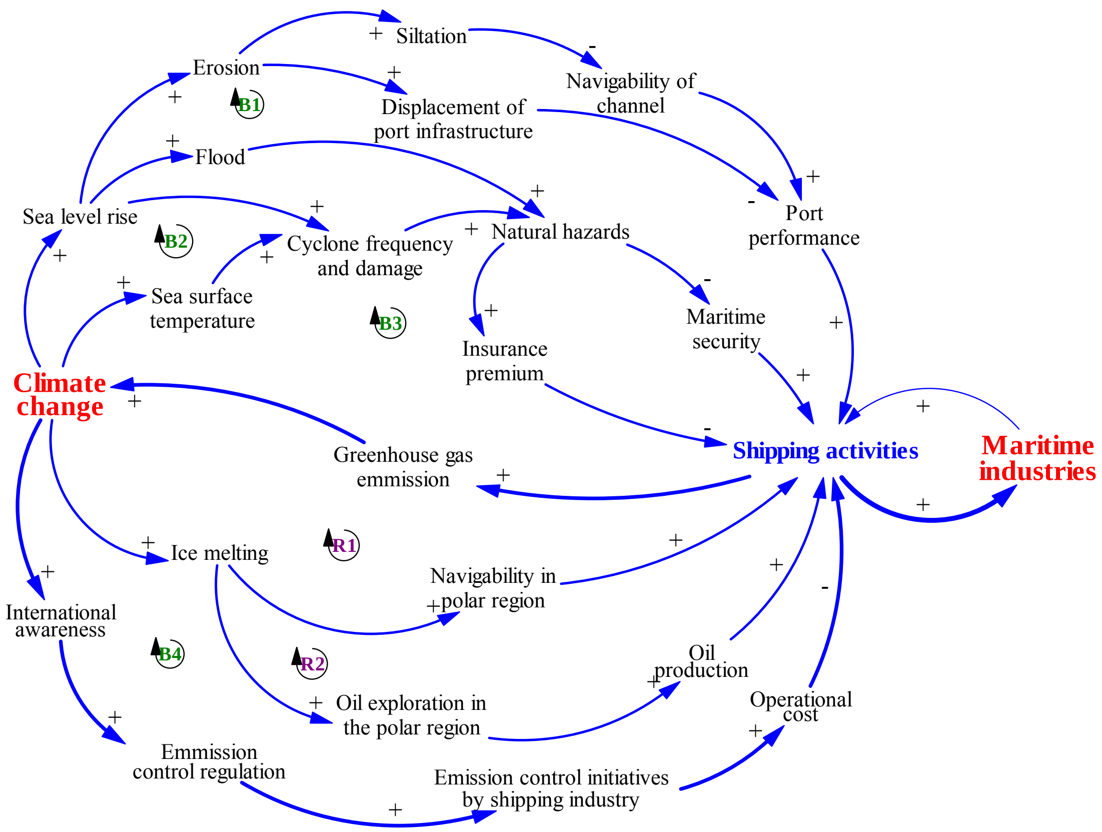


Figure 18: CLD showing impacts of climate change on maritime industries

If shipping activities increases, maritime industries also increase. Growth of maritime industries will be decreased with the reduction of shipping activities. On the other hand, increase/ decrease of shipping activities because of increase/ decrease of maritime industries have a weaker relationship because shipping activities will be increased on the basis of market demand, not because of the growth of maritime industries.

3.2 Change in oil production and transportation due to climate change

World population is increasing day by day. Increased populations have a growing demand on energy, especially on oil. For this reason, the world's oil demand will also be increasing. Some countries will be continuing to produce oil and some will be importing from another countries. Climate change will open the door of oil production for some countries. Oil is mainly shipped by maritime transport. Change in oil production will influence existing shipping route, which is an indirect impact of climate change.

The Kyoto Protocol (1997) entered into force on 16 February 2005 that focuses on the reduction of six GHGs namely Carbon dioxide ($C0_2$), Methane (CH_4), Nitrous oxide (N_20), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6). According to the protocol, annex B countries (please see the protocol) have set specific targets (Table 3) on GHG emission, by the year 2008 to 2012, comparative to the base year 1990.

Table 3: Annex B countries and their emission target

Country	**Emission target**
EU-15[3], Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland	-8%
US	-7%
Canada, Hungary, Japan, Poland	-6%
Croatia	-5%
New Zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

(Adapted from UNFCCC, 2006)

[3] Fifteen member states of EU have redistributed the emission target by themselves.

Most of the developed countries, except Australia and the USA, as they have denied ratifying the Kyoto Protocol, have to cut down their emissions by 2012. To reach the targeted emissions, some countries are forced to reduce the use of fossil fuel, especially oil. These countries will pay their attention to renewable energy (the energy that do not use exhaustible hydrocarbon; Wind power, photovoltaic, Geothermal, Biomass and Hydropower are treated as renewable energy) instead of oil.

On the other hand, non annex-B countries will use more oil, as they do not have any target emission. Thus, the Kyoto Protocol is going to influence the use of oil and subsequently all modes of transportation. Furthermore, some countries are cautious about using oil since the oil crises of the early 70s.

In reaction to the 1973 oil shock, Denmark put emphasis on energy conservation and searched for alternative fuel to reduce the country's dependence on oil imports. Individual heating systems were replaced by more efficient district heating systems. An energy tax was introduced on oil and coal to keep consumer prices high. The issue of global warming led to the introduction of a CO_2 tax in combination with incentives for decentralized electricity generation using renewable resources. Other incentives are funding of up to 30% of the cost of biomass-fired boilers and biogas plants, and support for research into modern biomass energy crops and systems (FAO, 1997). In 2002 Denmark produced 16.7% of its total energy demand from renewable sources (Nakakuki & Kuda, 2003). However, Denmark’s present position in world’s wind power record is fifth, with Germany being in the leading position. Spain, USA and India are in the following positions respectively.

With this dynamic increase continuing, it is expected that windmills corresponding to a production of 120,000 MW will be installed worldwide, in the year 2010. Today, wind energy delivers around 1 % of the global electricity generation of the world, with some countries and regions reaching 20 % and more (WWEA, 2006). Figure 19 represents the yearly wind energy installation and shows that it has increased 7,475 MW (Mega Watt) in 1997 to 58,982 MW in 2005. The increase was 24 % in the year 2005 and 21 % in the year 2004, and the high growth rate indicates the potential and demand of the sector.

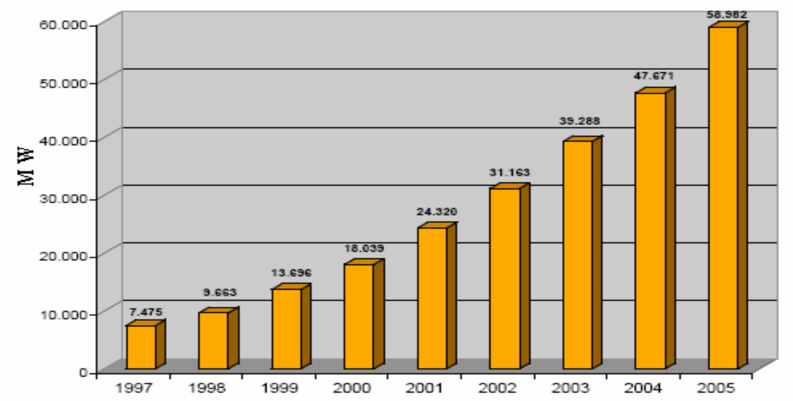


Figure 19: World wind energy installation as on December 2005 (Adapted from WWEA, 2006)

Europe is a pioneer in developing and implementing of wind energy project. Though Denmark was the initiator for this clean energy, Germany and Spain showed significant growth in the recent years. Germany is producing 39% of the global wind energy by its 16,000 windmills and targets to produce 12.5% of the country's electricity by 2010 (Hawley, 2004). The high growth rate of windmills in Germany affected landscape of the country. For this reason, the German are planning offshore wind farms, as far as 40km out at the sea. By the year 2020, the country is expected to produce 20,000MW of electricity from offshore wind farms (Taipei Times, 2006). However, there are some impacts of the offshore installation of windmills, for example the limitations to shipping routes.

Other European countries are also showing strong interest in wind power because of growing awareness of the European about GHG emission and clean technology. France, Portugal and the Netherland have placed strong legislation to favor wind energy. The European Commission (EC) has an individual directive for renewable energy electricity. Technology inventions, peoples' interest about renewable energy, strong wind environment and European Renewable Energy Directive have led Europe to the leading position of wind energy. Besides Europe, America and Asia are also taking strong initiatives to produce this energy.

1% of America's national electricity comes from wind energy and the country is expected to produce 6% of its electricity demand from wind source (AWEA, 2004). Electricity consumption rate in America is very high and the country emits 23% of global fossil fuel emission, especially carbon dioxide (Warrick at el., 1993).

India, China and Japan are the main drivers in Asia for wind energy production. Following the World Wind Energy Conference in Beijing in November 2004, the Chinese government adopted a renewable energy law at the beginning of 2005 and set an official target for the year 2020 from 20 gw to 30 gw (WWEA, 2006). Increased wind energy in China will decrease the oil dependency of the country, which is second largest oil consumer in the world. China's wind energy target will accelerate the growth of this energy sector.

The big CO_2 emitters; the USA, China and India are not covered by the Kyoto emission targets. The countries do not have any bindings regarding the volume of emission to the atmosphere. However, growing international concerns will prepare the countries to think the issue with more seriously. The recent hit of Katrina to New Orleans raise the voice of the Americans to consider the government about emission target. India and China are vulnerable to sea level rise. So, these countries will rethink about their emission and their use of fossil fuels, especially oil to reduce the frequency of these extreme weather events.

The development of wind power will affect shipping sector in two ways. Firstly, wind power will replace oil or coal fired power houses. And since both oil and coal are transported mainly by ships, the reduction in the use of oil or coal will reduce the need for transportation of the mentioned energy sources. Secondly, the high growth rate of windmill is decreasing the availability of space for its installation in the terrestrial area. Present wind mill installation tendency is growing towards sea. These offshore wind mills will reduce the area of shipping routes. Ship lanes will have to compete with the sector for space that will limit its free movement.

The emissions of shipping sector are showing a slight increase. The emissions from aviation and shipping are not treated as a national emission of any nation. Thus, UNFCCC does not calculate the reduction of emission from shipping industry. But reduced emission target by Annex –B countries will force them to reduce the use of oil, which will reduce the transportation of oil. This will affect shipping industry a considerably. Consequently, climate change will cause reduced oil transportation. As oil is the main cargo of shipping industry, reduced oil transportation will limit the scope of the business.

3.3 Change in agricultural pattern due to CC and its impacts on Shipping

Agricultural pattern and production is different in different parts of the world because of its dependency on some natural variables. Influential variables are temperature, rainfall, moisture content of soil, availability of light, and abundance of carbon dioxide. Climate change will change these variables and hence agricultural production will also be changed. It is predicted that agricultures of northern countries (mostly developed countries) will be benefited because of warming of the globe and that of the countries near the equator will be affected because of excess temperature.

In northern areas climate change may produce positive effects on agriculture through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation (Olesen & Bindi, 2002). The rise in temperature and availability of light in the northern region will help plants to conduct photosynthesis. Getting the favourable condition for growth, some plant species will move towards the North Pole creating new forest or agricultural land.

Besides, temperature rise, climate change will increase precipitation in the Northern region. Lang (2001) concluded that agricultural production in Germany will be increased by 12% with 2.5°C temperature and 15% precipitation rise. Stuczyinski (2000) estimated that a 4°C rise in temperature will increase 15-20% precipitation in Poland resulting 3-10% increase in sugar beets and 20-30 increase in Sunflower, Soya and corn yields. Similar increase in agriculture will be observed in most of the cold countries.

On the other hand, countries of hot weather will be looser in agricultural production because of rise in temperature and reduced precipitation in some places, for example, African countries. Kumar & Parikh (2001) estimated that 2ºC rises in temperature and a 7% increase in precipitation will cause loss of about 8.4% of agricultural production in India. Corobov (2002) estimated the decrease yield of winter wheat by 18–39 per cent, by 2020s and 22–50% by 2050s in the Republic of Moldova. By the year 2050, rice and wheat production in Bangladesh may drop by 8% and 32% respectively because of negative impacts of climate change (Faisal & Parveen, 2004). The calculations of Turpie et al. (cited in Meadows, 2005) suggests that climate change induced losses of wheat and sugar cane production of South Africa will be reduced by 10 - 20% by the year 2050.

Agricultural production in this world is not distributed proportionally to population. Countries of less agricultural production need to import grains from the countries of over production. The future development of grain trade depends mainly on weather pattern and population density of an area Ma (2005, p.17). Agricultural production of the countries of high population in a year may influence the grain transportation. China, the country of a population of 1.3 billion, has failed to produce sufficient grains this year and importing the grains from other countries, which led to a higher freight rate in the shipping sector (Ma, 2006).

Climate change, more likely, will reduce agricultural production in India and China, two countries of highest population in the world. Any extreme weather event may cause crop failure in the countries, and shipping activities will increase in such a situation. Africa is a main importer of grains. It is forecasted that agricultural production of the region will be decreased by climate change. In the situation of less agricultural production, the African countries will have to increase more grains that will result in increased shipping activities.

Russia is a country of cold temperature and also a grain importer. Climate change, by increasing temperature in Russia will help the country to increase its agricultural production. Higher agricultural production will reduce the Russia's grain import. Other cold countries will also reduce their grain imports because of higher agricultural production in warmer climate. Reduced grain imports by the cold countries will reduce shipping activities as well. However, the quantification of increase or decrease of shipping activities as a result of climate change is a matter of further research.

3.4 Environmental Aspects

The Arctic is a unique natural environment of the world. The geographic location and the climatic conditions have contributed to this situation. The Arctic wilderness and beauty is unique in that it is largely untouched from human being. The Arctic is home of polar bears, caribou, the musk oxen, several different whales as well as a number of bird species. Any change in the region will hamper the natural beauties of the Arctic and also threat the existence of arctic animals, especially the polar bear.

Shipping activities in the Arctic, especially through the NWP will cause a major threat to the natural environment of the Arctic. Increase of ship traffic through the NWP and other parts of the area will pose a potential threat to the environment. Oil spills is a great concern of pollution from ship around the globe. Offshore oil drilling is another potential source of oil spill in the area. MacDonald (2006) mentioned that 16 years after the Exxon Valdez spill affected populations have not yet recovered, some fisheries are still closed, and there is still significant amount of oil along the coast of Prince William Sound. The severity of damage by Exxon Valdez spill is high because of cold environment of the area. Such accidents in the Arctic may cause truly long-term impacts to the area.

Any type of oil pollution in the Arctic will have a grave threat to the environment because of cold environment. In the equatorial area, any spilled oil evaporates very first because of high temperature. Clean up activities in that areas are easier and cheaper as well. But if any spill happen in the arctic, oil will not evaporate because of low temperature and clean up activities will be very hard for the adverse environment. Clean up may be even impossible in some places. To avoid pollution, especially oil pollution in the Arctic has to protect to save the unique environment.

Shipping activities in the Arctic imposes another threat to the by the introduction of invasive species, which is the second greatest threat to global biodiversity after habitat loss, and half of the species listed as endangered are threatened by invasive species (Linden, 2006). A ship plying through the Arctic may carry invasive species with her hull or may discharge ballast water in the area that contain invasive species. It is obvious that possibility of surviving a new species in the arctic is negligible. But, in any case, if a species is able to survive in that environment, it may take over the other species of the area and biodiversity of the arctic will be severely affected.

The weather of the Arctic is very rough and the ships playing in the area may be affected by extreme weather event, causing ships to break up. In such situations, search and rescue activities will be very hard, expensive, and in some cases may be impossible. A large ship such as a super tanker breaking up in the Arctic may cause contamination that will last for several decades.

Article 234 of UNCLOS (1982) emphasised for the protection of ice-covered areas. A parliamentarian conference (Nuuk Meeting, 2004) held in 2004, among the participations from all the Arctic countries[4] except the USA, decided to encourage the development of improved ship technology for the use in ice-infested water. Shipping communities have to develop ship technology to move in such important and sensitive areas. NWP could be declared as A Particularly Sensitive Sea Area (PSSA), which is defined by Marine Environment Protection Committee (MEPC, 2002) of IMO as-

> *PSSA is an area that needs special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.*

IMO should declare the area as PSSA during navigational period through the Arctic or should take other protective measures if PSSA declaration is not possible for any technical reason. The Arctic countries have to take pioneer initiatives to implement the mentioned protective measures to protect the ice-covered area for the greater benefit of the globe.

[4] Arctic countries are Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the USA.

4. Response of Maritime industries to Climate Change

A quick overview discussed in the previous chapter shows that maritime industries will be affected by climate change to a certain extent. The industry has to find out the possible solutions of the upcoming abnormal situation imposed by climate change. At the same time, the sector has to take necessary plan to enjoy the optimum advantages of the change. For any global change, two things come to one's mind and those are mitigation and adaptation. To decide about the mitigation of climate change or the adaptation of maritime industries to the change, let us distinguish between mitigation and adaptation as Smit et al. (1999) did-

> *'mitigation is a response to the broad issue of climate change and involves reducing or stabilizing greenhouse gas emissions or levels, in order to mitigate changes in climate.' ….. 'adaptation refers to adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts.'*

So, mitigation refers to the control of GHG emission and adaptation refers to adjust with the situation. Shipping sector is a stakeholder in the climate change regime as it is contributing to global GHG emission. The sector is able to cut down its emission and thus can play an important role in emission control. The sector has to develop some adaptive measures to adjust with the upcoming situation as well. Right mitigation and adaptation initiatives are necessary to keep the stability of the industry.

4.1 Mitigation

To minimize the emission, the industry has to find the exact way. Improved fuel quality, use of energy efficient engines is the task of ship owners to cut down the emission. At the same time, international communities need to formulate policies and implement those effectively to have a lower emission in reality.

Article 2.2 of the Kyoto Protocol (1997) to the United Nations Framework Convention on Climate Change demands that the Parties included in Annex I shall pursue for the reduction of emissions of greenhouse gases, working through IMO. To reduce GHG, IMO decided to develop a mechanism in the Assembly number 963rd (IMO, 2003). The mechanism included GHG emission baseline, developing GHG emission index for ships and the evaluation of technical, operational and Market-based solutions. Interim guidelines for voluntary ship CO_2 emission indexing for use in trials was approved at the 53rd session of the Marine Environment Protection Committee (MEPC) of IMO (2005a). The guideline recognized CO_2 as the main GHG emitted by ships. Reduction of emission of CO_2 from is concerned with the reduction of GHG of shipping sector.

Alternate energy could be one option to reduce GHG. Robert Hefner III (Cited in Hirata, 2001) of GHK Company stated that age of solid fuels ended in 19th century. The 20th century is the age of liquid fuel, which is at a decreasing state and will be finished by 2100. The first half of energy source of this century would be natural gas and the next fuel after natural gas is Hydrogen (figure20). A Worldwatch Institute (1995; cited in Hirata, 2001) forecasts that a new fuel, which is a combination of 20% hydrogen and natural gas, called ‘hythen’ would be a new source of energy by 2020. Using that energy, CO_2 concentration in the atmosphere would be stable at 450ppm by the middle of this century, which is 360ppm at present. The whole world is looking for a cleaner energy to minimize the GHG emission to the earth’s atmosphere. Shipping sector have to find out the perfect clean energy for its sustainability and have to develop strategy to adapt with the new energy regime. The industry should conduct research to see whether Hythen is a viable source of energy for its future activities.

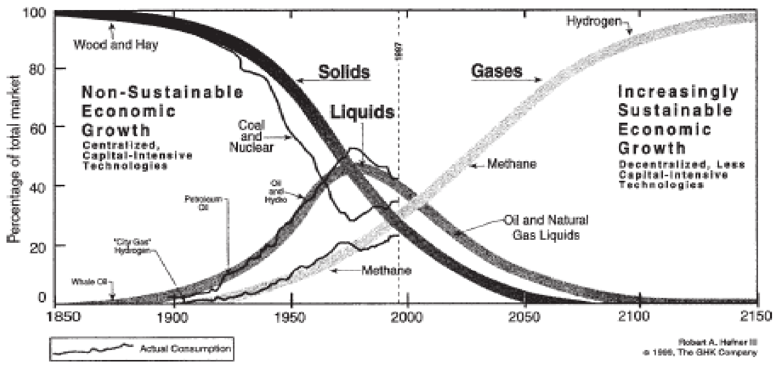


Figure 20: Transition of global energy (Source: Hirata, 2001)

Global transport as well as shipping sector has passed a long way to reach to today's modern system. Today's modern and gigantic ships have taken over wooden boat for international water transportation. Once upon a time, the ships were moved by paddle, or wind driven sail. Afterwards, it was the age of steamships, which gradually developed to up-to-date modern ships. The change will be continuing as the time passes. As shown in the figure 20, the oil regime has already started to decline and will be ended by the middle of this century. So, alternate fuel sources for the shipping industry have to find out any way. Search for the new power should have to be green to keep the emission target at a lower volume.

Presently we have a stock of natural gas that could serve the world for 247 years, based on world's consumption rate in the year 1995. Gas resources could be used even a longer period of 511 years, if the large depth gasses are included. Adapting the shipping industries to the gas energy is a possible solution that has long time energy assurance and is cleaner, in compare with other fossil fuel like oil. Main problem of gas is that it demands an extensive pipe network throughout the world. But, once the pipe infrastructure is developed, it will become a semi-permanent energy supply-chain, because this pipe network could be used for hydrogen energy supplies, which will probably be the next energy source of the globe (figure 20).

Research is going on to find out the right form of energy and technology to meet the demand of the sector. Out come of one research seems to have the possible way of solution of the future energy crisis of shipping sector. Researcher Ivo Veldhuis of University of Southampton has designed a special type of ship that is run by Hydrogen fuel and almost two and a half times more speeder than the conventional shipping speed (Wilson, 2005). Liquid Hydrogen is 2.5% lighter than bunker oil and is usable in the international shipping. However, the design proposed by Veldhuis (2006) is good for smaller ship size of 600TEU, which is very small compare to the conventional 8,500TEU larger ships. Though the ship design is smaller, its high speed will be able to serve just-in-time service of the sector. This ship design should be upgraded to feed the future needs.

Research on low cost hydrogen production is the interest of present trend. Kim (2002) introduces low cost hydrogen production from carbonaceous wastes and Ginkel et al. (2004) shows its production from food processing and domestic wastewaters. Besides saving cost, using carbonaceous wastes in hydrogen production also helps to get rid of these dangerous wastes that emit high volume of CO_2 if incinerated. Waste is a great problem for many nations. This technique will help to convert these wastes into wealth. Hydrogen production from wastes shows a great potential of clean energy production.

Growing international interest to decrease GHG has leaded the world to develop clean fuel. Brazil and Iceland has shown great interest in hydrogen fuel. Iceland declared its economy to be an economy of hydrogen by 2030. Canada, USA, EU, Norway, Japan, China and Korea are also advancing hydrogen energy. Norway has developed a 580-km long hydrogen highway that runs from Stavanger to Oslo with sufficient hydrogen fueling stations on the way (Solomon & Banerjee, 2004). Big industries like DuPont, Siemens, Micro, Ashahi, Toshiba, and Ford are also paying attention to hydrogen energy. There is no significant report to design ship to run by hydrogen fuel by any ship building industry. Ship designers and builders should think this issue critically. It is true that ship builders build the ships according to the demand of the shipping companies. Those days are not very far when shipping companies will ask the builders to build a hydrogen-powered ship. To have sufficient supply to that demand, ship building industry should plan the future needs.

However, production of hydrogen energy is not clean as the energy itself. Its production method is responsible to produce CO_2, which is equivalent to the use of conventional fuel as well. But it is possible to produce this gas from natural gasses, other fossil fuels and also from nuclear powered electricity.

Most of the world's refineries are located near ports where hydrogen fuel production is located. So, CO_2 produced in the hydrogen production system could be captured easily and stored in Carbon Capture and Storage (CCS) system (Please see Lenton & Cannell, 2002; Anderson & Newell, 2004). Carbon dioxide produced in hydrogen production will not be added to the atmosphere, which will be an advantage of emission control. In such a case, hydrogen production facilities will be near the port area, its transportation to the ship those called at that port will be much easier.

Almost 80% of the world commercial fleets are run by residual fuel (Corbett & Fischbeck, 1997) that contains Sulphur, asphalts, ash and other contaminants. Because of high concentration of contaminants, emissions by ships contain higher level of pollutants. Use of clean fuel can reduce this pollution level. Designing of efficient engine are also necessary to reduce emission. According to Regulation 14(1) of Annex VI of MARPOL 73/ 78 (IMO, 2002), Sulphur content of ship fuel should be 4.5% m/m or lower. IMO is monitoring Sulphur content of fuel since 1999, having records on global bunkers and found that Sulphur content in bunker was 2.6 percent in 2004 (Baker, 2005). To lower down the Sulphur emissions, some area specific initiatives naming SO_x emission control areas (Secas) were taken by IMO. In Secas, highest limit of SO_x emission is 1.5% by mass and the first Secas area in the world is the Baltic Sea that is effective from this year. The North Sea will be treated as Secas by 2007. European Union is trying to have a discussion with global community, especially with IMO to have Sulphur content as low as 0.1% by 2010 when the ship is at berth. Similar methodology could be used to emit lower level of Carbon dioxide emission from ship.

4.2 Adaptation

Adaptation is necessary to adjust with the climate change impacts. The ability to adapt and cope is a function of wealth or income, technology, scientific and technical knowledge and skills, information, infrastructure, policy and management institutions and equity (Chatterjee & Huq, 2002). Shipping sectors has to consider all the factors to adapt with the situation. Some factors to be considered within the industries and some should be adapted with other stakeholders.

Shipping sector is responsible for the movement of the significant part of global trade. It is very difficult to quantify the financial involvement of the sector. However, United Nations Conference on Trade and Development (UNCTAD) has an estimation of USD 380 billion involvement of shipping sector in the economy of the globe (IMO, 2005b). As the financial involvement of the sector is huge, it has to invest a high amount of money to protect the industry from potential impacts.

The industry should form a climate change fund that will be used for adaptation and mitigation of climate change event. Different implications of the fund are shown in the figure 21. Firstly, part of the fund would be used to meet the extreme event of climate change. The fund will be used for affected unit, in addition to the claimable insurance. If the climate change fund remains unused, it could be used for the development of the sector. But money invested for the increased premium will go the insurance companies and will not be available to shipping sector, if not used.

In figure 21, it is clear that climate change fund will help shipping sector to protect the raising of insurance premium (R3).

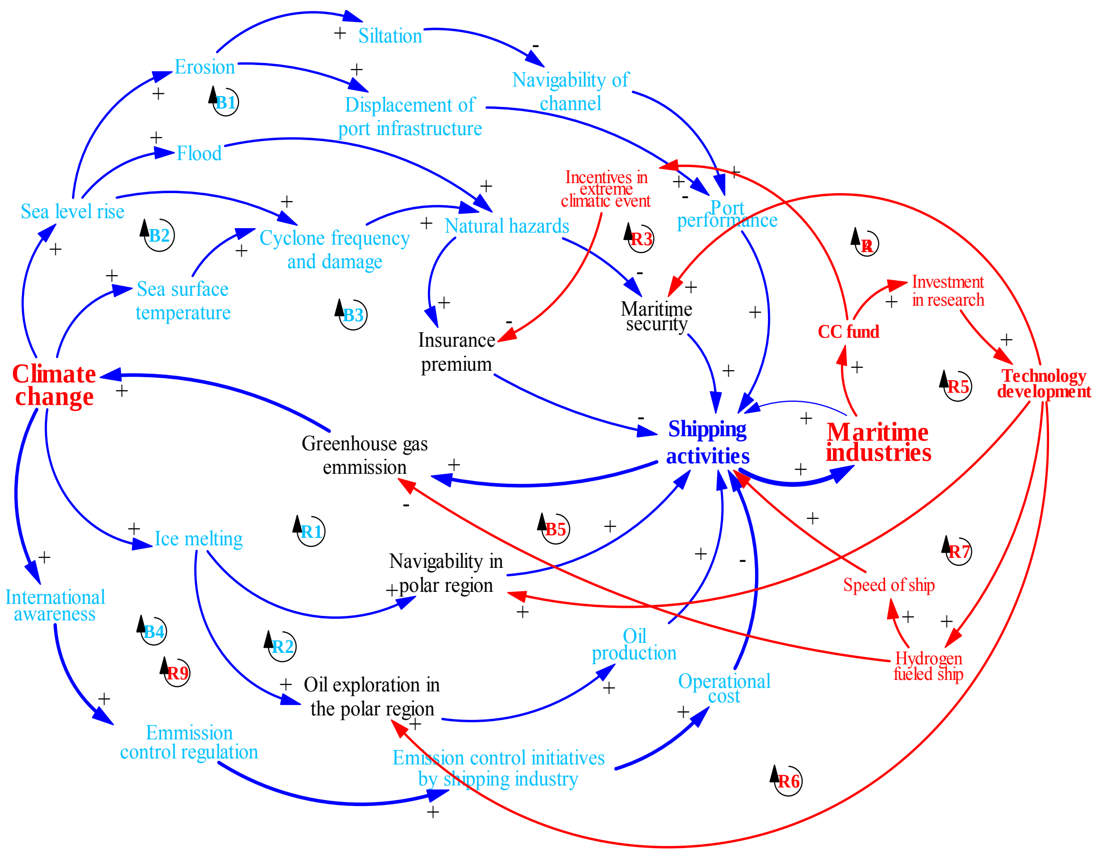


Figure 21: Role of maritime industries in adaptation and mitigation of climate change

Part of the fund will be used in innovation and technology development. The technology will find out the way to increase maritime security by developing speedy and disaster tolerate able ships. Increased maritime security will increase shipping activities (R4). Technology search using the fund will be able to find out the way to navigate in the polar region in an efficient way. Navigability in the polar region will increase shipping activities with minimum cost (R5). Research will also find out the way to explore oil in the polar region. More and more oil production in the region will increase shipping activities as well (R 6).

Climate change fund will be used partly to develop technology for searching clean energy for shipping sector. One option could be hydrogen fuel development. As discussed earlier that hydrogen fuel is clean fuel and hydrogen fueled ships have a speed of two and a half time more than the conventional ships. So, hydrogen fueled ships will offer a quick and reliable service to the shipping service users. Increased ship speed will increase shipping activities as well (R 7). As hydrogen is a clean energy, it will emit zero carbon dioxide. So, GHG emission by shipping sector will be verbally zero that will mitigate climate change (B5). If shipping sector emits zero level GHG, there will be no pressure from the international community to the industry to minimize the emission that will decrease the operational cost of the sector (R 9).

5. Concluding Remarks

It is widely accepted that the world's climate is changing and the upcoming warmer climate will affect maritime industries both positively and negatively. It will affect navigability of channels by causing erosion and siltation. Erosion may cause displacement of port infrastructure that will have a negative impact port performance. Climate induced changes in the weather patterns will lead to more frequent and stronger storm events. This will increase the insecurity of the shipping industry and will increase the insurance premiums.

Climate change will cause ice melting, which is going to contribute positively on the shipping sector. Ice melting is expected to create favorable conditions to explore and extract oil and gas in the Polar Regions. Oil production in Polar Regions will aggregate shipping activities. The melting of the sea ice will allow ships shorter on the northern hemisphere, such as between Europe and East Asia.

The Arctic is unique with its wilderness and intact natural environment. Increased ship traffic through the Arctic will pose pollution threat. Accidental oil spills from ship or from offshore oil production in the Arctic may cause a huge damage to the environment.

Climate change will change the agricultural pattern by changing temperature and rainfall. The colder countries will enjoy the advantages of climate change and will be able to produce more crops, whereas agricultural production in the countries of warmer climate will be reduced. Changing agricultural pattern will change the shipping activities.

As a result of more ship traffic taking northerly routs through the Arctic Sea, some southern ports, especially Singapore and Hong Kong may have to face decreased ship traffic or at least a slower growth. Canada might have to face a debate with the global shipping community about the issues whether NWP is an internal territory of Canada or is an international shipping route.

Growing public concerns on climate change is building international awareness. UNFCCC has designated IMO to find out ways to reduce CO_2 from shipping sector. IMO is working on this issue. Whatever the emission control regulation will be, this will increase the cost of operation and maintenance of the sector that will eventually affect freight prices and/or the economy of the shipping industries.

Shipping industry has a great potential to contribute to the reduction of the release of GHG, especially CO_2 emission. Using clean fuel is a mode of emission control. Hydrogen gas has a great potential to be used in shipping industry that will help the industry to achieve a zero emission target.

This study suggest that the industry should form a climate change fund to be used for research on climate change issues and how to manage climate change crisis from the perspectives of the shipping industry. The fund should be used for technology development to find a clean technology for the industry; special attention will have to put on hydrogen fuel.

This study also suggests that it is necessary to develop a plan and formulate a policy to get optimum benefits out of the new navigating routs in the Arctic Sea. The policy must consider environmental aspects and should be formulated to overcome the potential conflicts between Canada and Russia(??) and the rest of the world for the use of the NWP and NEP. Singapore and Hong Kong ports should develop a long term plan to meet the new situation when a significant volume of traffic will move to the more northerly routs. Furthermore the industry should develop emission targets and find out different alternatives to reduce GHG emission. Prospects of hydrogen fuel to run the ships should be studied. In addition, IMO should facilitate the implementation the recommendations.

The study also consists of a qualitative analysis. This analysis shows the climate change impacts on the industry in a more reliable way. Policy makers of the shipping sector are likely to be more active if quantitative figures can be presented to them. Using STELLA, a famous tool of system analysis, could do the proposed quantitative analysis.

Climate change is crucial for every economic sector of the world. The shipping industry will not be able to avoid the negative impacts, even though the industry will have some benefit from it. To overcome the climate change induced problems, the industry should formulate effective adaptation and mitigation policies and implement those without delay. The International Maritime Organization, the most influential organization of the sector, should consider this issue as a matter of highest priority.

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