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Seaborne chemical trade prospects

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Abstract: the number of chemical products transported by sea is very high. They have different physical and chemical properties, and thus come together in very different ways when they are released into the water. In response, the environmental modeling impact is difficult, and consequently, the co-operation and preparation for potential accidents are particularly essential. The high demand for chemical substances due to a high volume of transport, which is worldwide continually growing. The chemical products transport is different from the oils and petroleum products transport and requires special vessels, specialized equipment, and complicated handling, but also the specialized training of the company, both theoretically and practically. Those involved need to understand the nature of the different substances and to be aware of the possible perils involved in their manipulation. Maritime transport of goods implies enormous costs and requires significant investments. Therefore, governments impose stricter regulations and restrictions on environmental protection. It is expected that such regulations will restrict the market in the long run. It is also expected that geopolitical issues and political instability will limit the offer for chemical products transport.

Keywords: seaborne trade, chemical products, future prostets

1. Introduction

Substances are widely used in many ways, for example, raw materials in different industrial sectors, so that the number of chemical substances transported by sea is very high. These substances have different physical and chemical properties and act in very different ways as they are released into the water. In response, environmental impact modeling is difficult, and therefore staffing and training of staff for eventualities are particularly essential. The high demand for substances is due to a large volume of transport, which is growing globally every year. However, the number of chemical substances has decreased with the increase in transport volume. This is probably due to the gradual elimination of the chemical tankers with a single hull, the tighter legislation, and the new technical supplies. With all of the above, none of this actions can entirely prevent the accidents.
Substances and mixtures are present as solids, liquids or gases. Other elements also include flammable, explosive, radioactive, corrosive, oxidizing and toxic substances. Chemical products are used as raw materials in various industrial applications, for example in silviculture, farms, electronics and plastics, paints and varnishes. The transport of goods is different from the transportation of oils and petroleum products, as they require specialized vessels and complex handling. At sea, chemical products are shipped or packaged. The substances in bulk are divided into solids, liquids, and gases, and the others can be transported either by chemical carriers or by gas carriers.
The range of chemical products displaced had enormously increased in modern days and a particular queue of ships - chemical tankers, has been developed to meet the needs. Most shipments of chemical products are made using chemical tankers equipped with separate cargo holds. Consequently, several different substances may be transported in a single ship, although, of course, not more than ten different elements are transported to the same vessel.
The handling and transport operations of the goods differ from any other mode of transport by the fact that a large number of interfaces with different properties and stability and degree of perilousness can be transported simultaneously in a single voyage and many products can be handled to one berth. Even smaller, less sophisticated products are more complicated than oil tankers.A specialty chemical terminal is characterized by the existence of many individualized technologies and operations,

including special tanks, hatches, docks, ships, barges, wastewater, emergency response, and all require one of the best handlings in the field.
The transport of the chemical substances at sea involves not only specialized vessels and specific equipment but also the preparation and specialization of the company, theoretically and practically, for the sake of understanding the skepticism of the different substances and to be aware of the possible perils involved in their manipulation. Sea transport is often seen as high risk in the transport chain of chemicals. The fact that accidents involved is infrequent in comparison with oil products, and is due, in the first place, to the difference in transport volumes and high safety standards in the sector. The overall trend of shipping development is strong growth, with more ships, new routes, and many potential areas for groundings or collisions.

2. Materials and Methods

Chemical tanks are highly sophisticated ships with more sophisticated storage systems capable of transporting up to 60 different types of chemical substances, depending on their transport patterns, their own syringe, and pumping system. The goods carried often presents extraordinary challenges and extraordinary difficulties for safety, and many chemicals are also a much greater threat of pollution than crude oil.
Chemical/petroleum tankers ship bulk chemical products. Most shipment of chemical substances is made in compact loads. Vessels for this type of cargo are versatile, projected to carry a wide range of liquid chemicals. On the outside, they look similar to oil tankers, but they are divided or parted in 10 to 60 separate cargo tanks. These have a total disposability of about 3,000 to 40,000 tons, although many are less than 40,000 tons. Some goods require heating, and others have to be cooled off, others are so volatile that they must be kept in safety under a blanket of inert nitrogen, others are violently reacting with water and must, therefore, be handled in arid conditions. Some commodities are very corrosive and require tankers made of high-quality stainless steel, while other tanks must have a special coating. Some goods have to be kept in motion, so they can not stabilize, and others can only be transported in a tanker that has not transported under any circumstances other the incompatible goods. Some commodities may be affected by the residue of a previous spill just after a stainless steel tank has been cleaned with its meticulousness. Some products react violently to others or exposure to the atmosphere. Many are flammable, explosive, or exhausting noxious vapors, so safety will always be a significant one. Some are edible. Many of these goods are extremely valuable and require very high standards of cleanliness to maintain the purity of the product and must be discarded until the last crack on board.
New products are being developed all the time by the industry around the world. Keeping them is an individual responsibility for the maritime industry which has a modern fleet of vessels. Chemical products discharged into the sea combine in different ways, depending on the properties and environmental conditions. By the way, the substances may evaporate, float, dissolve or sink as they are released into the sea. Their behavior is often more complex, and a product of chemicals can, for example, evaporate into the air and dissolve in water. By the physical properties of the substances, it is possible to anticipate the behavior of the substance after soaking. The classification system covers the gaseous, liquid and solid substances. The system aims to organize products in groups of the property so that the substances from the same group behave similarly in the water and could be similarly reshaped.

3. Results

The analysis of legislation specific to the transport of chemicals by sea shows the following:

- Regulations on the maritime transport of chemical products are incorporated in the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Marine Pollution (MARPOL 73/78);
- The regulations concern chemical products transported in bulk and packed with chemical tankers. The relevant regulations regarding the transport of dangerous perishable liquids in bulk are: The international shipbuilding consignment for the transportation of perishable substances on the ship (IBC) and the International Ship for Ship Consortium and Shipping are transported in liquefied gas (IGC). Both conventions require that charters designed to comply with the IBS are provided, providing international standards for maritime transport in the safe seals of perishable life vehicles, through the prescription of the ship's standards and construction standards implied in such shipments and supplies. In the first instance, ship types are related to the dangers of the products regarding the regulations. Any of the products may have one or more dangerous characteristics, such as flammability, toxicity, corrosivity, and reactivity. The IBC lists the substances and their dangerous features and gives the type of ship to transport them, the quantity and the degree of risks to the environment. The rules for chemical substances carried in packages form are part of Annex III from MARPOL - Regulation on the prevention of pollution caused by noxious substances transported by sea in packaged form and the International Marine Corps for the transport of dangerous goods by sea (IMDG);
- Ships specially designed for the transportation of chemical products by sea, known as chemical tankers, are vessels designed to transport dangerously liquefied, volatile and corrosive chemical substances in bulk. The MARPOL 73/78 Convention defines the notion of the chemical tanker as "a ship built or adapted primarily for the transport of dangerous liquefied goods in bulk." The SOLAS Convention defines the notion of the chemical tanker as "a ship constructed or adapted for the transport of flammable liquefied goods " and is included in the category of oil ships[1].

The analysis of the evolution of chemical tankers shows the following (Figure 1):

- The development of specialized vessels in the chemical products transport has expanded and has grown exponentially in the last 40 years. After the Second World War, the growth of the chemical industry in the United States has led to the emergence of the need for sea transport of chemical products;
- Beginnings of the worldwide fleet of dedicated vessels were made through reconversions/modifications (the installation of casual, double-bottomed, structural changes and pipelines) to a series of oil tankers produced in the significant number during the war;
- Chemical tankers are smaller in size and capacity than oil tankers, but are much more technologically sophisticated;
- Chemical products transported by sea have become more complex and more dangerous, and their nomenclature has been rapidly increasing, also requiring supplementary tonnage;
- Chemical tanks called "parcel tankers" are specially designed ships for the simultaneous transport of several cargo parties. In the mid-60s, tankers for liquefied chemical products already constituted a unique distinction of specialized vessels, fundamentally different from other ships [4];
- Chemical substances, the most dangerous substances transported at sea, pose risks and particular problems for the ship, the crew, and the surrounding environment, and require specific design, construction, and exploitation of the chemical tankers;
- Although of relatively small size, the chemical tankers are more complex, have a much higher number of cargo carts than oil tankers, much smaller in volume, the pipelines, and the associated facilities being devoted to each tank, being more numerous and more complicated;
- The operations and loading procedures are laborious and very strict to prevent the contamination of goods and pollution of the surrounding environment. The internal construction of tankers is greatly simplified to minimize the possibility of products being contaminated;
- during designing and execution, consideration shall be given to the characteristics of the substances to be transported, the handling and storing conditions, the avoidance of stress on the strength

of the vessel, the avoidance of fissure and cracks that could lead to goods contamination, the materials used, construction technical procedures and the welds are of the top quality;

- Due to the transport of particular and incompatible goods, the segregation of the goods is necessary and is ensured by the help of cofferdams, the double hull, and the double bottom. The bulkheads are made of special materials, several of stainless steel (easy to maintain and wash), but due to incompatibility with many chemical products, a range of paints and special materials were made for protection.

Depending on the number of chemical products transported, chemical tankers are divided into three major categories: multi parcels, ships specially designed for the transport of chemical products that can simultaneously carry several kinds of chemicals in individual storage spaces, serviced by operating and handling facilities separate and independent combinations; chemical tankers specially designed for the transport of chemical products, intended and developed in order to carry a single assortment of goods; the tankers for the transportation of the products are suited to the inland waterway and have a maximum displacement of 60,000 dwt.

The International Maritime Organization classifies cargo ships in three categories, such as I-type tankers, transporting shipping products with a higher degree of risk/danger. These substances are not biodegradable. Ships with this type of cargo have a double bottom in cargo spaces, and in addition, freight carts are arranged in the center of the ship to prevent and reduce the risk of pollution in the face of a collision or collapse; type II tankers, vehicles transporting dangerous cargo built into a double-spindle system with a double bottom, with lateral spherical passages, and the cargo being transported is at a distance of 10 inches of shell; the III-type charters, shipping vessels carrying dangerous liquid products that have a much higher degree of calamity. These ships are standard, with no additional structural or functional modifications [2].

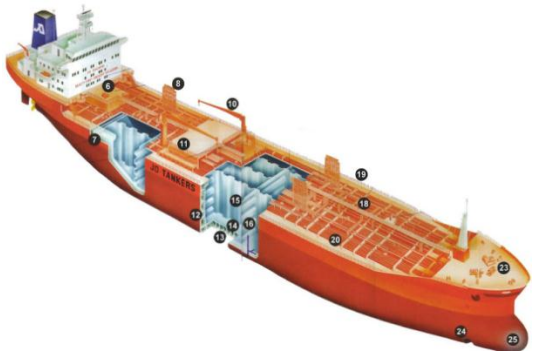

Figure 1 Standard structure of a chemical tanker [17]
Source: https://forshipbuilding.com/ship-types/tanker/

Legend:

1. Balanced rudder with conventional propeller	14. Tanktop
2. Auxiliary unit	15. Longitudinal vertically corrugated bulkhead
3. Lifeboat in gravity davits	16. Transverse horizontally corrugated bulkhead
4. Hydraulic prime mover	17. Cargo pump
5. Cargo control room	18. Catwalk
6. Tank heating/tank washroom	19. Railing
7. Cofferdam, empty space between two tanks	20. Deck longitudinals
8. Vent pipes with pressure-vacuum valves	21. Deck transverses
9. Hydraulic high-pressure oil-and return lines for anchor and mooring gear,	22. Cargo heater
10. Hose crane	23. Forecastle deck with anchor-and mooring gear
11. Manifold	24. Bow thruster

12. Wing tank in double hull	25. Bulbous bow
13. Double bottom tank	

The chemical products analysis carried out at sea shows the following [8]:

- the most common bulk chemical products transported by sea (table 1) can be classified into several categories: heavy duty products produced in large quantities, the most common being sulfur sulfide, phosphorus aspartate, nitrogen azide, amoniacul; melase and alcohol; vegetable oils (soybean, palm kernel, sunflower) and animal oils (lard, fish oil); petrochemicals: benzene, xylene, phenol, styrene; tallow coal products: benzene, phenol, naphthalene;
- the most frequent chemical substances carried by sea are ammonium, acetone, ethylene glycol, phenol, phosphorus, methanol, sulfur sulfide, styrene monomer, and caustic soda.

Table 1 Goods transported by chemical tankers

Vegetable and animal oils			**Heavy chemical products, alcohols, and petrochemicals**
Dry	**Semi-dry**	**Non-dried**	
Linseed oil	Cottonseed oil	Oleomargarine from bacon	Fenol
Tuna oil	Sesame oil	Olive oil	Sodium hydroxide solution
Shin Corn Oil	Corn Oil	Groundnut Oil	Acrylonitrile
Soybean oil	Wheat oil	Ricin oil	Methyl alcohol
Hemp seed oil	Sunflower oil	Rapeseed oil	Acetic acid
Nut oil	Ulei de cod	Peanut oil	Sulfuric acid
Natural rubber oil		Rice oil	Toluene
Poppy oil	Ulei de herring	Spermacit oil	Nitric acid
Tall oil	Shark oil	Seal oil	Coconut oil
	Whale oil	Palm oil	Etylen glycol
	Sardine oil	Ulei Kernel palm oil	Metyl etyl ketone
	Fish oil	Coconut oil	Carbon tetrachloride
		Oleomargarine	Ethylene dichloride
			Furfural
			Acetone
			Toluene
			Benzene
			Xylene

The storage and handling of these types of chemicals is a matter of special care and precision, a meticulous planning and a great deal of experience and specific knowledge that the marine officers have to offer. It is not unusual for such ships to have a discharge plan that includes different harbors with specialized docks, pruning and dredging operations in the same port. So, there are some special training courses for officers on these ships, and they require solid knowledge not only about certain types of cargo but also about all the shipments of the various products that may be present in the port. New products are constantly developed and made available for use and must also be transported. Keeping up to date and refreshing knowledge is one of the primordial responsibilities of those who take care of it, and despite the enormous dangers presented by the merchandise, they enjoy a great deal of safety due to a fleet of new ships.

4. Conclusions

1. Many of the changes in the day-to-day life of recent years have resulted from the development of the chemical industry. A large variety of customary products are derived from the same complexities. The industry is one of the largest and most important industries in the world. The United States of America is the world's largest producer of chemical products, the value of its production was more than 797 billion dollars in 2015. With an income of nearly 50 billion US dollars in 2015, Dow Chemical is the largest producer of chemical products in the world and the second worldwide after BASF in Germany. In 2016, some of the world's most important chemical products companies announced mergers, effectively modifying the dynamics of the global industry. The European regulators approved the merger of Dow Chemical and DuPont in March 2017. After Germany, the USA, is the world's largest exporter of chemical products. In 2015, exports of chemical products were worth about 184 billion US dollars. The bulk was generated by exports to the Asia-Pacific region. The most important destination countries for the export of chemical products were Canada, Mexic, and China. With all of the above, U.S.A. it also has a great deal of import of substances. In 2015, imports were worth about 205 billion US dollars [7, 9].
2. Corresponding to its size, the chemical industry is a significant employer. Approximately 810,000 people have been in the United States, including in the pharmaceutical sector, down from the end of the 1990s, with almost a million employees. The chemical industry is confronted with significant challenges, while the value chains are moving from east to east, attracted by the economic boom and the Asian market opportunities. A more competing environment is formed. Fragile economic forecasts are not enough to manage volatility on land in salt, but the flow of commercial streams gradually shifts direction. Understanding what challenges mean, and, more importantly, identifying strategic options that are likely to develop in such a new competitive environment can help chemical products companies to resist the environment.
3. From the mid-1980s onwards, the global chemical industry increased around 7% annually. Most growth in the past 25 years has been driven by Asia. Given the steady upward trend, world global markets are expected to grow at an average of 3% over the next 20 years, Asian manufacturers will hold two-thirds of the market by 2030. At the same time, economic growth in Europe is expected to be only 1%. It is to be hoped that more than 30% of jobs will be lost to the European industry by 2030, due to slow growth.
At present low cost of raw materials and the rise in investment capital have generated many new projects in the chemical industry. While this growth is a good thing for the industry, the resulting increase in the transport demands, emphasizes the need to address the existing transport infrastructure problems. New logistical challenges could spur the movement of new substances and won't the allow industry to make the full benefit of the production growth. The industry will expand to Asia, and by 2030 only half of the first ten companies will be from Asia or the Middle East [9].
4. By 2030, three trends will be seen in the global environment: the changes of competition, the shifting of networks of values to the east and the volatility of economic growth. As a result, this has dramatically increased the demands in the transportation of the substances at sea, and the shipbuilding of the vessels specially developed for the transport of the island has developed. Ships built in harmony with this type of transport were and are more sophisticated vessels ever built.
5. Each country or region has its statistics on maritime transport of goods, and there is no global system to centralize such data. With all this in mind, it is possible to provide an overview of the chemical products transported worldwide by ships in the form of water vapor (including gases). In the year 2015, 155.6 million tonnes of liquid goods were carried and can be divided into three main categories [10]:
- 50% were petrochemicals, such as benzene, xylene, and styrene;
- 30% were animal or vegetable oils and fats, including palm oil;
- 10% were inorganic substances, such as mineral salts, multiple ores, certain corosable substances (sulfur dioxide, sulfur, and phosphorus) and certain gases (ammonia, chlorine);

- 10% were produced differently, grouped into a separate category.

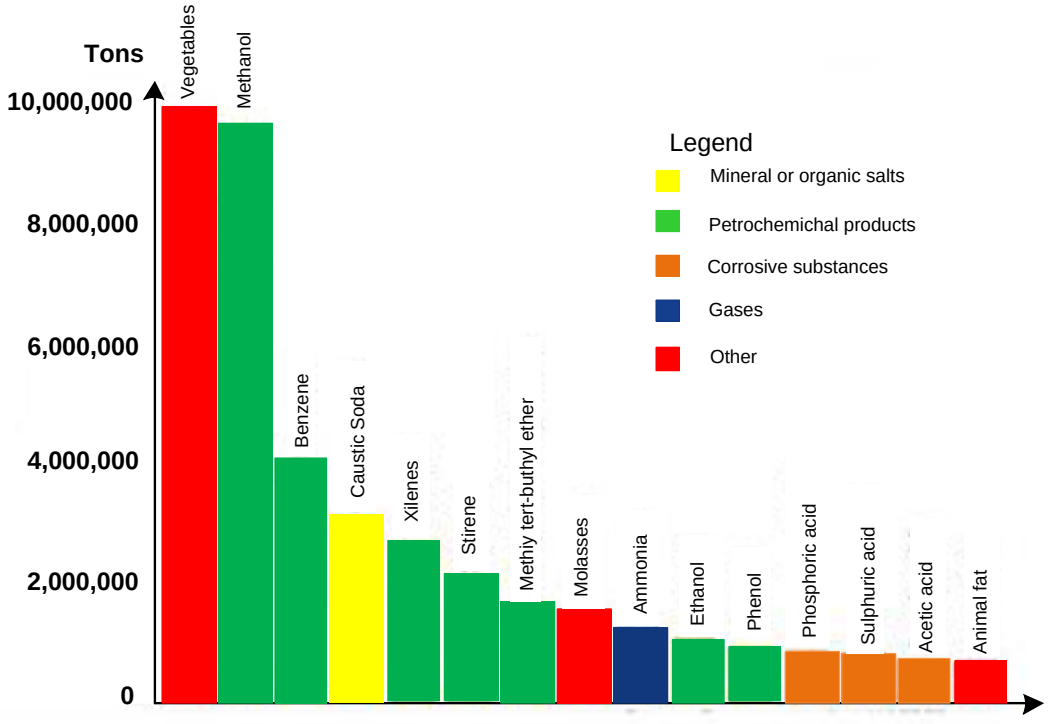

Figure 2 Seaborne important chemicals products [8]

6. At the end of 2017, the world fleet had a displacement of 43,225,000 dwt (2.3% of the total fleet displacement and 4% of its value) [11]. The purely chemical tanks and their fleet was down to size, and the ships were more often replaced by flexible vessels such as petroleum /chemical tanks. As far as the supply/delivery of vessels is concerned, it is stable with a tonnage of available tonnage. The rebuilding of newly built ships has risen to nearly 200 units, with a total of over 5,000,000 dwt [10]. In total, 59 vessels totaling 1, 500,000 dwt have been registered in the last year, compared with 46 ships shipped in the same period, adding 1,300,000 dwt of the world fleet. Given the delays experienced, the prospects for chemical product transport are very favorable for owners and operators over the next two years.

7. The seaborne chemicals trade measured in ton-miles reflect the distance traveled and the employment of ship capacity increased to 1,111 billion tons in 2018 [18] (Table 2 and Figure 3) compared to 580 billion tonnes of in-miles in 2000 (52.2% increase in 17 years, with an average of 3% per year).

Table 2

2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
580	589	620	632	650	676	713	747	759	783
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
848	888	903	925	920	961	993	1058	1111	

8. Chemical seaborne implies enormous costs, as maritime accidents have resulted in massive loss of marine life, investment, and others. Governments, therefore, demand strict environmental restrictions and regulations in the field of chemical product transport. It is also expected that environmental regulations will restrict the long-term market. Geopolitical problems and political instability among the significant chemical transporter countries are also likely to limit the chemical transport offer.

9. From a structural point of view, the tanks differ in some measure from one another. With all the differences in construction, all the chemical tanks are made up of the following three sections: the bow section designed to provide services to the ship and navigation; the center section consisting of the whole cargo; the aft section for berthing, auxiliary and latching machines. The aesthetical structure must be at the highest standards. The washing of the tanks is of great importance for the purity of the goods, which is avoided as much as possible and the presence of other stable structures or other objects on the bottom of the table can be minimized. The tanks have to be scanned and built very carefully, so the forces are acting to produce less solicitation and to reduce the occurrence of ruptures and cracks in the walls of the tan. When passing the shape of the tank itself, it should be taken into consideration, and the type of goods will be marred: some are twice as thick as water, while others have to be transported at high temperatures to prevent their solidification. Both factors can affect the structure of the tank. Welding and other technology must be of better quality. The tanks were more likely to be used by the cofferdam, double bottom, and similar spaces for the oil tankers. To ensure that goods incompatible with each other can not come into existence, the cargo carts are separated through cofferdam, the space between the walls of two stomachs. Most vessels have the carts divided by the outer limit of the ship by the double bottom or double shell. In the face of a collision or failure, this space should protect the cargo carts from getting damaged. Viewed from the outside, chemical tanks are very similar to refined vessels. Differences between the tanks are that they are entirely made or lined of special material: stainless steel, Teflon, resistant to the various types and sizes are equipped with heating or freezing equipment. These dimensions are much smaller than the oil tankers, and much more significant, well-defined, making it possible to transport several types of substances simultaneously.

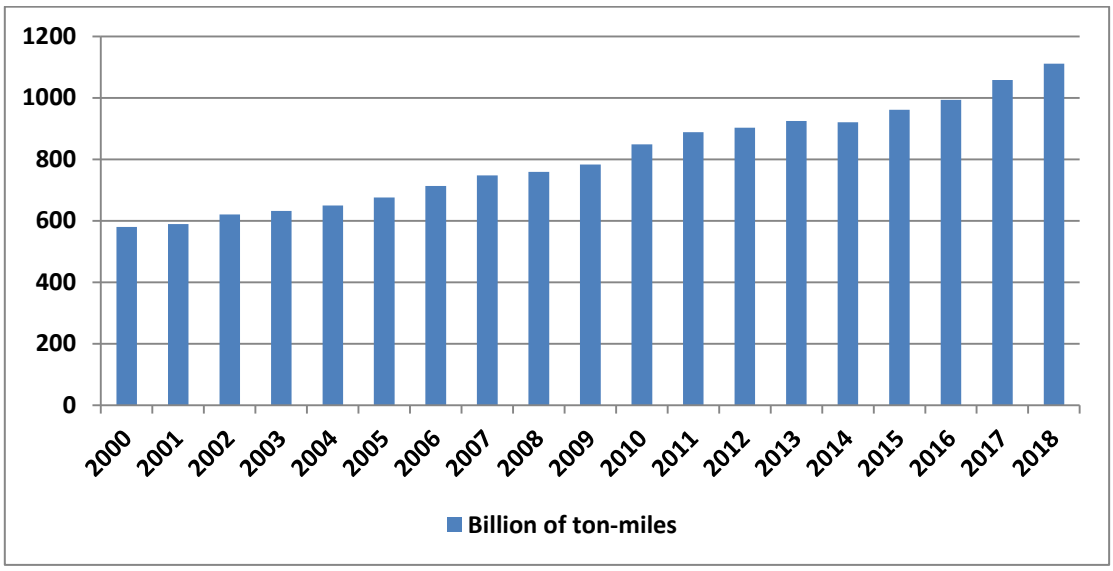

Figure 3

10. The prospects of petrochemical seaborne are as follows: the global petrochemicals market was valued at USD 419.4 billion in 2015. The industry's future growth trajectory is determined by the high demand for its derivatives in automotive, textile, construction, industrial, medical, pharmaceuticals, electronics, and consumer goods industries [13]. Petrochemicals Market is expected to witness significant growth with a CAGR of 6.7% over the forecast period to 2023 and reach USD 1075.19 Billion during the period by Forecast to 2023. Petrochemicals are organic compounds derived from hydrocarbons[14]. Heart of the chemical industry extends în Asia until 2030 half of 10 chemical companies would be from Asia or the Middle East (Table 3 and Figure 3) [15].

Table 3 Trend of the global chemical industry up to 2013 [16]

Year/Region	Asia	Europe	NAFTA (North American Free Trade Agreement)	Rest of the World
1985	15	45	30	10
2010	49	25	19	7
2030	66	15	12	7

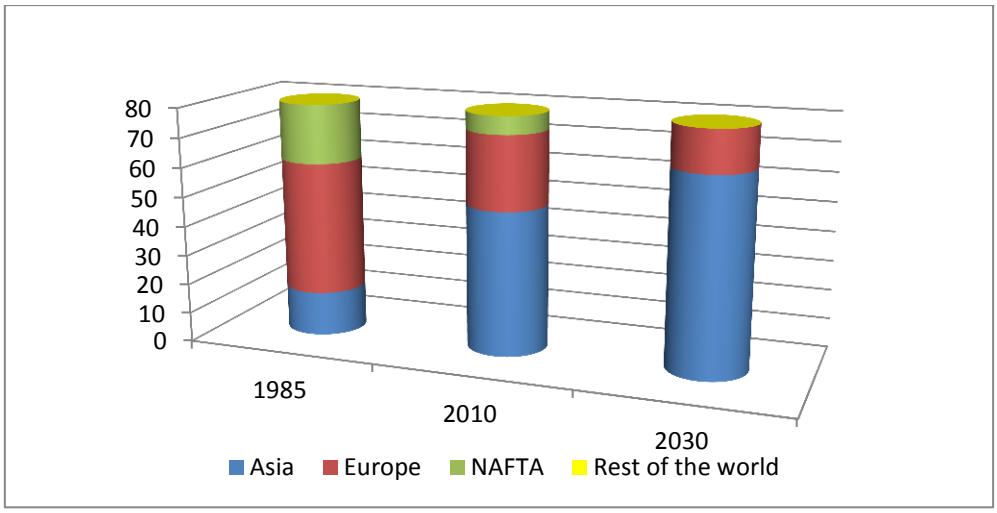

Figure 3 The extends of the global chemical industry until 2030 [9]

11. There are currently two main trends. First, new terminals will be constructed (Figure 4), and some wider terminals will be enlarged. One reason for this is optimizing the entire transport logistics chain as a result of globalization. The second trend is the rapid decomposition of new biofuels for automotive and industry [17].

Figure 4 Position of the world major chemical terminals [17]

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