

NHH



Analysis of the economics of Valemax vessels

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Abstract

In 2008, Vale, the Brazilian mining giant signaled a significant transformation in the dry bulk shipping industry. The firm ordered the biggest vessels, ever constructed, called the Valemaxes (400,000 tons deadweight) to transport its iron ore from Brazil to China. The destination between these countries is far and in comparison with the company's big Australian competitor costlier. Vale needed to cut its transportation cost and one solution was the economies of scale in ship size. Constructing bigger vessels with twice the transporting capacity of the traditionally chartered Capesize vessels can provide significant cost reduction. This strategy raised fears of monopolistic attempts over this route resulting in a ban by the Chinese authorities leading to Vale's shipping cost increase. This paper, analyzes the operational and economic aspects of the fleet of Valemaxes and attempts to find out the formation of the transportation cost after the imposition of the unexpected ban.

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1. Introduction

The shipping business is crucial for the development of economic activities, as ships provide a cost effective way of transporting large volumes of basic commodities and finished goods from the places of production to the places of consumption. The demand for shipping services derives from the demand for commodities. Freight would not be transported to a location if no customers demanded the particular product. In fact, the economic growth generates the international trade that creates demand for transport. The demand for sea transport is driven by the demand for the physical commodity and is affected by a number of factors such as political factors, the world economy, the seaborne commodity trade, the distance on which the cargo is shipped and the transport cost which essentially is the price of the transport service. Supply is affected by the fleet size and the operational efficiency (Cheng et.al, 2010).

Dry bulk shipping can be defined as the transportation segment used to carry commodities such as iron ore, grain and coal that can be more easily handled if transported in bulk or large quantities, (Stopford, 2009). It is classified in two categories major and minor bulk. Major bulks are iron ore, coal and grain which are shipped in larger ships and minor bulks are fertilizers, steel, sugar, cement etc., which are carried in smaller and more versatile ships, (Bornozis, 2006). Its development started back to the nineteenth century as a result of the need to cut the transport costs, when the shipment size of commodities increased so much that the commodities should be transported in shiploads and the economies of scale could be utilised, (Grammenos, 2002).

During the past few decades, the dry bulk trade volume has considerably increased and represents one third of the world trade due to the development of Asian economies. The industrialisation, the liberalisation of the international trade, the technological advances and the higher demand for dry bulk commodities have led to an expansion of the dry bulk fleet and the ship size. By using bigger ships, shipowners can gain maximum profits as these ships have lower unit costs and cargo handling. However bigger is not always better due to the lack of flexibility and trading routes. Constraints exist due to the larger size, as the number of ports and terminals where they can berth is constrained since special infrastructure to handle them should be built, (Stopford, 2009).

Dry bulk shipping has been capable of carrying of over 300000 tons deadweight with the main categories: Handies, Handymax, Capesize and Panamax. Other dry bulk carriers are the combined carriers and the VLOCs (Very Large Ore Carriers). Iron ore has been the largest of the dry bulk commodity trades and is the primary raw material for making steel. The urbanization and industrialization of the Chinese economy led to a sharp increase of the steel production, which requires high consumption of iron ore, (Sukagawa, 2007). Despite the fact that China belongs to the biggest iron ore producers, the production was not sufficient to cover the industrial needs, rendering China the biggest importer of iron ore in the world. This triggered an augmentation of the iron ore demand that ended up to high prices, intensified by a simultaneous increase at the freight cost. When the financial crisis hit the iron ore market and the prices plummeted, Vale the Brazilian mining giant and one of the main iron ore suppliers of the Chinese steel industry faced challenges. Besides this, the freight cost that Vale faced was twice the freight cost of its competitors.

To respond to these challenges, Vale decided to build the biggest dry bulk vessels existed in order to transport its iron ore to Asia and mostly to China. Hence, in 2008, they ordered 35 valemax vessels of a capacity that reached 402,347 tons deadweight, to be delivered in 2012. These ships have twice the capacity of the capesizes used for the transportation of iron ore. The rationale behind this was to take advantage of the economies of scale that the bigger size of the vessels would render and shrink the geographical disadvantage. Nevertheless, the market conditions had changed by the delivery period and Vale's venture faced serious opposition. The Chinese government did not allow the valemax vessels to berth to its ports claiming safety reasons resulting in Vale's soaring shipping costs. Thus, the firm has made an alternative plan to ship its production to Asia. They will use two floating transfer stations in Philippines and a storage and distribution centre in Malaysia to transship the cargo to smaller vessels, approved by the Chinese authorities and allowed to unload to the country's ports.

Thus, it turns out that numerous factors affect the operation of the dry bulk shipping market and numerous actors involved in the business whose decisions are interrelated. The trading and sea transportation of the commodities have a central role in this business since the efficiency and the availability of services of the first ensure the effective economic development and trade. The purpose of this thesis is to provide further evidence on the ongoing Valemax discussion. Vale is both shipowner and charterer of the vessels. It charters Valemaxes under a 25- year contract of affreightment. However, the company proceeded to

the called vertical integration strategy, under which Vale is a cargo owner who owns his own vessels to handle the transported capacity. Both types of deploying the Valemaxes for the transportation of iron ore entail a high cost after the Chinese intervention.

The total cost of three different transportation systems for the route Brazil- China will be computed and compared over 2012-2014. One is the transportation of iron ore from Brazil to China, transhipping the cargo into smaller vessels at the Subic Bay in Philippines, the second is the direct transportation of the cargo from Brazil to China and the third is the deployment of capesizes from the spot market to transport iron ore from Brazil to China. The purpose of this thesis is to investigate the issue from every economic aspect and give an answer on the questions aroused concerning the Valemaxes profitability

The rest of the study is organized, as follows. Part I is the introduction of the thesis. Part II is the literature review. Part III includes the composition of the problem and the methods used to solve the question. Part IV is the final section where the data and the conclusions of the research are presented.

2. Literature Review

2.1 Dry bulk shipping industry

2.1.1 Structure of the dry bulk market

By definition, dry bulk shipping is associated with the sea transportation of commodities in an unpackaged form on a “one cargo/one ship basis”, (Gratsos, 2010). The demand and supply of the dry bulk services and the market structure are the main drivers of the dry bulk market’s performance. Recent research suggests that dry bulk market structure is nearing that of perfect competition. First, there is a large number of ship-owner firms, providing services. Secondly, information can be accessed to some extent, as freight rates are indexed in the Baltic Dry Index and the existing customers are disclosed through shipbrokers. The barriers to entrance exist because large capital is requested to invest in ships but there is support from the shipping commercial banks that provide some financing, other than that the entrance barriers are weak. Regulatory or economic obstacles are very few and firms have no strong motivation to withdraw from the market, even if they exit the market there is no decrease of tonnage as the firms are able to sell it to other firms who operate in the second-hand and purchase market. Lastly, the freight rate, the price and fleet size are determined by the market largely.

2.1.2 Demand and supply Drivers of the dry bulk market

The demand for dry bulk sea transport services derives from the demand of the physical dry bulk commodities and it has five determinants. First, the world economy is a determinant of the demand, as a positive relationship between the global economy growth and the shipping trade is observed from two different aspects. On the one hand, the world economy generates the demand for sea transport through imports of raw materials from the source of production to the region of consumption. The strong growth of the Chinese economy generated the growth of the iron ore trade and as a result increased the demand for sea transport services. On the other hand, the economic cycles are reflected to the demand for ships. A recession in the world economy coincides with a recession in the seaborne trade.

The second decisive factor of the demand for ships is the seaborne trade, related to the cargo volume of the commodities transported. This effect is apparent in both short term and long

term, which concern the seasonality of some commodities and the economic characteristics of the commodities' industries, respectively. Average haul is the average distance over which the cargoes are transported and is closely related to the time needed by the ship to complete a voyage. China's demand for iron ore exceeded the Australian abilities to supply iron ore resulting in the expansion of its supply network. Brazil was the next China's top supplier and therefore, bigger ships for longer distance were in demand.

Political factors play also a central role in the demand for ships, often known as random shocks. Their impact can destabilise the activity of the economic system, giving rise to the cyclical process. Some candidates of the random shocks are weather changes, wars, new resources, commodity price change. The last component of the sea transport demand is the transportation cost that depends on the shipping operations, as the transportation of raw materials occurs, only if the transportation cost decreases to a reasonable level or a principal benefit is secured by the quality of the product, (Stopford, 2009).

The supply of sea transport refers to the amount of transport services provided by the shipowners based on the optimisation of their freight revenues, or else the available capacity for carrying cargo from one port to another by sea, namely the supply of tonnage and mainly concerns the fleet size. Its main drivers are four parties. Shipowners resolve whether to order new ships or scrap old ships. Shippers order new space to transport their cargo from the shipowners. As a result, shippers may exert some influence on the shipowners' decision for ordering new ships or not. Bankers control partly the market, by selecting the lenders of the capital and regulators implicitly affect the fleet capacity through the safety and environmental legislation, (Cheng, 2010).

There are four determinants of the supply for sea transport services. The merchant fleet is fixed in the short-run, but in the long run scrapping and deliveries determine the fleet growth, (Stopford, 2009). By the end of 2013, the dry bulk fleet has grown considerably and the delivery of the valemax vessels has contributed to this, creating an overcapacity situation in the market, (BRS-Paris, 2014). The supply of dry bulk carriers does not only concern the number of ships in service but also to the operational efficiency of the worldwide fleet, often called, fleet productivity.

Fleet productivity is measured in tonne miles (tonnage) per deadweight and depends on speed, port time, deadweight utilization, and loaded days at sea. Speed is the main

determinant of the time required to complete a voyage. If a ship is designed to take on a voyage with a low speed, then the time to discharge is greater and as a result, the transport capacity is reduced. Port time is associated with the ships' physical performance. Heavy congestion in ports decreases the availability of ships for trading. The deadweight utilization brings up the issue of the cargo capacity lost due to factors such as bunkers and stores. The time of vessels, divided into loaded days and unproductive days, affects the operational efficiency and is subject to the prevalent market conditions, (Stopford, 2009).

Dry bulk market consists of four interrelated markets, (Cheng, 2010):

- Freight market, which involves the sea transport services trading
- The new building which concerns the ordering and building of new ships
- The sale and purchase market where second hand ships and vessels are traded
- The demolition market, where old vessels are sold for scrap to dealers.

The shipbuilding production plays a central role in the adjustment of the fleet that does not take place quickly or easily. In fact, the time lag between ordering and delivering is between 1 and 4 years. Scrapping and losses deal with the rate of the fleet growth through deliveries of new ships and deletions of ships from the fleet as scrapped or lost at sea. Finally, freight revenue is a mechanism that the market uses to make decision makers adjust the capacity in the short term whilst in the long term is seen as a way to reduce the costs and improve the provided services, (Stopford, 2009).

2.1.3 Dry bulk freight market

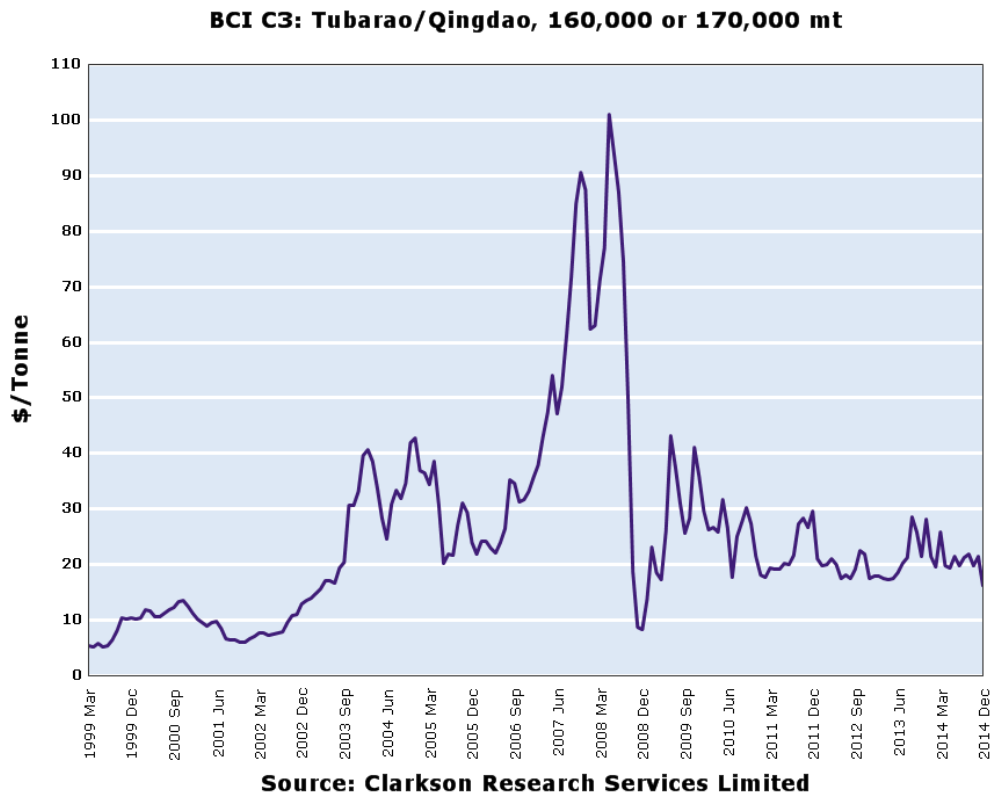
The freight market is the adjustment mechanism linking the supply and demand described in the above section. Shipowners and shippers negotiate to determine a freight rate, which reflects the balance of ships and cargoes available in the market. Too many ships in the market mean a low freight rate and very few ships a high freight rate, (Stopford, 2009). Therefore, the construction of the Valemaxes affects the freight market and is important to assess what this impact is.

After 2003, the emergence of the fast growing economies of China as a major importer caused a sudden positive change in the growth of demand, which brought a boom in freight rates and freight volatility, ultimately triggering a rise of the supply growth. Scrapping stopped and new building started. Uncertainty around the future fleet requirements and the

risk of over tonnage aroused following of a prolonged peak freight volatility. Xu et.al (2011) also noticed that a positive change in the fleet size growth will boost the freight volatility and that the spot rate volatility of Capesize dry bulk has a stronger influence on the change of fleet size because Capesize ships are more susceptible to market changes due to the trading inflexibility of larger vessels. The strong iron ore demand from China led to a continual upward trend of the freight rates up to the middle of 2008 when the freight rates reached the peak, as the Dry Baltic Index reached the all-time high of 11973 and the new building order book was full at over 170 million deadweight tons. The volatility of the freight rate and its increasing trend raised significantly Vale's shipping cost, which hired capesizes from the spot market. Thus, just before the economic collapse Vale decided to reduce its exposure to the freight volatilities and establish its presence to Asia by creating its own fleet.

By the end of 2008, the financial crisis hit the dry bulk market and the Dry Baltic Index plunged to 663 points. As a consequence the capesize earning dropped by 90%, creating serious financial problems to the capesize shipowners who were not able to cover their marginal cost, namely their running costs and had to pay for the capital costs, (UNCTAD, 2009). As a result, many capesize shipowners did not send their vessels to load in Brazil and Vale found itself in default. The graph below shows the spot freight rates of the capesizes for the route Tubarao-Qingdao. The freight rates remained at the relatively low levels generated in 2008, when the rates plunged. It seems that the reduction of Vale's shipping cost would be on the right direction if the ban rebounded. The spot freight rate of capesize is almost the same as the cost of the direct transportation of iron ore from Brazil to China with the Valemaxes, reckoned by alphabulk to be around 17-18 US\$ per ton, while transporting twice the quantity that capesizes can carry.

In 2013, the majority of the valemax vessels was delivered, bringing about a series of troubles. First, the smaller vessels around the size of 300,000 tons deadweight faced employment difficulties but the most important issue aroused from these vessels is that the Baltic Exchange 4TC averaged at the lowest rate ever recorded during this super cycle. The blame is put on the expansion of the valemax fleet which consisted by 1st April of 2013 of 26 vessels, (BRS-Paris, 2014). Fortunately, the low levels of freight rate prevailed over the first seven months, as later the spike of the tonnage demand brought the recovery. Thus, 2013 is characterised by a split in two regarding earnings, (RS Platou, 2014).



(Figure 1: BCI C3: Tubarao/Qingdao, 160,000 or 170,000 mt. Source: Clarkson Research Services)

Views differ over the extent to which the injection of valemaxes affected the freight rates and capesize earnings. Currently there are 29 valemaxes adding 11.6 million tonnes capacity to an oversupplied market, which depresses the capesize rates. These vessels have though some positive effect on the market as their innovative design increases the fleet productivity and efficiency in the dry bulk transport, while the transshipment hubs engage feeder ships necessitating the employment of the smaller ships.

2.2 Iron ore market

2.2.1 Supply and Demand sides of the iron ore market

The iron ore market is the starting point of the valemex vessels' construction. The reason that Vale wanted to achieve a cost advantage was to sell cheaper iron ore to China. Thus, it is essential to comprehend the supply and demand sides of this market to conceive its changes and effects on the case.

Supply side:

- Mining companies: In the iron ore trade, the supply is determined by the production and stockpiles of iron ore, which increase the availability of the source. If the availability is higher than the demand, prices will decline. The opposite happens when the supply is lower than the demand. Vale together with the Australian BHP Billiton and Rio Tinto are the mining leaders as their exports amount to 70% of the world iron ore exports which can be observed in the following table.

	2010	2011	2012	2013	2014	2015	2016	2017
Australia	402	439	493	525	588	678	749	779
Brazil	311	313	333	372	411	443	467	489
India	96	63	43	46	46	46	44	40
Canada	33	34	36	37	37	38	38	38
South Africa	48	54	58	64	67	71	75	79
West Africa*	11	12	14	15	17	23	35	47
World exports	1051	1075	1149	1213	1279	1355	1439	1500

* West Africa includes Guinea and Mauritania.

(Table 1: Iron ore exports, 2010-2017. Source: BREE, 2012)

- Bulk Capesize Owners and Operators: They provide the transport service on the main iron ore routes and as iron ore trade is mostly served by capesizes, they determine the demand.

Demand side

- China: Its strong steel production and massive demand of iron ore have led to its prevalence on this side.

	2010	2011	2012	2013	2014	2015	2016	2017
European Union	133	136	139	142	144	146	149	152
Japan	134	128	134	136	138	140	142	143
China	619	645	713	742	757	770	813	854
Korea, Rep. of	56	64	67	72	75	78	80	83
Chinese Taipei	19	22	23	23	24	25	25	26
World imports	1051	1075	1149	1213	1279	1355	1439	1500

(Table 2: World Iron ore Imports, 2010-2017. Source: BREE, 2012)

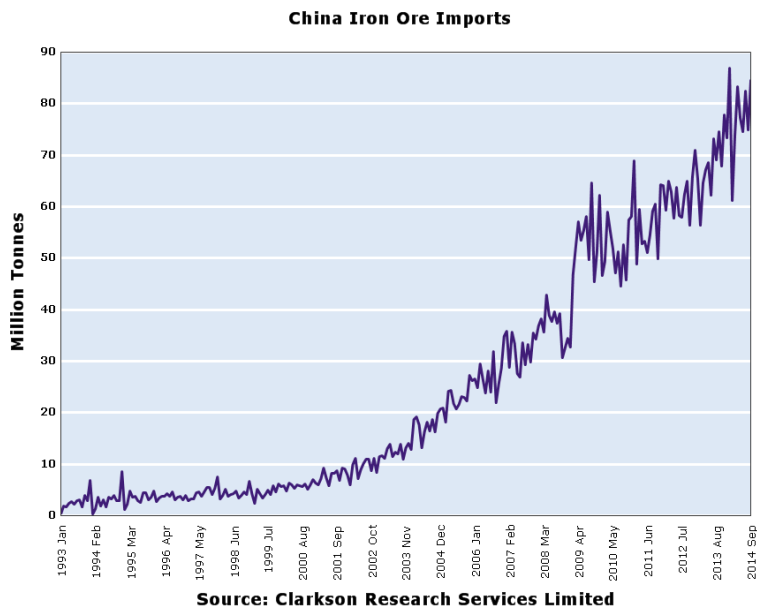
2.2.2 Production and trade

Iron ore is a dry bulk commodity used as an intermediate raw material for the production of pig iron and steel, combined with finished steel constitutes the world's second largest

commodity by value after crude oil. Iron ore is categorised by the place of production, pricing and the ferrous content, expressed as a percentage. Ores carrying high quantities of hematite or magnetite (> 60% of iron concentration) can be fed directly into the iron making blast furnaces. The most merchantable grades of iron ore lie between 58% and 66%. Mining iron ore is a highly capital intensive business as it requires strong investment in infrastructure and transport facilities. As such, the supply side of the iron ore trade is dominated by few countries, (Intercontinental Exchange, 2010).

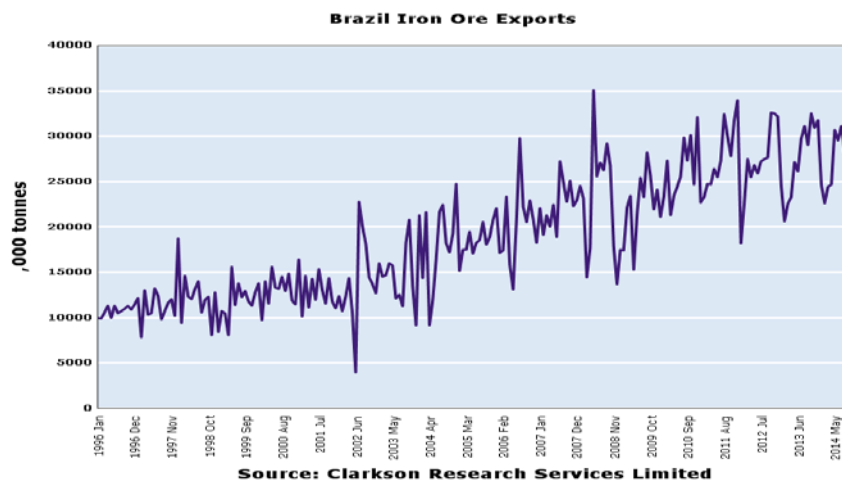
Iron ore trade is of crucial importance. It is one of the the demand for transport services' determinants and the main reason that led Vale to construct the Valemax vessels. Iron ore demand is driven by the steel production. The global production of iron ore used to be stable at 800 to 900 million tons per year by 2000, when it started to increase and reached approximately 2950 million tons of annual production by the year 2013. The sharp increase of steel production is not a coincidence, (Hellmer et.al, 2012). The large-scale urbanization and industrialisation of the Chinese economy led to a consumption of almost 480 million tons of steel over this period. As the domestic production was not sufficient to cover its industrial needs, China turned to the foreign suppliers, becoming the biggest importer of iron ore in the world and the main driver of the iron ore market's demand side.

The reason for this outcome is the limited supply of construction materials and the limited labour force, as the rapid economic growth overcame the available amount of producing factors. However, the main reason for the rapid increase of imports is that most mines in China are old and the deposits are magnetite. The iron content of magnetite is low, estimated to be between 25% and 40% and even though the Chinese government promoted the expansion of the domestic iron ore mines, many had to undertake an elevated operational cost and they shut down, (Sukagawa, 2010). China is the only country that steadily increases its imports, as indicated in the graph below.



(Figure 2: China Iron ore Imports. Source: Clarkson Research Services)

The quality of iron ore is a salient factor for the steel producers because it reduces their operational cost. The Brazilian iron ore is considered to be of high quality (>60% of iron content) and thus in high demand by the booming Chinese steel industry, resulting in its increasing exports as showed in figure 3, where large spikes are observed in the exports but the general trend is increasing. Vale increased its production to keep up with the growing Chinese demand. After 2008, the production of iron ore fell and reached 1.6 billion mt, the first drop in production after seven consecutive years of growth. Steel production also fell the first quarter of 2009 but quickly recovered due to China that increased its steel production by 13.5%, (Magnus Ericson, 2010).



(Figure 3: Brazilian Iron ore Exports. Source: Clarkson Research Services)

Iron ore market keeps growing until 2011 while Chinese production declines, rendering Australia and Brazil as the dominant suppliers who control the iron ore production. India may also have large and good quality resources of iron ore but its steel industry continually grows and Indian iron ore is domestically used. However, the growth in the world of iron ore market stopped in 2012 and the production declined marginally. Among the major producers, Australia was the country that grew its output by 8.9% while Brazil, India, China dropped its production and Australia became the dominating force in the iron ore production. The rate of the economic recovery in 2012 is rather slow and the Chinese economic growth slows down but the demand for iron ore remains strong up to 2013, according to Metal Miner. The concentration of iron ore supply side increases and the supply of iron ore rises as BHP Billiton, Rio Tinto and Vale invest in new major expansion projects with the purpose of keeping the prices high enough to cover these costs but at the same time low enough to prevent the entrance of new players in the market. China's inventory of iron ore shrank. The imports weren't stockpiled but the end consumers directly used them.

In 2014, Vale has been unable to provide new tonnage in the Chinese market, being at risk for losing the title of the biggest iron ore exporter and the Rio Tinto will replace its place. Australia has gained the lead in the demand response and Fortescue Metals enters the market, growing rapidly its production and thus becoming the fourth largest iron ore producer. The year, 2014 is a transitional year. The market is moving from a deficit to a surplus condition. Taking into consideration the certain and probable projects, 536 million mt will be added by the end of 2015, whilst 230 million mt will be needed. However, the reversal of the market cannot be assured yet due to several factors. The most important is that the market will be maintained tight, the large iron ore producers have the flexibility to reach their expansion plans and a segment equal to 150 million mt of the Chinese capacity may be closed down to keep the price at the present levels, (UNCTAD, 2013).

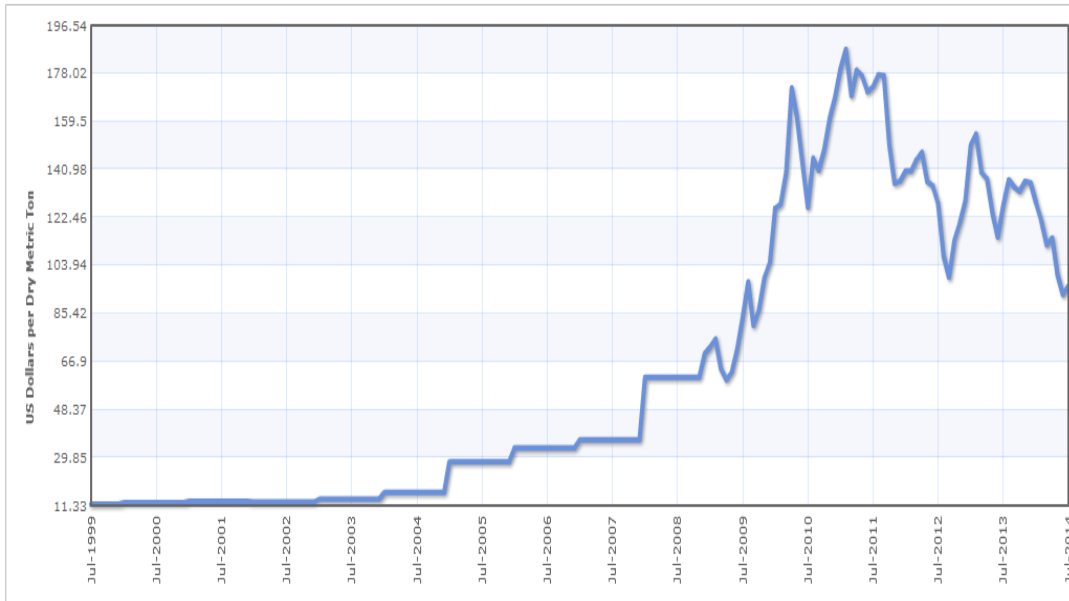
2.2.3 Pricing mechanism

Historically, the iron ore market is characterised by the producer pricing, that is, large producers and consumers in two dominating regional markets, negotiated an annual price, called benchmark price. The main reason for this pricing regime is that the demand of iron ore is sensitive to changes in the GDP growth and both iron ore and steel producers favoured the stabilisation of pricing. During the past few years, a change of salient importance has occurred in the pricing mechanism. The largest volumes of iron ore are traded in the spot

market. In 2010, the benchmark system abandoned and replaced by the system of quarterly negotiated prices, influenced by the spot market prices during the previous quarter, (Wårell, 2013).

Iron ore prices are categorized between two types: Freight on Board (FOB) and Cost and Freight (CFR) or cost insurance freight (CIF). The former indicates that the seller of the commodity is responsible for paying the transportation cost to the port of shipment and the buyer pays for the cost of loading/unloading of the goods on both the port of export and import, inland haulage cost, customs clearance, origin documentation charges, demurrage if any and port handling charges. The latter indicates that the seller also pays for the freight between the port of delivery and the destination port and the risk transferred to the buyer once the goods are loaded on the vessel. In CIF terms, the seller is in charge for the insurance too, (Mining Journal, 2012). The spot price in China is the basis for pricing in all the parts of the world and there are three main series: Metal Bulletin, Platts and SBB, but uncertainty over their representativeness and security is aroused, (E&MJ, 2010).

There are some oppositions concerning the introduction of a spot market of iron ore by the European steel industry, as they claimed that this could bring more volatility to the steel prices. However, Wårell (2013) conducted an analysis on the effect that the change of the pricing regime would have on the iron ore prices. The conclusion of this research supports that the volatility indeed increased after the spot prices were introduced and the effect of this change is also significant but not from the consumer point of view where the volatility exists in the transportation cost market. The price of iron ore is essential; as it is the revenue derived from the iron ore transactions and determined by the interactions of iron ore demand and supply under the new pricing system. Vale used to sell its iron ore on a FOB basis but in 2010, it switched to the CFR spot prices. As it referred above, China is driving the demand and has a central role in the price formation. In the below graph it can be noticed that the strong demand after 2009 along with severe weather conditions and delays to expansions have caused supply disruptions which led to a price increase, triggering the entrance of suppliers in the market, (Resource Capital Research, 2012).



(Figure 4: Iron ore price. Source: www.indexmundi.com)

However, the high prices did not last for long as by 2014 prices dropped to levels below US\$ 100 per ton (Figure 4), a level not affordable by the high cost Chinese producers. If the price does not recover, the Chinese will exit the market. The main trigger for this reduction is the significant low cost production added by the big three mining companies: Vale A.S, BHP Billiton and Rio Tinto. The fall of the iron ore price affected Vale's performance that saw its losses to increase since its production cost estimated to be US\$104 per ton and thus, higher than the sales price, urging its need to reduce the cost, (Boling, 2014).

According to Murilo Ferreira, increased production can lower the cost and improve the quality that in its turn can substitute other productions inside and outside Vale that have higher cost and lower quality. He added that the transportation cost of iron ore from Brazil to China is much higher than its competitor's US\$ 7.5 to \$10 per ton, should be significantly lower. To decrease the shipping cost Vale signed, as referred above, a long-term contract with COSCO, according to which they transferred four of its Valemax vessels (400,000 tons dwt) to them that will be chartered back to Vale for 25 years, (Fan, 2014).

As Martins, explains:

" We do not need to be the owner. To have or not have the ship is not the strategy. It is a financial issue. If I can get a better freight rate by selling them, sure we would sell, as long as we have the long term contracts of affreightment on the ships.", (TW, 2013).

However, it is expected that the iron ore market will be characterized by tight conditions within the coming years, while prices will decline slowly as new production is coming on stream, but sufficiently high to keep the Chinese iron ore mining industry operating at 222 million mt, (UNCTAD, 2013).

2.3 The case of Valemax

2.3.1 Vale's profile

Vale S.A. or Companhia do Rio Doce is a Brazilian multinational mining company operating in more than 30 countries around the globe and one of the largest logistics operators in Brazil. It produces a wide range of products such as ferroalloys, manganese, copper, bauxite, potash, kaolin, aluminium and alumina, while being also active in the energy sector and operating nine hydroelectric plants, but the largest production comes from iron ore, pellets and nickel. In fact, Vale is the largest producer of iron ore and pellet and the second largest of nickel in the world. Iron ore found as fines, in the form of grains like sand, is turned into pig iron and in combination with coking coal and energy, is then used to produce crude steel. The most merchantable grades stand between 58% and 65% of ferrous content, (Global Business Report, 2013).

Vale operates four systems in Brazil for producing and distributing iron ore (northern, southern, southeastern and Midwestern systems). Two of these systems are fully integrated (the northern and the southeastern systems) and consist of mines, railroads and a marine terminal and a port. The southern system consists of three mining sites and two maritime terminals. Ten pellet plants are operated in Brazil and two in Oman. During the first quarter of 2012 three of the pellet plants, operated in Brazil, were suspended due to the market conditions. They also have a 50% stake in a joint venture that owns 3 integrated pellet plants in Brazil and a 25% stake in two pellet companies in China.

As referred above, this firm is the leading operator of iron ore logistic services in Brazil and other regions of the world due to its extensive logistics infrastructure, including railroads, ports, maritime terminals and distribution centres. Two of the four iron ore systems are integrated and linked to the ports and terminals. In this way, the fast and efficient transportation of the firm's products is ensured. Iron ore market is highly competitive. The biggest producers are Australia, Brazil, India, South Africa and China and the biggest

consumers are Japan, Korea, China which accounts for 60% of the global steel production and other developed and developing countries, (Intercontinental Exchange, 2010).

Vale's main competitors come from Australia, including its subsidiaries and affiliates of BHP Billiton, Rio Tinto Ltd and Fortescue Metals Group Ltd. Brazil and Australia account for 70% of the world's iron ore exports. Asia and in particular China is the main driver of the iron ore trade and Vale's biggest trading partner (China absorbs 36% of Vale's sales), Australia is privileged due to the close proximity to Asia and as such a lower transportation cost than Vale is undertaken. Vale's distinctive advantage over Australia is the quality of iron ore (65% of iron content, according to the China iron and steel association). The higher the quality of ore the less the levels of impurity are, the less the need for ore processing is and thus steel making companies are ensured minimum cost of production, (Vale's annual report, 2013).

In 2008, they ordered from the Jiangsu Rongsheng Heavy Industries (RSHI) 12 vessels of 400000 tons deadweight, called valemax vessels and in 2009, they acquired 22 Capesizes and ordered another seven from the South Korean Daewoo Shipbuilding and Marine Engineering (DSME) with a cost at around \$140 million a vessel. Additionally, another 16 ships of similar vessels will be constructed in China and South Korea for other shipping companies, but will be chartered to Vale under long-term contracts. The first Valemax, Vale Brazil, was delivered in 2011 and it was expected that all the 35 of them would be in operation by 2013 but 2014 has come and four of them are still under construction.

Valemaxes belong to the VLOC fleet and are mostly deployed for the transportation of ore from Brazil to China. Some authors claim these vessels form their own fleet category of the Ultra Large Ore Carriers (ULOCs). Their carrying capacity is estimated to be slightly over 400000 tons deadweight. Their length is 362 meters and draught of 23 meters, slightly larger than the Chinamax vessels (380000 ton deadweight). They are designed to sail for 30 years and are up to form their own fleet category. In total, the company controls 80 vessels of various sizes. This venture signals a big transformation of the dry bulk market as it represents a fleet expansion and affects all the major parties involved in the iron ore trade and transportation.

2.3.2 Vale's strategy

Since iron ore is the company's main product and the demand for it from China and the Asian countries was strong, Vale decided to establish its presence to Asia. To achieve this goal, they needed to reduce the transportation cost, which was much higher than the Australian competitors' due to its geographical proximity. A ship loaded with iron ore takes an average of 45 days to make the journey from Brazil to China, while the journey from Australia to China completes in 10 days. The big distance in association with the robust demand from China which was almost doubled the freight rates by 2008 raised the delivered cost of ore to China above a comparable cost of Australian ore and led Vale to search for a strategy that would remove the distance related competitive disadvantage.

Generally, competitive advantage is the ability attained through attributes and resources to perform at a higher level than other competitors do, operating in the same industry or market. In other words, an organization manages to outperform its competitors by developing an attribute or a combination of attributes. It is an advantage over competitors gained by offering consumers greater value through either a lower price or providing greater benefits and service, which justify the price, (Stutz and Warf, 2009). This is what Vale is trying to achieve, that is, the company intends to lower the price offered to the buyers by reducing the cost. Another definition of competitive advantage, first set by Michael Porter (2009) in his generic business strategies was that of the cost leadership, where a company intends to become the lowest cost producer in the market. Such a producer will make profits if the selling price is at its lowest level that can be reached, if a firm is able to operate at a lower level than its rivals do.

One approach to do this is the economies of scale, which are cost advantages obtained due to size, output or scale of operation with the cost per unit of output decreasing with increasing scale as fixed cost spreads out over more units, (Sheffrin, 2003). The shipping cost consists of three parts: capital cost, operating cost and voyage related costs. The fixed cost is comprised of the capital and operating cost. Capital cost depends on the price of the ship, the ship financing and the operating cost that constitutes expenses in insurance, hull and machinery, crew wages, administration and other day-to-day costs. Capital cost is subject to economies of scale because big ships cost less per ton than smaller ones. The voyage costs are the variable costs associated with the costs of a specific voyage and it includes items such as fuel costs, canal dues, port dues and cargo handling costs such as stowage, loading

and discharging charges. Optimizing the ship design can minimize these costs. Factors that affect these costs are the size, the speed, the age, the type of the vessel. Larger vessels consume more fuel than smaller ones and older vessels consume more fuel than the newer vessels, (Kassemble et.al, 2011). Therefore, fuel consumption per ton-mile strongly affects the voyage cost as it determines the fuel cost. The improvement of the vessels' technological features can greatly contribute to the transportation cost cutting.

It has been observed that a larger vessel is more benefited by sailing with low speed under long voyage and this can explain the fact that dry bulk carriers keep a low speed in the voyages. Selecting the speed that minimizes the transportation cost, often called economical speed is of high importance and positively related to the fixed costs. When the fixed costs go up, the speed also rises and vice versa. A negative relationship exists between the bunker cost and the vessel's speed. A drop at the bunker cost will result in a rise of the speed. Thus, the bunker prices have a central role at the speed design since a high bunker price may be translated into savings for the shipowner when the vessels keep a slow speed, but a slower speed means that less cargo is delivered and decreases the supply of tonnage, (Shun et.al, 2010).

Jonkeren et.al (2012) studied the effect of the fuel price and the freight price on the speed taking into consideration the endogenous character of the freight price and their results indicated a positive effect of the freight price on the speed and a negative effect of the fuel price on the speed. Technical innovations in the ship hull and engine power may allow the augmentation of the cruising speed resulting in a larger number of round voyages, while at the same time the fuel consumption may be reduced. Higher sailing frequency means faster delivery and responsiveness to customers, implying the possibility of higher income and lower unit cost since the latter is allocated to a greater number of trips.

Investing in larger ships has traditionally been the way to increase the capacity of cargo transportation and raise the profitability of shipping through higher freight income, (Laine et.al, 1994). Kendall (1972) described that the optimal size of a particular vessel used on a particular route, is the one that minimizes the total transportation cost. In the total transportation cost he included the terminal costs (port cost, dredging, berthing cost, handling cost and storage cost) and not only the cost incurred by the ship at sea. According to his theory, the size is determined by the trade volume, the value of the cargo and the

distance, as demand will cause tonnage which will determine ship size and the ship size will affect the depth of water provided by the ports.

Cullinane and Khanna (2000) point out that on any given voyage the overall efficiency of a ship is contingent on the total time the ship takes to complete the voyage. The reason that stands for this is that the time spent in port is unavoidable, as cargo need to be loaded and unloaded, but the time in port is a function of the port's cargo handling rate and infrastructure and as such its improvement is not directly related to the increase of the ship size. Hence, as Jaason and Shneerson (1982) stated, the optimal ship size is obtained by the trade off between the economies of size in the hauling operations and the diseconomies of size in the handling operations. In port the handling cost per ton increases with the ship size but the hauling cost per ton declines with the size of the ship. Larger ships are deployed for larger distances.

Investments in ship size, cruising and loading speed are interrelated their trade-offs are traced starting from the traditional operations and extended to the new opportunities offered by new technology, (Laine et.al, 1994). The technical economies of scale were what Vale wanted to exploit in order to significantly reduce its transportation cost and become competitive. Valemax is an innovative ship design, the vessels have the ability to load 13500 tons/h delivered to each of the seven holds in a single pour. This mode of loading has drastically diminished the loading time.

Traditional bulk carriers cannot support this loading rate and during the loading operation, the ship loader needs to move alongside the hull in order to keep the vessel stable and under minimal levels of stress. This trait is vital for Vale as it ameliorates the terminal productivity. In addition to this, the vessel's main engine is highly efficient with very low fuel consumption of about 108t/ day at about 15 knots. In energy and transportation, the vessels are able to cut the carbon emission by 35% per ton of cargo carried in comparison with older ships. All these features combined provide Vale a very competitive transportation cost and a much greater capacity to ship iron ore to clients, (Sterling, 2012).

Thus, the benefits from the Valemaxes are twofold for Vale. One is the competitive advantage over Australia due to the less expensive shipping options and the other is the risk mitigation for the Cape freight rate volatilities. Since 2003 and until the mid-2008 the Cape freight rate increased substantially, having a straight impact on Vale's trade margins. This is

because the high levels of freight rates for ore cargoes from Brazil to China were far higher than freight rates from Australia, as the voyage involves a much greater distance about 3.5 times the Australian one. Higher freight costs mean higher delivered cost of the Brazilian ore to China way above the costs of Australian ore. Therefore, Valemaxes would provide a cost profile considerably lower than a Cape spot chartering strategy, offering a greater cost control. Vale does not desire to depend on the spot freight to move more than 100 or 150 million tons of ore. That is why they built the fleet of 19 valemaxes costing \$2.3 billion and agreed to a 25-year contract of affreightment valued at \$5.84 billion with STX Pan Ocean Co., a Seoul based shipping firm to haul its ore from Brazil, (Bloomberg, 2012). The construction cost and the bunker consumption are the main drivers, which contribute to this perspective.

In 2008 that Vale placed its first orders the potential to obtain a much lower pricing than the Capes per dwt basis existed and the savings were estimated to be 40% down than the Cape quotes. In 2009 that Vale placed the second set of orders, Cape newbuilding contract prices had dropped by 50% while Vale's orders had a 20% discount to the prices prevailed in 2008. As a result, the Valemaxes lost the capital cost advantage eliminating the gains that Vale would make otherwise, (Sterling, 2012). Initially the cost of transporting iron ore from Brazil to China was expected to be at around 17-18\$ per ton which is cost saving as the transportation for the same route with capes currently costs 21-22\$ per ton, (Antonioli, 2011). This can be translated into an almost 20% -25% cost reduction.

To conclude, Vale followed a strategy called vertical integration strategy which occurs when the same firm directly controls both the production process and the shipping of one or more of its inputs or outputs, (Casson, 1986). It refers to cooperation among the stages of the supply chain, (Van de Voorde, 2009). Under vertical integration, the economies of vessel size in a route may create a natural monopoly, which the company can exploit by raising the price of its services, (Casson, 1986). The construction of Valemax is part of a logistical solution that brings Brazil closer to China. However, the larger size imposes some constraints concerning the physical characteristics of the ports of loading and discharge, cargo handling facilities and the draught factor. Valemaxes cannot have access at all the ports and terminals. In fact, the loading terminal options are restricted to the terminals: Tubarao and Ponta da Madeira located in the southeastern and northeastern part of Brazil, respectively. The same applies to the discharge terminals which are few, among them

Qingdao (Dongjiakou) and Dalian in China and then Rotterdam. Apparently, such a strategy could not be implemented without any challenges and oppositions.

2.3.3 Vale's challenges

Two factors that dramatically altered the economics of the above plan. One is the collapse of the global dry bulk freight market in 2008. The freight rates plunged and remained since then at low level, diminishing the additional cost of transporting iron ore from Brazil's long distance exports to Asian countries and thus, the advantage of the Valemax employment reduced. The second contributing factor to undermining Vale's strategy was that after the first delivery of the Valemax in 2011, the Chinese authorities banned the Valemaxes' berthing at the country's ports. These ships especially designed to anchor to the Chinese ports: Dalian, Dongjiakou and Majisan near Shanghai, but the Chinese government did not allow anchoring to these ports because they are not equipped with the necessary facilities to accommodate them.

Hence, they claimed port safety grounds due to the ballast crack that Vale Beijing had and took on water ahead of its maiden voyage. This incident did not have any serious consequences as there was no injury and after this, the ship was able to sail with 200,000 tonnes of cargo. The real reason behind setting this restriction was that the local shipowners complained that the carriers would deteriorate the oversaturated bulk market by dropping the freight rates even further and the steel makers were worried that the new vessels would ensure the vale's control over pricing and delivery on the iron ore market, if received in full, (TW, 2013). Vale had gained the monopoly on the Brazil-China route, which might result in losses for other shipping companies operating Capesize ore carriers. Apparently, the Chinese government persuaded by these arguments, prevented Valemaxes from berthing in China. The vessels' delivery delayed: the Chinese shipyard delivered only one Valemax vessel in 2011, while the agreement was for six vessels.

Besides this, the loaded voyages of the first delivered Valemax ships: Vale Rio de Janeiro, and sister ships Vale Brazil did not sail to China as it intended. The Vale Rio de Janeiro entered the port of Rotterdam on eighth of January 2012 and the Vale Brazil was re-routed Italy while she was on her way to China, (Ellsworth & Blount, 2011). The first and only VLOC that docked at Dalian port in China was the 380,000 tons Berge Everest in December 2011. Since then, none of Vale's carriers was allowed to dock to the Chinese ports and in

January 2012 the Chinese Ministry of Transport officially announced that dry bulk carriers exceeding the 350,000 tons dwt will not be allowed to berth at the country's ports.

The Chinese regulations have significantly weakened Vale's initial plan to become more efficient. The firm's shipping cost escalated and the realized saving diminished. According to Paris Analyst's calculations, the ships had cost \$344 million more than the chartering of conventional capesize tonnage from the spot market by the end of 2013. During the first 18 months, the operations of Valemax cost \$160 million in freight costs in comparison with the conventional spot market capes and this number almost doubled seven months later. It was recently estimated that it cost Vale 35\$ per ton to shift its iron ore to China due to the high capital cost of the vessels which means that it cost at least \$16 per tonne more than the \$19.53 per tonne that it would have cost Vale if it had relied on fixing spot. However, alphabulk calculations suggest that even if the vessels berthed directly from Brazil to China, it would still cost \$6 per tonne more than the spot market tonnage. The newly built vessels reached to cost \$126 million each, with the most expensive being \$140 million. Alphabulk has reckoned that during the first quarter of 2013, Vale paid \$87 million above the market and in the second \$67million. Vale argues claiming that their strategy is sustainable while the spot conventional chartering is not, (TW, 2013).

2.3.4 Vale's alternative strategy

To combat these challenges and oppositions, the company looked into the alternative solutions, ended up to a hub and spoke network. Hub and spoke concept is a distribution model that has become very popular in marine transportation for container carriers and the one implemented by Vale. In maritime, the hub and spoke network's major ports are usually selected as hub ports based on their location and the demand of freight shipping while the other ports serve as feeder port, often known as spoke ports, (Chaug-Ing Hsu et.al, 2006). Large ships operate on a limited number of transshipment terminals (hubs), serving the main lines and smaller vessels (feeders) provide services between the hub ports and the other ports (spokes), (Monaco et.al, 2009). Main lines are usually shipping services between two continents or regions such as Transpacific, Transatlantic, Asia-Europe and Asia-Australia services while feeder lines are mainly the ones used to collect or distribute freight within a continent or a region.

Vale built two floating transfer stations in the Philippines to use them as transshipment hubs and an emerging port and terminal operation in Malaysia as sites to transfer cargoes into smaller, China-approved vessels. In February 2012, the company started to operate the first floating transfer station, Ore Fabrica (284,500 tons dwt), formerly a crude oil tanker which now operates as a platform for unloading the Valemax vessels and transferring the ore to smaller vessels that are eligible to unload to the Chinese ports. In 2013 the company built the second floating transfer station, Ore Sossego (260,600 ton dwt) at the same position as the first one. Both stations are mobile and possible to move them to operate in different offshore regions, always close to its main customers in South East Asia and other parts of Asia, (Almeida, 2012). It is said that a third transshipment vessel, Ore Brucutu (251,200 tonnes dwt) is also operated, (TW, 2013). In this way, Vale achieves greater operational efficiency and shorter delivery time for the customers. The fleet of Valemax is deployed to transport iron ore for 85% of the distance from Brazil to its Asian customers, which is the distance from Brazil to the floating transfer stations in Philippines, while the remaining 15% of the distance is served by the smaller Capesize vessels hired from the shipowners via public offers, (Leung&Fabi, 2012). The transshipment of freight means extra cost to the company due to the extra shipping distance, time, port charges and loading/unloading charges but if there is enough flow, economies of flow for direct service can be exploited. Additionally, the trade of dry bulk commodities requires that suppliers have constructed some storage facilities in order to handle and ship the commodities into the consignment size, requested by the customer.

In this way, the continuous availability of the iron ore is ensured. Receivers' purpose is to secure reliable transport services. To achieve this goal they permit the direct integration of inbound transport within the production process, while maintaining a certain level of inventories to be protected by possible irregularities in the transport performance. Another factor that affects the operational efficiency of dry bulk logistics is the stock in transit. Thus, the core of the dry bulk logistics management is to balance the production capacity of shippers and receivers against inventory. Dry bulk inventory management is governed by three main principles. The first is that inventory should be concentrated at strategic points to minimize the stock. Following of this, is that the stock should be located in a place that minimizes the transport cost of the small shipments and the last one is that the level of inventory should allow the sales' maximisation while minimizing the storage cost, (Comtois et.al, 2012).

Based on these principles, Vale started securing the few deep-water ports to mitigate the effect that the Chinese ban had on the cost. The port of Sohar in Oman was one of them and in July 2012, three-loaded Valemax were on their way to this port. Vale would build super hubs there based on three traits: the ideal location, iron ore pelletizing plant and port facilities of discharging. Because of a joint venture with Sohar industrial port, a production facility and a distribution centre of iron ore pellet were built there. Vale's commitment to such a venture was equal to \$1.356 billion and the target group from this hub was India, UAE and Saudi Arabia. By 2013, nine ports have received Valemax vessels: Dalian (China), Villanueva (the Philippines), Tumbrao and Ponta da Madeira (Brazil), Taranto (Italy), Rotterdam (Netherlands), Sohar (Oman), Kimitsu, and Oita (Japan). The second super hub that Vale will construct is Teluk Rubiah in Malaysia. After the completion of its marine terminal in Teluk Rubiah during the first half 2014, they will set up an iron ore pelletizing plant in Lumut, in Malaysia. Once the Teluk Rubiah distribution center begins operating, iron ore will be transported in Valemax there and then distributed customers in China, Japan and Taiwan in smaller ships. This distribution center will increase the capacity from 60 million mt to 200 million mt per year, when completed.

Vale has so far made 31 deliveries with 18 vessels to seven different terminals and all of them proved safe which is opposed to the Chinese allegations. The ban has cost Vale \$2/mt or \$3/mt of ore due to the construction of the transfer vessel Ore Fabrica in Subic Bay. Vessels that should be saving \$6/mt have actually cost more money to Vale, (Gambrel, 2013). Under the alternative plan, Vale's VLOCs had transported 34 million tonnes of cargo, including 15.4 million tonnes to Subic Bay for transshipment, 11.2 million tonnes to Sohar Oman, 1.16 million tonnes to Japan and 4.86 million tonnes to Europe, (TW, 2013).

In association with the previously analysed strategy, Vale refused to load any of the China Ocean Shipping Group Co. (COSCO) new 300,000 tonne iron ore bulkers in Brazil. It is believed that this action was a sort of retaliation for Beijing's efforts to prevent the Valemaxes from discharging at the country's ports, (Gambrel, 2012). However, China needed the Brazilian high quality iron ore and Vale needed to sell its iron ore. China will not receive Vale's iron ore if Vale's vessels are not allowed to dock to the Chinese ports and Vale cannot sell iron ore without allowing COSCO's ships to load to the Brazilian ports. The end of this conflict was a silent cooperation as Vale began loading COSCO's fleet of 300,000-ton vessels at its Sao Luis and Tubarao terminals and then COSCO began hauling Brazilian iron ore to the Chinese terminals in its fleet. China's Transport Ministry in 2012

approved plans to build berths for iron ore vessels of up to 400,000 metric tons to at its eastern port Nigbo-Zoushan port. This reveals that there may be the possibility that Beijing may lift the ban on Valemax vessels in the future, (Gambrel, 2012).

More recently, Vale signed cooperation with COSCO. According to this agreement, Vale will transfer to COSCO 4 of its existing Very Large Ore Carriers of 400,000-ton dwt. These ships will be chartered back by Vale under a long-term contract of affreightment for 25 years. In addition, 10 new Valemax vessels will be built by COSCO, (Vale, 2014). The additional capacity will rather keep the freight rate low, which is the key to ensure low iron ore prices, (Valor Economico, 2014). Prices of iron ore have dropped by 39% this year, signalling the slowing down of the Chinese demand. As Vale, BHP Billiton Ltd. and Rio Tinto increase the production, the less competitive miners will be forced to exit the market. Therefore, it is highly likely that the iron ore prices will remain to the current low levels, (Peter Millard, 2014). Rumours say that no official ban ever existed for Valemax into China but the ships were never allowed to operate at full load in Chinese ports, (Valor Economico, 2014). This agreement could potentially open the Chinese ports to the Valemax vessels and give permission to dock, (Spence, 2014).

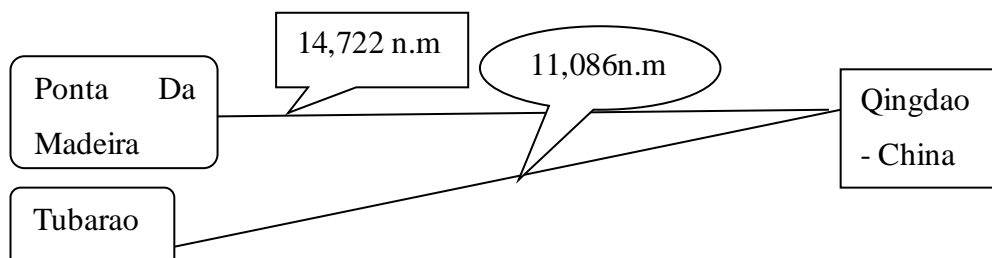
3. Methods

One of the objectives of this study is to provide as far as possible properly information on the cost of carrying cargo in Valemax vessels under the company's alternative plan as described above, the initial plan and the traditional way of transportation. Following of this, the shipping cost, generated by three different transportation systems, is estimated over the route Brazil- China. The considered transportation systems are: 1) the direct transportation of iron ore from Brazil to China in Valemaxes, 2) the transportation of iron ore from Brazil to the Subic Bay in Phillipines with Valemaxes and the cargo transshipment into smaller vessels and 3) the transportation of iron ore in Capesizes chartered from the spot market. Vale paid a high capital cost for the acquisition of the ships to shipbuilders, based on the perception that the capital cost per ton is less, while enabling the carrying out of less trips per year by transporting a greater quantity of cargo.

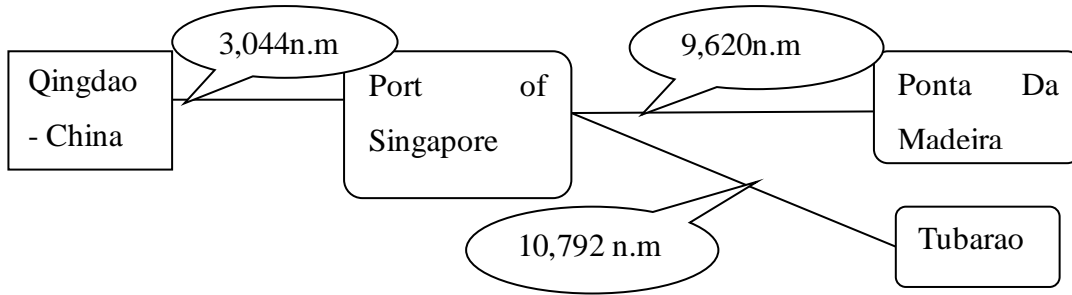
The transportation cost is calculated considering Vale either charterer or shipowner. However, the cost efficiency of a sea transportation system is a very wide issue, which includes the operational efficiency of the ships. The cargo quantity that was annually transported by each system, the number of voyages that may be completed, the waiting time at port, are measures of operational productivity that may increase the demand response and the efficiency.

Routeing

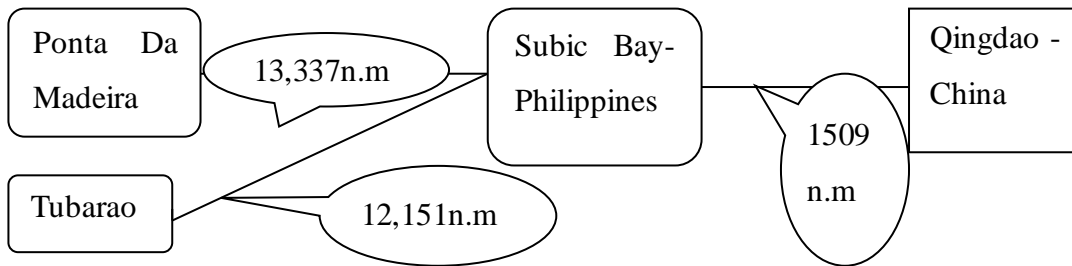
The big size of the Valemax vessels restricts the number of the ports that the vessels can berth and operate due to the high draught. The only ports possessing the necessary infrastructure to load iron ore to the Valemaxes are Tubarao and Ponta Da Madeira. The same limitation applies to the discharge port and as such, Qingdao is the only Chinese port of discharge considered. The first transportation system is the Vale's initial plan of cost reduction and that is, the direct shipment of iron ore from Brazil to China as illustrated in the below scheme. For this route, Vale used capesizes of 170,000-180,000 tonnes dwt employed from the spot, the benchmark system for this study. In 2008, Vale ordered the Valemax vessels to deploy them under the direct transportation system. The distance between the ports calculated by using an online sea distance calculator (ports.com), as showed below.



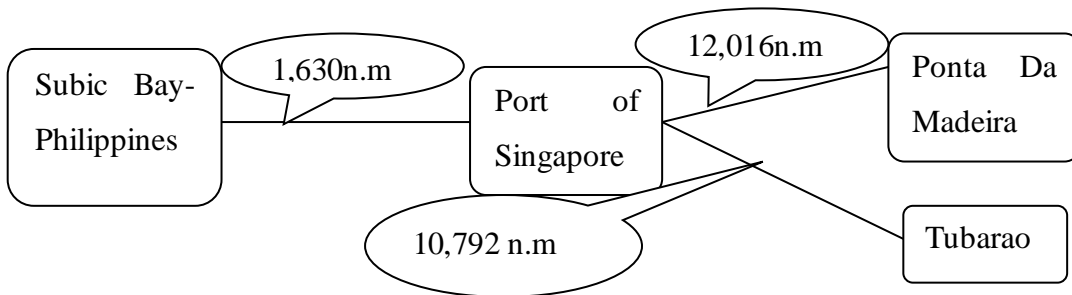
The return trip of the vessels under the direct transportation system, depending on what the end port is, on each voyage, is:



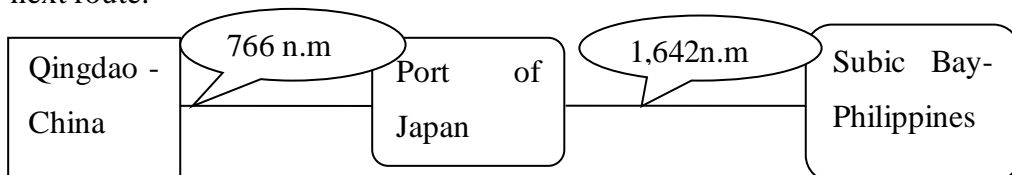
After the delivery of the vessels in 2011, China banned fleet's berthing at the port and since then the transportation system has differentiated. Valemaxes transport iron ore from Brazil to the Subic Bay Freeport Zone in Philippines and from there the cargo is transhipped by using three transshipment vessels: Ore Fabrica (284,500 tonnes dwt), Ore Sossego (260,600 tonnes dwt) and Ore Brucutu (251,200 tonnes dwt). Cargo is transhipped in these three vessels and then into smaller capesizes of 170,000-180,000 tonnes dwt to transport the iron ore to China.



The return trip of the Valemax vessels under this system is:



The return trip of the Capesizes, used to transport the transhipped cargo to China follows the next route:



Total cost of transportation

Vale's cargo is moved under a contract of affreightment, a long-term agreement according to which a shipowner agrees to a series of cargoes at a fixed price per ton within a specified period. The length of the contract of affreightment is 25 years. A shipowner will accept a voyage if the freight rate at least equals the cost of the voyage, in order to find the price which is worthwhile, we require that the sum of the present value of all the years is zero, as follows:

$$NPV = 0 = \frac{\sum_{i=1}^{30} (R - \text{Voyage cost} - \text{Operating cost})}{(1+r_{wacc})^i} + \frac{\text{Scrap Value}}{(1+r_{wacc})^{30}} - C_o \xrightarrow{r_{wacc}=8.5\%} C_o =$$

$$(R - \text{Voyage cost} - \text{operating cost}) * \frac{(1 - \frac{1}{(1+r_{wacc})^{30}})}{r_{wacc}} + \frac{\text{Scrap Value}}{(1+r_{wacc})^{30}}$$

$$\xrightarrow{\frac{1 - \frac{1}{(1+r_{wacc})^{30}}}{r_{wacc}} = 10.75} R = \frac{C_o - PV(\text{Scrap value})}{10.75} + \text{Voyage cost} + \text{Operating cost}$$

Thus,

$$R = \frac{C_o - PV(\text{Scrap value})}{10.75} + \text{Voyage cost} + \text{Operating cost}, \quad (1)$$

Notation:

R= Revenue from a contract of affreightment

C_o = capital cost

i = the life of the ship and the contract $\in [1, \dots, 30]$

r_{wacc} = weighted average cost of capital

The discount rate used here for the present value is the weighted average cost of capital, r_{wacc} . According to Vale's financial statements, r_{wacc} is equal to 8.5%. To calculate the US\$ per ton cost of transported cargo, the trip duration is needed and defined as the sum of the port time and the total sailing days, where port time is defined as follows, depending on the considered system each time:

$$\text{port time}_i = \text{loading time}_{iA} + \text{waiting time}_{iA} + \text{discharge time}_{iB}, \quad (2)$$

Notation:

i = each Valemax vessel

A= Tubarao, Ponta da Madeira

B= Subic Bay, port of Qingdao

Accurate data of cargo intake (carried quantity of iron ore on the vessels), loading days and waiting time at the Brazilian ports were collected by the LBH Group for all the trips and for both the Capesizes and the Valemaxes. Additionally, data of the discharge days of Valemaxes at the Subic Bay, in Philippines were collected by the AIS activity, for the period, 2011-2013. For the missing trips and for 2014, the average discharge time was calculated and assumed constant for all the trips and for the direct system. The discharge time at the port of Qingdao was assumed 2 days. It should be noted that the delivery of cargo takes place on a quarterly basis, while the average trip duration lasts no less than 3 months and thus both the trip duration and the cost associated with the voyage are computed on a quarterly basis. The cost per ton of cargo is:

$$N = \frac{365}{D} , \quad (3)$$

$$TC = \frac{R}{N \text{ trips/quarter} * \frac{Q \text{ tonnes}}{\text{quarterly trips}}} , \quad (4)$$

, where N= the average number of round trips per quarter and D is the average duration of all the trips carried out each quarter for each year for the period, 2012-2014 and is defined as the sum of port time and sailing days.

Capital cost (C_o)

This is a fixed cost and represents the actual price of the ship. In 2008, Vale ordered 12 Valemaxes for construction by Jiangsu Rongsheng Heavy industries and entered into agreement with the Export-Import Bank of China and the Bank of China Limited in 2010 to finance the construction of the vessels. The agreement provided a credit line up to US\$ 1.229 billion, which corresponds to 80% of the ships' required cost to fund their construction. The credit line has a 13-year maturity and the funds will be disbursed during the next 3 years. Hence, the total capital cost of the fleet is US\$1.53625 billion, translated into US\$128.028 million for each vessel, (Vale's annual financial statements).

The scrap value of the ships is the value of the ships when the shipowner considers that the vessels are not needed any more. According to Martin Stopford (2009), the scrap value is the product of the lightweight of the ships by the scrap price of the ships measured in US\$/lwt, but Valemaxes are very new ships and the information concerning their lightweight and their scrap price, is not disclosed. Therefore, it is assumed that the scrap value of tanker vessels with a similar size can offer a good approximation of the Valemaxes' scrap value. The scrap

values of UL/VLCCs oil tankers were obtained by the Clarkson Research Services database. It is also assumed that the vessels will be scrapped after their end of life, 30 years. However, it is not possible to know what the scrap price is going to be in 30 years. Thus, the average of the UL/VLCCs historical scrap values was calculated, discounted to the present and assumed that this value will be constant for the next 30 years.

Operating cost (OPEX)

Operating cost is comprised of crew salaries, insurance, protection and indemnity, maintenance of hull and equipment, consumable stores, spares, virtuals and other similar expenses. The operating cost, also known as running cost, is included to the vessels' fixed cost. It does not change with the specific voyage and is time related. After a vessel is agreed to carry out a round trip, the operating cost is payable from the day the vessel is present at port until the day that the trip ends. The Valemax vessels' operating cost is not disclosed but it is not expected to significantly affect the shipping cost, as a fixed cost. It is assumed that their operating cost is a bit bigger than the one of the capesizes, due to the economies of scale. As such it is assumed to be equal to 10000 US\$/ day and remain constant. Capesize operating cost was obtained by Stephen Moore database. The table below, makes obvious that the operating cost of the capesizes does not change significantly, supporting the adopted assumption.

Operating cost Daily rate (US \$/day)	2011	2012	2013	2014
Capesize	7,437	7,758	7,433	7,500
Valemax	10,000	10,000	10,000	10,000

Then, the operating cost is reckoned as:

$$\text{Operating cost} = \frac{10000\$}{\text{day}} * N \text{ trips per quarter}, \quad (5)$$

Voyage cost (VC)

- **Transportation system with transshipment at the Subic Bay**

The voyage cost refers to the cost per ton incurred at sea and port, is comprised of fuel cost, port charges and the cargo handling cost. Port charges including tugs, pilotage, conservancy, agency fees and light dues are ignored for simplification reasons.

The most important factor of the voyage cost is the time, as increased time at sea and port may increase the cargo cost per ton. Time spent at port is an unavoidable component of cost, since loading and unloading of cargo are necessary procedures and a function of cargo handling cost which includes loading, discharging, trimming, lashing, cargo handling equipment. However, Vale transports iron ore on freight and cost (CFR) or cost of insurance and freight (CIF) basis. Recalling that according to the INCO terms, the buyer, China pays the loading and the discharge cost at both the port of import and export, which is China. Thus, the cost of cargo handling is not relevant for Vale and excluded from the calculations.

The port cost was obtained from a database published in 2009 and assumed to have remained constant for the next years. The charges were fixed and analogous to the vessels' deadweight, but not updated for the newly built vessels. For the Brazilian ports Tubarao and Ponta Da Madeira, the maximum quantity loaded was 310,684 metric tonnes and the charge equal to \$132,071. Valemax vessels have a greater deadweight and the port cost assumed a bit higher and equal to US\$ 150,000 for both ports. The same charge is assumed for the port of Qingdao when the direct transportation system is considered.

The fuel cost is the most essential component of the voyage cost and defined as the product of bunker prices and the fuel used. The Fuel used depends on the vessel's fuel consumption, measured in days/ton. Thus, sailing days are crucial for the determination of the fuel used and cost. The length of the trip depends on the speed of the vessel, a not easily accessible information. However, accurate data on the speed and the days of the trip for each ship of the valemax fleet were collected for the period, 2011-2013 by the AIS activity. The data on speed does not provide complete information concerning the operated speed of the Valemaxes over the considered routes, but the same is not true for the sailing days. The exact length of the trips that Valemaxes carried out during 2012-2013, (when more Valemaxes delivered and started operating), is given over the considered routes. Using the complete sailing days, the accurate speed for each ship was calculated, according to the formula:

$$U_i^L = \frac{D_{Go}}{\frac{24hr}{day} * SD_i^L}, \quad (6)$$

$$\Rightarrow TSD_i = SD_i^L + SD_i^B, \quad (8)$$

$$U_i^B = \frac{D_r}{\frac{24hr}{day} * SD_i^B}, \quad (7)$$

Notation:

D_{GO} = Total distance from the port of Tubarao or Ponta da Madeira to the Subic Bay

SD_i^L = sailing days when the i vessel travels laden

SD_i^B = sailing days when the i vessel travels in ballast

D_r = Total distance from the Subic Bay to the port of Tubarao or Ponta Da Madeira

U_i^L = speed for i vessel when it sails laden

U_i^B = speed for i vessel when it sails in ballast

TSD_i = Total number of the sailing days for the i vessel

Then, the quarterly average of the speed was calculated (recalling that the costs are calculated on a quarterly basis). For the vessels and the trips that data is missing, it is assumed that they will be operated at the average speed of the above-calculated speeds in respect to the vessel's activity, since they serve the same route. The same approach is implemented to the length of the trip. The average length observed from the empirical data was estimated to be 42.89 days from Brazil to Subic Bay and 41.22 days from the Subic Bay to Brazil.

$$\left\{ \begin{array}{l} \overline{SD}_L = \frac{D_{GO}}{\frac{24hr}{day} * \overline{U}_L}, \end{array} \right. \quad (9)$$

$$\left\{ \begin{array}{l} \overline{SD}_B = \frac{D_r}{\frac{24hr}{day} * \overline{U}_B}, \end{array} \right. \quad (10)$$

\overline{U}_L = average speed when the ship is laden per quarter

\overline{U}_B = average speed when the ship is in ballast per quarter

\overline{SD}_L = average sailing days when the vessel sails laden per quarter

\overline{SD}_B = average sailing days when the vessels sails in ballast per quarter

The vessels consume fuel at both port and at sea. However, the fuel consumption at port is ignored because it is so little that does not affect the result. The consumption of fuel at sea is not given and thus, is estimated. Scientific research has proved that the vessel's fuel consumption is expressed by the following function:

$$F = a * U^b$$

Notation:

F= Fuel consumption measured in tonnes/day

U =Vessel's speed measured in knots or nautical miles per hour

α = constant

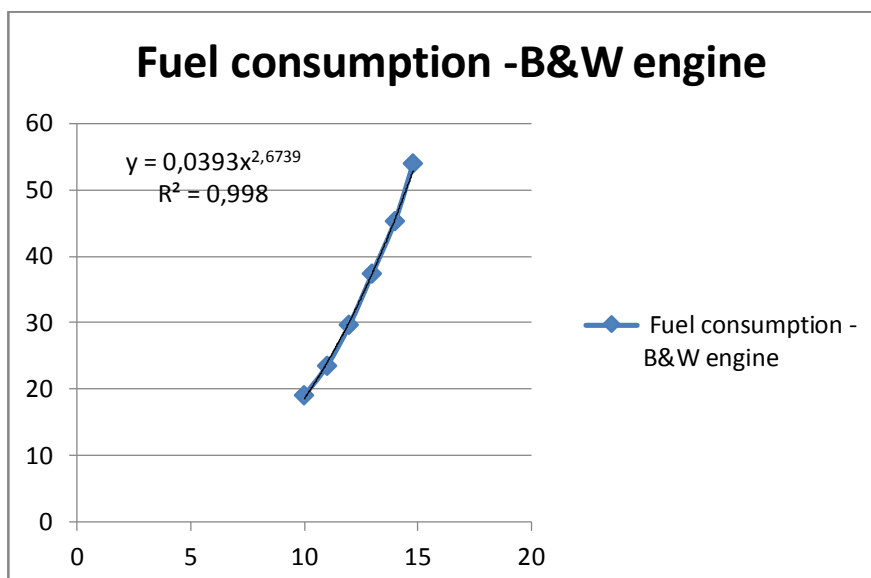
b = the elasticity of speed

The curve is ship- specific and strongly depends on the ships' technical characteristics, that is, engine type, hull design and hull condition. To estimate this curve for the valemex vessels, the coefficients α , b are necessary, but its estimation would require data on the vessels' consumption and speed, which is not possible to find. Using the data of the speed/power curve of the 181-eco ships with engine type B&W6S70-ME- C and similar technical characteristics with the Valemaxes, provides a good estimation of the Valemex fuel/speed curve. The table below shows this data.

	Speed (knots)	10	11	12	13	14	14.2	14.8
B&W 6S70ME-C (Mark VIII), without energy saving device	Fuel consumption design draft (tons)	19.0	23.5	29.7	37.4	45.3		53.9
	Fuel consumption design draft (tons)	21.3	26.3	32.8	40.8	50.1	53.9	

The first row contains the design speed of the Valemaxes and the coefficients of this particular curve are the best approximation for the respective Valemex curve. There are two ways to find out the coefficients a , b . The first is to convert the above equation into, $\ln(F) = \ln(a) + b * \ln(U)$ and conduct a regression to get the coefficients: a , b and the second is to plot the data of the fuel consumption on the speed, estimating the power curve. Both ways indicate the same results: $\alpha=0.0391$ and $b=2.673851$ leading to the estimated curve:

$$F = 0.0391 * U^{2.673851}$$



Having obtained the coefficients of the above equation and the speed of each ship, as described earlier, the fuel consumption by vessel is calculated, following the formula below:

$$F_i = F_d * \left(\frac{U_i}{U_d}\right)^b, \quad (11)$$

Notation:

F_i = the fuel consumption for each vessel

U_i = speed for each vessel

F_d = design fuel consumption

U_d = design speed

$b = 2.673851$

Using the speed of each ship when sailing in ballast and laden and applying them to the above formula, the fuel consumption is estimated for each Valemax vessel and for both laden and ballast voyages. It should be noted that due to the limitation of data on sailing days per valemax vessel, average speed was used to estimate the fuel consumption for the ships that no particular data existed. The design speed is 14.8 knots, according to the Clarkson Research database. Different sources state different rates of design fuel consumption that stands to the range of 95 tons/day to 108 tons/day. Thus the average design fuel consumption was used, 100 tons/day.

It is assumed that the Valemaxes are provided all the bunkers they need for the round trip from the port of Singapore after the discharge of the cargo at the Subic Bay and thus the distance between the discharge ports and Singapore has been included in the calculation of the sailing days that the ship travels in ballast. The port of Singapore was selected as bunkering port, due to its close geographical proximity to the Subic Bay and the lower fuel prices. As a result, the 380 cst bunker prices are used to calculate the fuel cost acquired from the Clarkson Research database. The Fuel cost is:

$$Fuel\ Cost_t = Fuel\ used_t * P_t^b \Rightarrow Fuel\ Cost_t = (SD_t^L * F_t^L + SD_t^B * F_t^B) * P_t^b, \quad (12)$$

Notation:

t = each quarter

$Fuel\ used_t$ = fuel used for each quarter

P_t^b = average price of each quarter

F_t^L = average fuel consumption of Valemax vessels per quarter when they are laden

F_t^B = average fuel consumption of Valemax vessels per quarter when they sail in ballast

SD_t^L = average laden sailing days per quarter

SD_t^B = average sailing days in ballast per quarter

The cargo is transhipped at the Subic Bay into smaller vessels hired by the spot market to sail from the Subic Bay to the port of Qingdao in China. The cost of the transshipment is assumed the same as alphabulk (2013) estimated and equal to US\$ 6 per ton. The vessels are standard capesizes of the size 170,000 -180,000 tons dwt. For this voyage leg, it is assumed that the ships are operated at the design speed. From the Clarkson Research Services database, it is possible to find Vale's time charter fixtures where some of the capesizes hired to serve this route are disclosed, it is assumed that all the employed ships for this particular route belong to this peer group, which consists of 511 capesize vessels, and have a size of approximately 175,861 tons deadweight. Their design speed is 14.88 knots on average and the design fuel consumption 62.8 tons/day. Another assumption made is that the Capesizes operate at the design speed for the round trip that takes 11.1 sailing days, plus 4 days due to discharge/loading activities and 5% margin for sea weather, 15.0683 trip days. Concerning the cargo intake, the ships are assumed to sail in full load capacity, which is equal to 175000 tons.

However, Vale charters Capesizes from the spot market. Their rates are attained by the Baltic Indices on the North/Pacific route (BCI C10_03: 172000mt Nopac round voyage). These are daily rates and are converted into US\$ per ton.

$$V. E. R = \frac{BCI_{C10} * Trip\ days + FC + PC}{cargo\ intake}, \quad (13)$$

Notation:

BCI = Baltic indices

Trip days = the round trip days

FC = fuel cost

PC = port cost in Qingdao

It should be noted that for this route, the Capesizes are assumed to load bunkers from the port of Oita in Japan, due to its close proximity and the fact that the Japan 380 cst prices don't exceed the Singapore's bunkering prices to a great extent.

$$Fuel\ cost_{capes} = (SD^L + SD^B) * F_d * P_B = \left(\frac{D_{SB-Qingdao}}{24 * U_d} + \frac{D_{Qingdao-Japan-SB}}{24 * U_d} \right) * F_d * P_B$$

Recalling, that iron ore is transported on a CIF or CFR basis and the buyer of the cargo should pay the cargo handling cost. Again, the fuel prices and the cost are adjusted on a quarterly basis to match the previously calculated values. The port cost is directly obtained by the database of the port cost and is equal to 72,800 US\$ for 172,720 DWT mt.

The total transportation cost for this transportation system is:

$$TC_{current\ system} = TC_{Valemax} + TC_{capesizes} + Transshipment\ cost$$

$TC_{capesizes}$, is given by equation (13) and accounts for the total transportation cost of the iron ore for the round trip, Subic Bay - port of Qingdao, in China. The cost of transshipment is 6\$/tonne, as explained above. $TC_{Valemax}$, stands for the total transportation cost of iron ore for the round trip Tubarao/ Ponta Da Madeira- Subic Bay and is calculated by equation (4). Noting that port time for this route is given by equation (2). Waiting time includes the time that Valemaxes waited to berth at either the port of Tubarao or Ponta Da Madeira and the time the vessels waited to discharge the cargo at the Subic Bay. Loading time is the time that Valemaxes spent to load iron ore at the Brazilian ports. Discharge time is the time Valemaxes spent to unload the cargo to Capesizes at the Subic Bay. The total trip days of the Valemaxes over this route, is then the sum of the port time and the total sailing days (equation (8)). The average of the trip days per quarter is plugged in equation (3) to obtain the number of trips per quarter.

- **Hypothetical scenario of the direct transportation of iron ore from Brazil to China**

Under this hypothetical scenario, the Valemax vessels are allowed to berth at the port of Qingdao in China, without the transshipment of cargo at the Subic Bay. However, no empirical data exists for this scenario, since the vessels haven't been allowed to berth to the Chinese port so far, but the route is almost the same with or without the transshipment as the transshipment adds an extra cost and deducts flexibility. The distance from the Tubarao to Qingdao without the transshipment included in the calculation, is 13,542 n.m. while the same route with the transshipment is 13,660 n.m. Similarly, the distance from Ponta da Madeira to Qingdao directly is 14,752 n.m. and the same route but with the transshipment included is calculated to be 14,846 n.m. The route that the vessels follow in any of the scenarios is exactly the same, the Valemaxes will pass from the Cape of Good Hope and

then will pass through Philippines to go to the Port of Qingdao and this can be verified by the fact that the distance doesn't make significant difference in nautical miles.

For this reason, the average speed for the ballast and laden voyage respectively reckoned in the above scenario is considered a good approximation for the direct transportation of iron ore too. The sailing days of the round trip are almost the same, as described above but the distance is a bit different. To account for the difference in distance, the sailing days are calculated, using equations (8), (9) but using the corresponding distance, as follows:

$$\overline{SD}_L = \frac{D_{Tubarao,PDM-Qingdao}}{\frac{24hr}{day} * \overline{U}_L}$$

$$\overline{SD}_B = \frac{D_{Qingdao-Tubarao,PDM}}{\frac{24hr}{day} * \overline{U}_B}$$

The speed is the same quarterly speed calculated in the previous system, which implies that the fuel consumption per quarter for the Valemaxes for the direct route will also be the same as calculated above. Thus, the fuel cost for this system is:

$$Fuel\ Cost_t = (F_{tL} * \overline{SD}_{tL} + F_{tB} * \overline{SD}_{tB}) * P_t^b$$

, where t= each quarter

Again, it is assumed that the Valemaxes load all the fuel they need to carry out the round trip at the port of Singapore. The port cost is assumed to be the same for both the loading ports (Tubarao, Ponta Da Madeira) and the discharge port of Qingdao and equal to 300,000 US\$ (US\$150,000 *2) for 400,000 DWT mt vessels. The total transportation cost over this route is given by equation (4).

$$TC_{direct\ system} = TC_{Valemax}$$

The port time for this hypothetical scenario is also given by equation (2). Waiting time includes the time the Valemaxes waited to berth at the loading ports (Tubarao, Ponta Da Madeira) and the loading time is the time that Valemaxes spent to load iron ore at the port of Tubarao and Ponta Da Madeira. They are assumed the same as in the transportation system with the transshipment included because the vessels would spend the same time at the loading ports, regardless of the Chinese acceptance to its ports. It is assumed that the vessels would not wait to dock at the port of Qingdao, while the discharge time is assumed 4 days. Therefore, the round trip days of the two transportation systems slightly differ. Their difference falls into the discharge time at the Subic Bay that is not relevant for the direct

hypothetical transportation system. Total trip duration is the sum of the port time and the sailing days. Plugging in equation (3) the trip duration, the average number of trips per quarter is received. After having adjusted for the operation cost in equation (5), equation (4) renders the total transportation cost for this system.

- **Employment of Capesizes from the spot market over the route Tubarao-Qingdao**

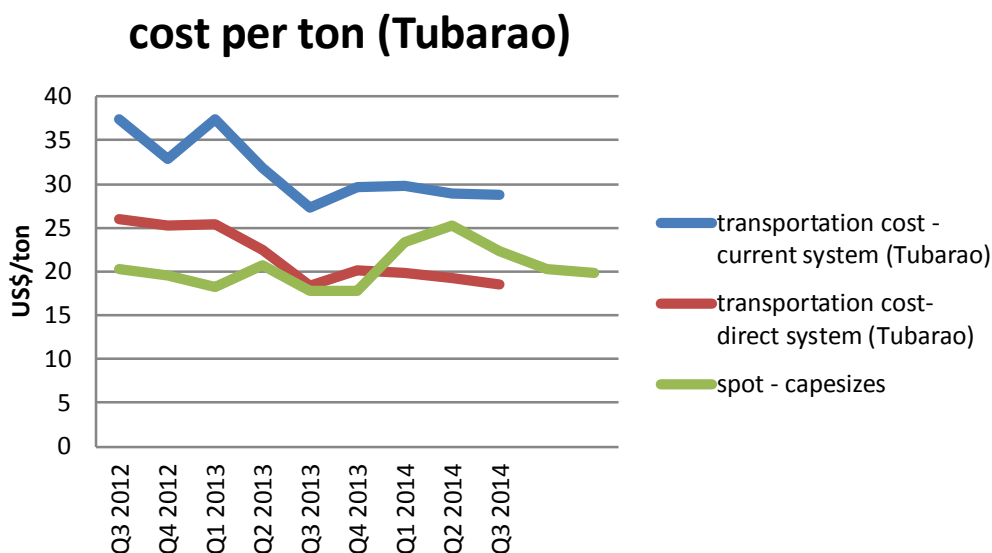
In the spot market, the seller of the cargo pays a specific freight rate that covers all the voyage cost over the route he wants to transport his cargo. Under this scenario, the rates are obtained directly from the Clarkson Research services and will be compared with the cost generated from the transportation with the Valemaxes.

4. Results and analysis

Vale is both a charterer and shipowner, 19 Valemaxes are owned and 16 Valemax vessels are chartered under a 25- year contract of affreightment (COA) agreement and the firm pays a fixed \$/tonne cost over the entire period. For simplification reasons in the following analysis, it is assumed that the whole fleet is either chartered or owned.

4.1 Cost comparison

From Vale's perspective, the strategy intended to provide a lower cost profile than the one of the Cape- spot based chartering strategy, while having a greater control on its cost. However, as expected the imposed ban of vessels' anchoring to the Chinese port has led to an additional cost of 9.81 US\$ per ton on average, when the vessels start their voyage from the port of Tubarao. Chartering capes from the spot would cost 10.9 US\$ per ton less than the Valemaxes, while if they were allowed to transport the iron ore directly to China that would on average cost only 1.1 US\$ per ton more than the spot chartering and as depicted at the graph below, it could even cost less than the spot market.



(Graph 1: cost per ton, starting the trip from the port of Tubarao)

Obviously, the ban had a significant effect on Vale's cost, the direct transportation is the most cost efficient way of transportation and it seems that the benefits would become even more apparent after the second year of operation. The transportation iron ore from Brazil to

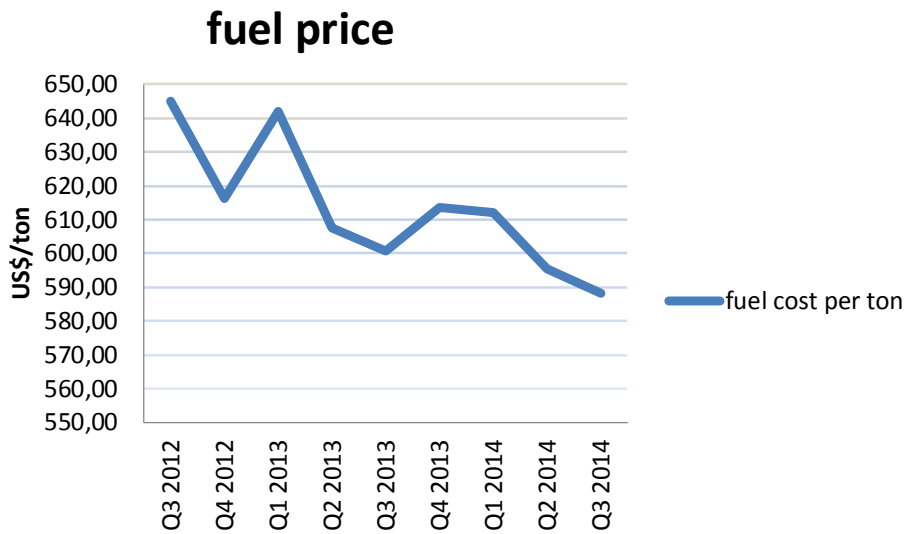
China with the Valemaxes without the ban becomes the cheapest way of all. In terms of average cost though, this claim is not supported by the output. It turns out that shifting one ton of iron ore from Brazil to China with the conventional capes chartering is 20.62 US\$ per ton, direct transportation with Valemaxes cost slightly more, 21.72 US\$ per ton and the transportation of the cargo with the transshipment hub in between averages out to 31.53 US\$ per ton.

Other important points that can be drawn from graph 1 are the co-movement of the cost curves of the two systems (the current transportation system, standing for the transshipment in the Subic Bay and the direct) and the almost convergence of the spot cape freight rate and the Valemax cost during the second quarter of 2014. The co-movement of the curve shows that even if the cost of the current system is higher the overall trend is almost the same with the direct iron ore shipment and is decreasing. This is evidence of economies of scale that in the future, the employment of the vessels may provide more benefits. In addition, during the third quarter of the year 2013, the cost differential between the current system and the spot-based capes became 3.94 US\$ per ton, which is a good sign. The average cost over time of each of Vale's transportation solution is formed as follows:

	Without direct access to the port of Qingdao	With direct access to the port of Qingdao	Capes –spot rates
Average transportation cost (US\$ per ton)	31.53	21.71	20.5

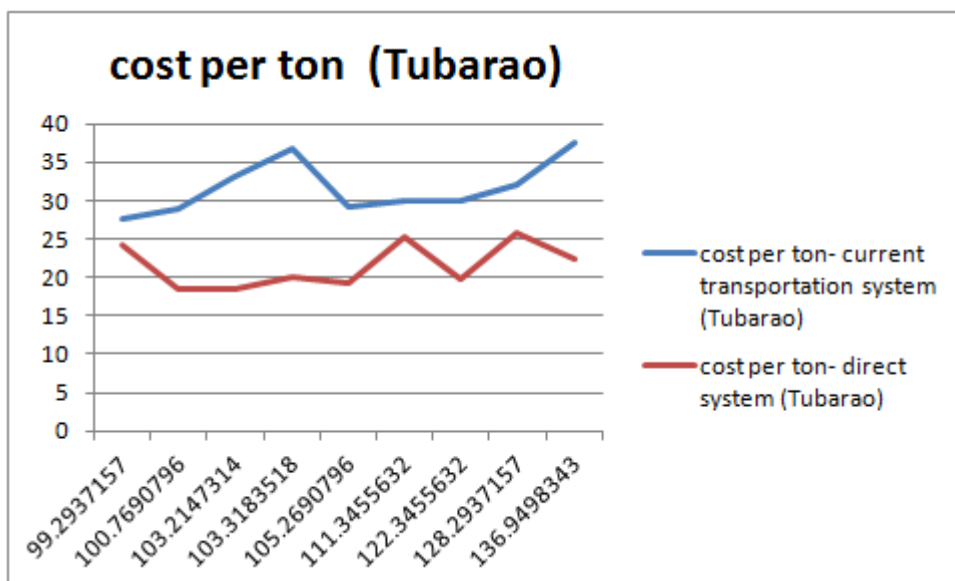
(Table 1: Average cost per ton for each system)

There are two peaks on the graph, one immediately after the Valemaxes were injected in the market and started to be in service (37.34 US\$ per ton) and another during the first quarter of the year, 2013 (37.39 US\$ per ton). The blame can be put on the per ton fuel cost, as it is not a coincidence that the fuel cost peaks during the same quarters as the transportation cost does, (graph 2). From graph 2, the co-movement of the fuel cost and the transportation cost including the cost of transshipment is pointed out.



(Graph 2: Fuel cost per ton)

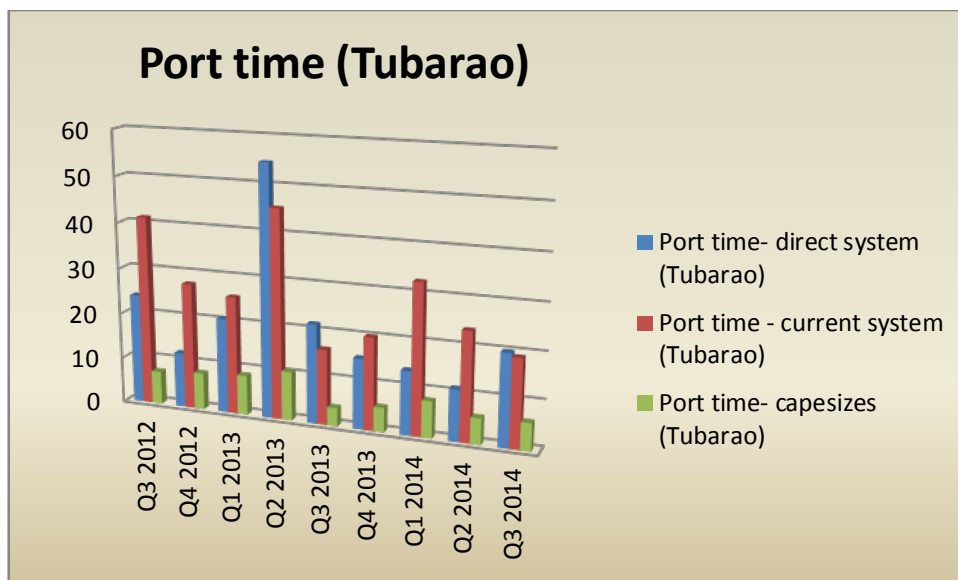
Another contributing factor to this outcome is the duration of the trip. The highest trip duration renders higher cost per ton. It turns out that the longer it takes to complete the round voyage the higher is the cost per ton of cargo with the imposed ban. During the third quarter of 2012 that Valemaxes started to depart from the port of Tubarao and the transportation cost peaks, the duration of the round trips was 136.95 days and in the next quarters the duration falls together with the cost too, which shows a positive relationship. The cost varies depending on the trip duration for both systems, (graph 3). However, the two transportation system denote an inverse trend.



(Graph 3: cost per ton by round trip duration- Tubarao)

The latter means that a higher level of trip duration is translated into generally higher transportation cost under the current system but the opposite seems to happen for the direct system during the greatest part of the curve. Strong conclusions though cannot be drawn on the relationship of the two due to the volatility, which can be most likely attributed to the speed variation and the port time (waiting time and loading/unloading time). The cost behaviour depends on the factor that has the strongest impact on the cost each time. Waiting time and loading/unloading time also enter in the displayed trip duration and they play a role to the behaviour of the cost, representing the port time.

Port time is an important component of the cost with two-fold character. Longer time spent at port means longer trip duration, higher operating cost, reduced number of trips and less cargo delivered to the customers. All these factors combined lead to higher transportation cost. The cost peak of the currently used transportation system of iron ore from Brazil to China, during the third quarter of 2012 can put the blame on the long port time, 41.3 days. The port time of Tubarao for both systems is showed in graph 4. The Valemaxes have generally been subject to a lot longer waiting time at the port than the capesizes on a quarterly basis.

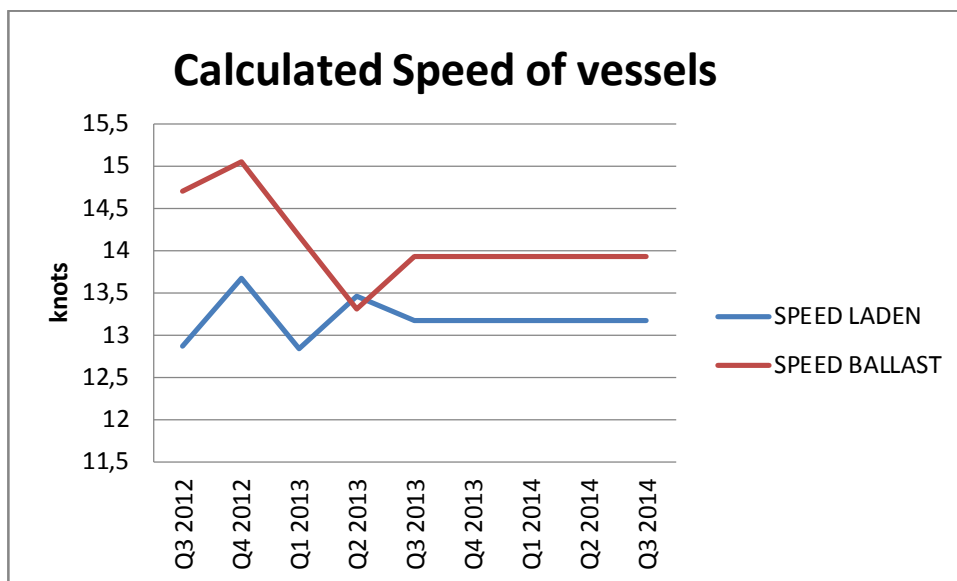


(Graph 4: Port time at the port of Tubarao)

If Vale were allowed to conduct direct shipment of iron ore with the Valemaxes, the port time would generally be much shorter. Thus, it is not only the waiting time at the port of Tubarao that delays the delivery and reduces the annual number of the fleet's trips but the transshipment of cargo is also timely. This does not hold in the second and the third quarter

of 2013. The data shows that the delay is completely owed to the potential lack of infrastructure at the particular port. It should not be omitted that by the lapse of the time, the port time has significantly decreased compared to the first year of operation, which means that the necessary adjustments are made at the ports in order to handle the Valemaxes more efficiently, in terms of time.

Port time accounts for 20.6% to 24.4% of the trip duration, the rest 75.6%-79.4% is the time spent at sea or else the sailing days, which in their turn depend on speed. Graph 5 shows the formation of the vessels' speed, as calculated from the data. This speed does not exclusively concern the vessels that depart from the port of Tubarao. The number of observations on both the speed and the sailing days, of the vessels starting their trip from this particular port was not sufficient and limited to a couple of observations and thus it cannot be a representative sample. For this reason, the speed at Tubarao is assumed the same as the average calculated quarterly speed delineated by the vessels that start their trip from both ports.

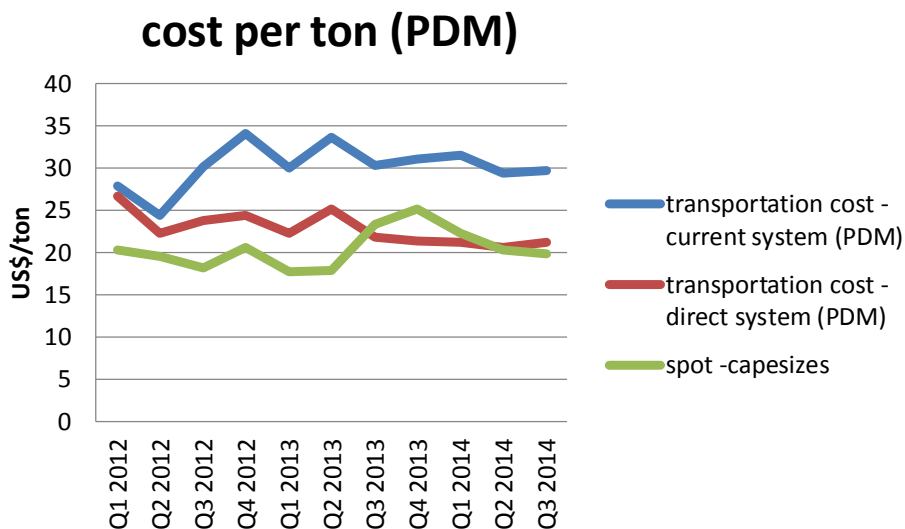


(Graph 5: The calculated speed)

The determination of the vessel's speed depends on the fuel prices. When the price of fuel is low, the party that is in charge for covering the voyage cost has a strong incentive to speed up. The cost will not go up while reducing the unproductive time at sea and increasing the number of trips carried out and the opposite holds when the price is high. Graph 2 displays the quarterly fuel prices and presents a steady decreasing trend after the fourth quarter of 2013 and that is why the Valemaxes have deployed a rather high speed. The fuel price can largely explain the speed volatility. The vessels operate at a considerably high speed, 15

knots during the fourth quarter of 2012, which collides with a 5% decrease in the fuel price. Speed is not only a determinant of the trip duration but also of the fuel consumption, which is a main part of the fuel cost. During the first quarter of 2013, a second peak of cost occurred. The responsibility falls to the fuel consumption that reaches its highest level of all the other quarters.

Most Valemaxes though depart from the Ponta Da Madeira (PDM) terminal and more data is available on this route. Although the Capes spot benchmark concerns the rates on the route Tubarao- Qingdao that is not the same route as the PDM terminal, they do not have a considerable difference in terms of distance and thus, they are comparable. Even if the transportation cost profile over this route is different, the conclusions made from the graph are generally the same. Graph 6 illustrates the cost of Valemaxes starting from this terminal.



(Graph 6: Transportation cost per ton – Ponta Da Madeira terminal)

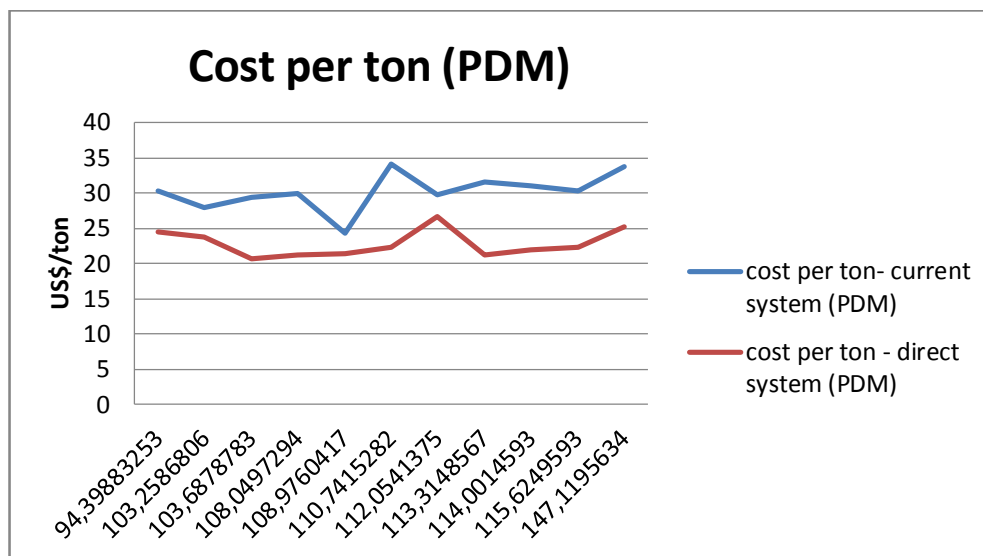
As expected, the imposed ban shrank the cost advantage that Vale would reap. The direct transportation of cargo with the Valemaxes proves even more profitable than the Capes-spot freight. The first half year of Valemaxes' operation denotes an impressive result. The transshipment of cargo adds almost no extra cost and the differential with the spot market freight is at its lowest levels. The transshipment in the Subic Bay costs on average 6.21 US\$ per ton more than the capes spot market does, (19.92 US\$ per ton on average, during the first half 2012). The result doesn't make a great difference on the costs if China hadn't ban the anchoring of Valemaxes at its ports, as it would 4.59 US\$ per ton more than the spot rates, resulting in 1.62 US\$ per ton cost difference between the Vale's transportation methods.

The bad news is that the situation described above does not last for longer time. During the next quarters, the results tend to converge to the same conclusions drawn earlier in the analysis. The least costly solution for the transportation of iron ore is the direct way. The additional cost incorporated into the total cost due to the transshipment process is less (7.35US\$ per ton) than before (9.81 US\$ per ton). The Capes spot rates cost on average 10.5 US\$ per ton less than the Valemaxes when they transship in the Subic Bay. If the vessels did not need to pass through the transshipment process, the cost would exceed the spot benchmark by 1.84 US\$ per ton on average. Obviously, the benefits of gaining direct access to the Chinese ports are many and could reduce the cost by 82%. Even so, the transportation cost, including the transshipment process, has entered a decreasing stage as shown in graph 6. The last quarter of 2013 and during the first three quarters of 2014 the cost is falling, which signals positive prospects for the economics of the Valemax fleet. For this route, the average cost for each system over time is:

	Without direct access to the port of Qingdao	With direct access to the port of Qingdao	Capes –spot rates
Average transportation cost (US\$ per ton)	30.21	22.83	20.5

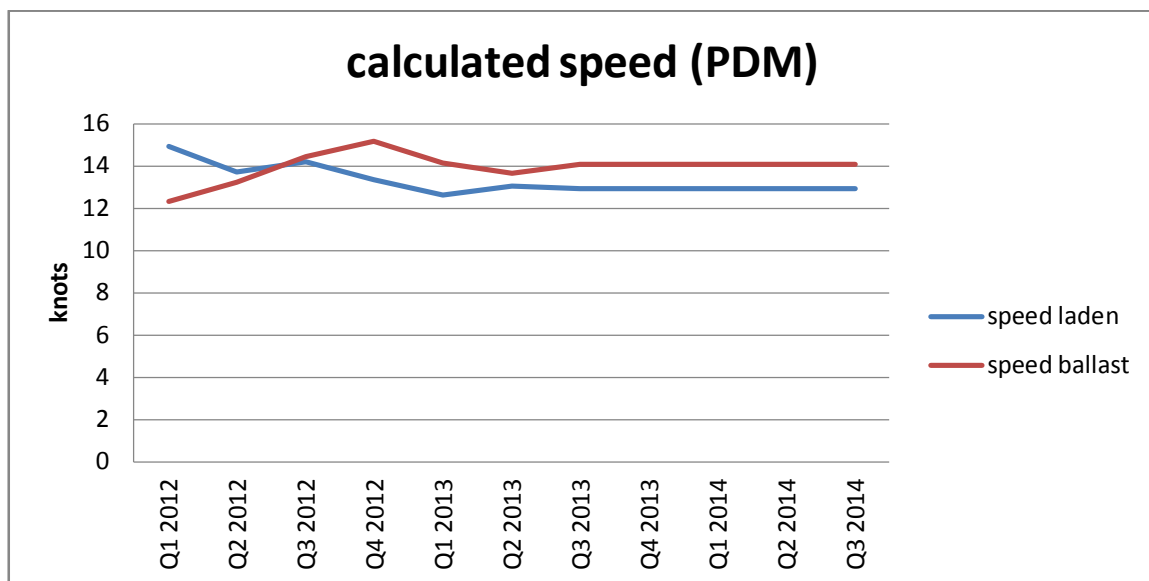
(Table 2: Average cost per ton for each system)

As already referred, the transportation cost depends on several factors and depending on the size of each factor's effect, the cost changes accordingly. Graph 7 shows the cost per ton in respect to the trip duration for the terminal of Ponta Da Madeira.



(Graph 7: Cost per ton by trip duration for the Valemaxes departing from the Ponta Da Madeira terminal)

The cost per ton of cargo shifted from the Ponta Da Madeira terminal demonstrates an overall increasing trend. Starting the analysis from the current transportation system, there are three spikes, easily distinguished. Two sharp cost reductions and one sharp increase. During the second quarter of 2012, Valemaxes' quarterly fuel consumption reached its lowest levels, around 22.8 tons/day in ballast and 39.4 tons/day laden, resulting in the lowest fuel cost which is responsible for the sharp drop of the cost at 24.4 US\$ per ton. The sharp cost increase is related to the exactly opposite concept, that is, during the fourth quarter when the cost became 34 US\$ per ton, the fuel consumption had reached its highest level (102.1 tons/day in ballast and 73.6 tons/day laden), bringing the opposite result. Fuel consumption is a function of the designed technical characteristics, namely speed and fuel consumption and the calculated speed. As already mentioned, the speed is the main determinant of the trip duration and from this terminal, the observations on the sailing days were adequate to compute a representative output on speed. Graph 8 presents the speed per quarter as calculated from the collected data and includes only the trips to the Subic Bay.

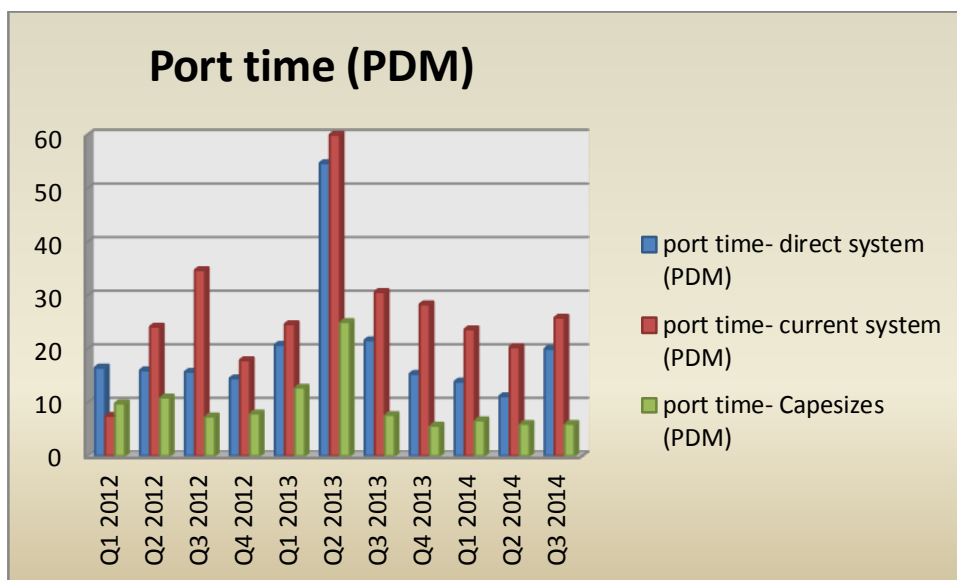


(Graph 8: Calculated speed for the Valemaxes departing from the PDM terminal)

During the first half of 2012, the Valemaxes were operated at a higher speed when they sail laden than in ballast, coming against the empirical finding which states that the ships speed up when they are empty and slow down when they are loaded. During the months that the vessels were loaded for the trip to the Subic Bay, the fuel price was falling. Thus, the most reasonable explanation for the pattern of the year 2012 is that the vessels speed up to take advantage of the lower prices and save on fuel cost. The cost of the firm had significantly

raised and they needed a source to save on cost. During the next quarter, the speed stabilises to 12.91 knots in laden and 14.08 knots in ballast.

The direct transportation has only one sharp cost increase, while other smoother spikes present but one spike is high and worthwhile of closer notice. After the first quarter of 2012, the cost is estimated as 26.7 US\$ per ton, explained by high fuel consumption, that is 100.3 tons/day in laden and 59.65 tons/day in ballast. Then, the cost started to drop until the third quarter that peaked again, due to the long port time, 55 days in the second quarter of the year 2013. Similarly, long port time is responsible for the cost increase of the transportation cost under the currently used system that during the same quarter the port time was 59.98 days. A lack of capacity accounts for highly lengthened port time at the terminal of Ponta Da Madeira. The port time incurred at this terminal for each system of transportation is provided in graph 9.



(Graph 9: Port time of the Valemaxes at the terminal of Ponta Da Madeira)

Again, Capesizes spend a lot less time at port than Valemaxes do, as expected. Capesizes are much older vessels and the terminals have already built the necessary infrastructure to accommodate them. Therefore, Capesizes are subject to shorter port time. The port time displayed to graph nine includes the discharge time and waiting time at the Subic Bay where that is relevant. The extra discharge and transshipment time spent in the Subic Bay is partly responsible for the Valemaxes' delay but the biggest source of delay is associated with the lack of infrastructure and capacity at the loading ports in Brazil. However, the negative

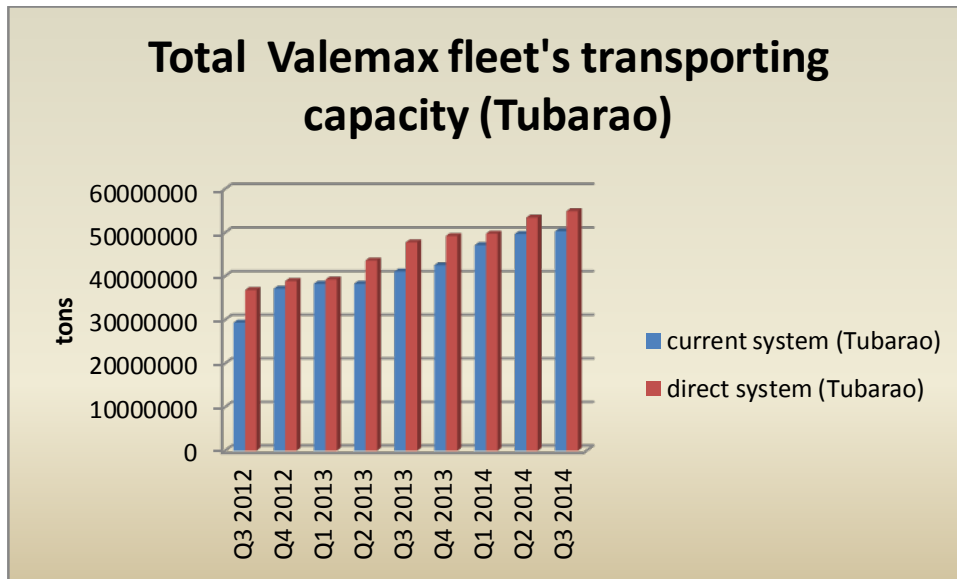
effect of the port time mitigates more and more by the lapse of the time without observing any high peaks by the end of 2014.

4.2 Valemax fleet's transporting capacity

One of the objectives of this thesis is to assess if there was a cost advantage for Vale with the construction of these vessels for the transportation of its iron ore to China. This section will provide information concerning the fleet's transporting capacity. Recalling, the cost advantage, otherwise called economies of scale due to the bigger size of the vessels, also refers to their ability to transport twice the capacity, the conventional Capesizes do, aside from the reducing average cost. Up to this point, the analysis has covered the transportation cost paid with the Valemaxes under the three available transportation options, but no citation of how much iron ore the fleet can transport.

One key point to the economics of the Valemaxes is the demand of iron ore by the Chinese steel producers. Iron ore demand is stable on an annual basis and as already mentioned, its delivery takes place 4 times a year or once per quarter. From Vale's financial earnings results, the actual quantities delivered to China every year since 2012, are: 200.875 million mt, 145.847 million mt and 156.540 million mt, for each year respectively. Dividing the annual demand into 4 equal portions, the demand that Vale should cover each quarter of each year since 2012 is 50.21875 million mt, 36.46175 million mt and 39.135 million mt, respectively.

Vale could abandon the conventional chartering from the spot market and the spot rate volatility over this route, only if the entire demand could be met by the total carrying capacity of the fleet of Valemaxes and China didn't forbidden the arrival of Valemaxes at the port of Qingdao. It turns out that the capacity of the whole fleet of Valemaxes is not sufficient to meet the entire demand, even if the entire fleet was in service. Graph 14 and 15 show the quantity of iron ore that the full fleet of Valemaxes would deliver if it were in service, according to the empirical data on complete number of trips and carried quantities.

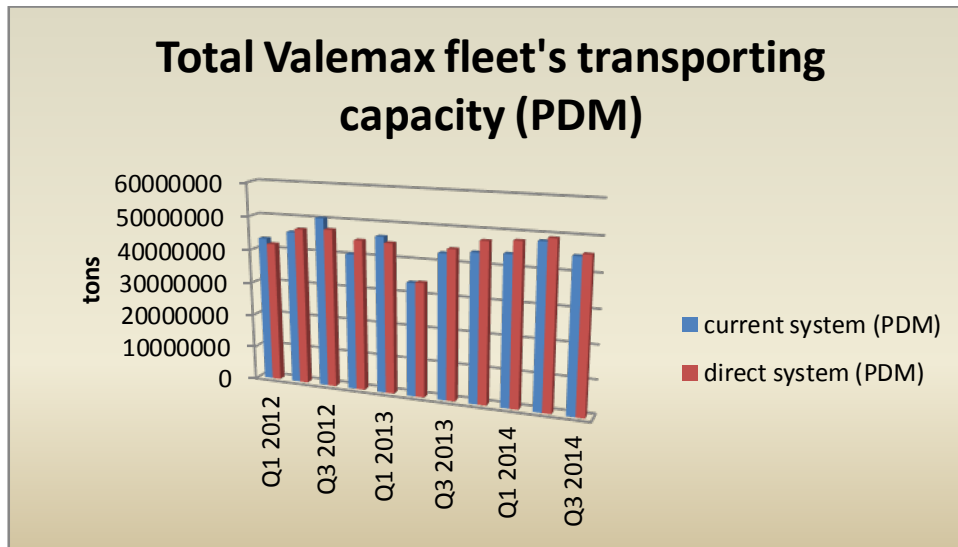


(Graph 14: Total transporting capacity of the Valemax fleet when loading at the port of Tubarao)

The full fleet at the calculated speed can cover one third of the annual Chinese demand, which means that the employment of capesizes is necessary. However, the quantity loaded can either reduce the employment of capesizes or increase it, if Valemaxes are loaded with a lot less quantity than their size allows. For instance, in 2012, the Valemaxes loaded a lot less cargo quantity at the port of Tubarao (311,903 tons on average) implying a deadweight utilization rate of 75%, which is low compared to the vessels' 95% average utilization rate.

A possible explanation for this fact is that fears and disputes rose over the deployment of the vessels. China blamed Vale for attempting to gain the monopoly over the particular route and thus, Vale had to carry less cargo in order to settle down the risen doubts over this issue. During the next years, Valemaxes sailed loaded with a lot more capacity of the maximum physical one, serving a higher fraction of the demand. In terms of cost, the employment of capesizes is currently the least expensive way of transportation but in terms of efficiency, Valemaxes are by 50% more efficient. At most 70 Capesizes transport the same quantity that 35 Valemaxes do. There are straight benefits of the direct system of transportation, as more cargo quantity can be transported. The fleet of Valemaxes can transport maximum 54.4 million mt without the ban and 50.3 million mt with the current system and loading from the Tubarao terminal.

Similar evidence reveals concerning the potential transporting capacity of the fleet when the vessels are loaded at the terminal of Ponta Da Madeira and whether the fleet can meet the iron ore demand, (graph 15).



(Graph 15: Total transporting capacity of the Valemax fleet when loading at the terminal of Ponta Da Madeira)

Further than that, graph 15 summarizes some additional important points not depicted at graph 14. It highlights that the very long waiting time in the second quarter of 2013 reaching an unprecedented high of almost 60 days at the Ponta Da Madeira terminal, significantly reduced the annual number of trips to 2.5 trips. As a result, larger difference between the quantity loaded on the Valemaxes and the demanded iron ore quantity served by Capesizes hired from the spot market, generated. 2.5- 2.7 million mt were added to the previously transported quantity that should be served by the spot conventional chartering. The importance of port time has been analysed in section 4.1. It can significantly affect the delivered quantity of cargo, reduce the sailing frequency and increase Vale's reliance on the spot market. Graphs 16 and 17 in the appendix display the sailing frequency over time of Valemaxes, as calculated from the empirical data. Loading from the Ponta Da Madeira terminal, Valemaxes can transport up to 49.3 million mt, directly shipping iron ore to China and 50.5 million mt, in the opposite case.

Ending up to the inference that given the quantity of iron ore loaded on the vessels each quarter, the speed operated over the route, the number of trips carried out and assuming that the whole fleet is on service, the maximum carried quantity does not exceed 50 million mt. This means that Vale does not have the potential not to rely on the spot market, given the current levels of demand, 2 thirds of the annual demand are satisfied with the Capesizes, regardless of the loading port.

Moreover, the fleet is not complete. The delivery of the vessels delayed and as of November 2014, there are three vessels of the fleet under construction. The fleet is currently consisted

of 32 vessels and the vessels were not delivered in one round but gradually. This means that the total iron ore quantity carried by Valemaxes so far, is less than showed in the graphs 14 and 15. Capesizes have also benefits, as they are more flexible, less costly after the ban imposition and they can sail more often. Sailing at the design speed, each capesize vessel can achieve 3.83 round trips per year, considering the average waiting time of 8 days at the port of Tubarao and assuming another 4 days of waiting and discharge time at the port of Qingdao. Even if the Capesizes can sail more frequently than Valemaxes can, their difference in the number of the carried out trips is not that high to outweigh the benefits that Valemaxes offer. Hence, comparing the two fleets, Valemaxes are far more efficient than Capesizes, as a much smaller number of vessels can transport the same capacity as hundreds of Capesizes, but their capacity isn't sufficient to cover the annual Chinese iron ore demand.

4.3 Discussion on the findings and the Valemax fleet's effect on the Capesizes spot freight rate

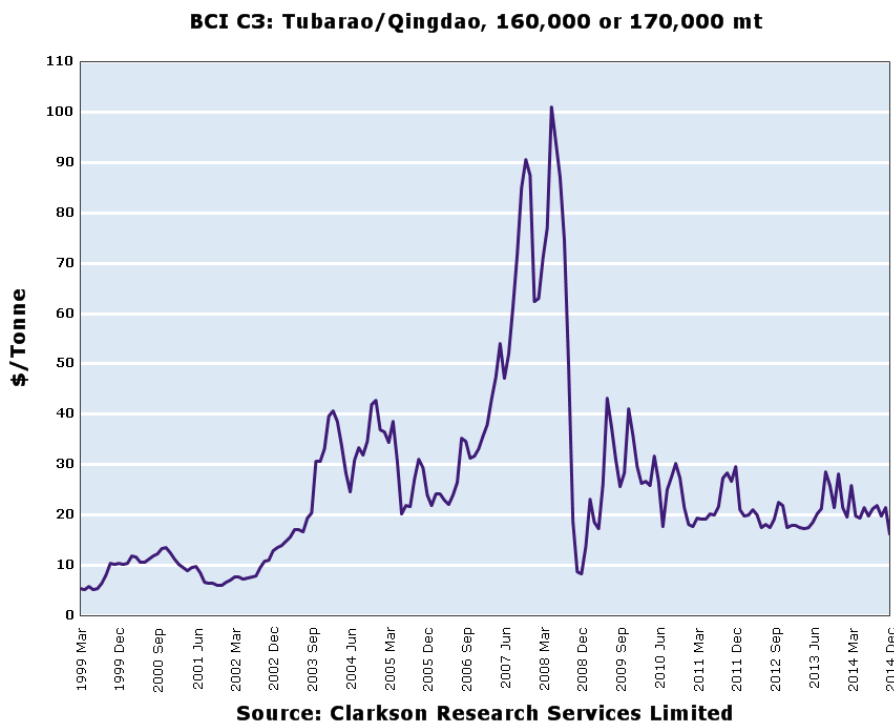
Long discussions and arguments have been aroused on the shipping cost of the Valemaxes and their impact on the spot freight rate and the Capesizes' employment. In the preceding analysis, Vale's cost averaged at 30.2\$/ton loading at the terminal Ponta Da Madeira and noticing a minimum of 24.4 \$/ton and a maximum of 34.01 \$/ton. The results come in accordance with the estimations that alphabulk made in 2013. They reckoned that Vale's cost in June 2013 was 35.74\$/tonne, excluding the waiting time but including the transshipment cost and the cost of moving the iron ore from the Subic Bay to China in Capesizes. The latter was estimated to be 4.08 \$/tonne which is almost the same with the one that the writer has calculated (on average 4.05\$/ton).

The same research group estimates that the direct destination from this terminal would be 25\$ per ton, while the writer found that the cost averages to 22.84\$/ton, ranging from 20.63\$/ton to 25.3\$/ton. Similarly, alphabulk estimated the cost from the Tubarao terminal to the port of Qingdao, found to be 24\$/tonne. In this study, the latter corresponds to the calculation of the direct transportation system, averaging to 21.5\$/ton, noticing a minimum of 18.4\$/ton and a maximum of 25.9\$/ton. In this case, the estimations differ but the range is close to alphabulk's estimation. There is no particular benchmark for the cost of the non-direct route loading from the Tubarao terminal provided by another research group, but the difference should be the same and around 10\$/ton and the findings of this study support this

differential. Thus, they are reasonable. However, it is important to note that the difference of the cost can be explained by the fact that alphabulk's results concern one discrete point of time, while the author's calculations are made on a quarterly basis.

As referred to the second chapter of this study, the freight rate on the spot is determined by the parallel movements of the supply and demand functions on the market. Consequently if a one or more of their determinant factors change the correspondent shift of the curve will occur, altering the freight rate level. The Valemax fleet can add as showed in the section 4.2 a capacity of 68.3 million tons if the vessels steam at full steam, which is a significant amount of supply in the market.

The introduction of the Valemax fleet has a two-fold character, as it shifts the supply increasing the merchant fleet and the demand by adding important transporting capacity, translating into a drop of the freight rate. That is why the delivery of the entire fleet delayed to protect the owners of smaller vessels. As it is not in the scope of this study to quantify and measure the impact that Valemaxes have on the spot market, it will only be discussed based on critical thinking and on the evidence presented on the figure 1 in the chapter 2 where the opinions of other writers are stated, obtained by the Clarkson research database. For the reader's convenience, the same figure is cited below.



(Figure 1: BCI C3: Tubarao/Qingdao, 160000 or 170000 mt. Source: Clarkson Research Services)

Looking at the figure and the spot price, we can infer that the freight rate plunged due to the financial depression and not because of the Valemax fleet. The fleet was ordered in the first half of 2008 before the crisis bursts into and when the freight rate peaked, to 100 US\$/ton. The sales price of iron ore for Vale at that point of time that Vale was based on reference pricing, was averaging to 76.03 US\$ per ton (Vale's quarterly results, earnings, 2008). In fact, Vale was in short notice in a financial loss and proceeded to an investment with high capital cost involved and a bit later the freight dropped to 10\$/tonne. However, during the delivery period, 2011-2014, the freight generally increases reaching the peak in 2013 to almost 30 \$/tonne.

Thus, the conclusion that can be made out of this is that the delivery of the vessels by definition has affected the freight rate at the spot market, by causing 25% increase of the spot rate. The spot freight rate remained at this level shortly, but after the injection of the majority of the vessels in 2013 the spot rate fell by 23%, translated to a 6.72 \$/ton decrease and since then it fluctuates on this level. Alphabulk (2013) agrees with this result, concluding that "*Vale pushed down the Capesize market by 10\$ per tonne*". Drewry Maritime Research (2014) believes that the recently signed agreement with COSCO for the Valemaxes will not only drop the freight rate further but will also increase its volatility. Consequently, the introduction of the fleet in the shipping market indeed affected the freight rate of Capes. Nevertheless, the writer's opinion is that strong deductions on the fleet's impact cannot be made, as there are several factors that affect the spot rate and thus, the blame cannot be put exclusively on Valemaxes' operation.

5. Conclusion

In this thesis, the economics of the Valemax vessels were studied by considering two different service strategies: hub-and spoke and direct shipment, over the route Brazil- China. The biggest question addressed was to find out Vale's cost profile and investigate whether economies of scale were realized or can be realized given the interrelated factors that affect the transportation cost. It was found that the fleet of Valemaxes is currently the most expensive way of iron ore transportation. The spot Capesize employment is currently the cheapest way of transporting the iron ore, but at most 70 Capesizes are needed to transport the same quantity that 35 Valemaxes transport. Hence, Valemaxes are currently costlier but a lot more efficient.

However, the fleet of Valemaxes is privileged over the employment of Capesizes for the considered route. Valemaxes are chartered under contract of affreightment that provides stability on the transportation cost, while the spot freight of Capesizes is highly volatile with rapid fluctuations, inserting a high degree of uncertainty for Vale. The cost follows a falling tendency, indicating serious evidence of economies of scale. As such, a high chance of further reduction of cost in the long term is implied.

To conclude, the fleet of Valemaxes is costly, but its falling trend is association with its operational advantages offer substantial benefits. Vale has a more effective control over the cost of transportation and the quantity carried, in particular with the vertical integration. In terms of systems, the inhibition of the Valemaxes in entering the port of Qingdao is not the only obstacle set. The delivery of the vessels seems that it was not by chance, but an effort to prevent Vale from controlling the iron ore trade and gaining the monopoly. The safety reason that China claimed for forbidding the access of the fleet was only an excuse. The real reason was to protect the local shipowners from the probable freight rate reduction, which later on was a fact, the spot rate dropped. No strong conclusions can be drawn on the size of the Valemax fleet's impact on the freight rate as multiple factors affect it.

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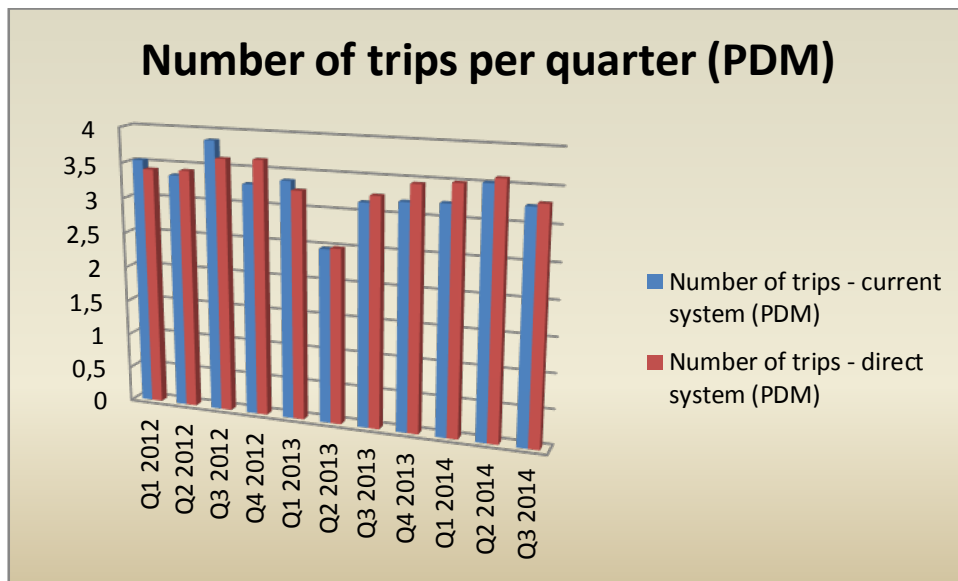
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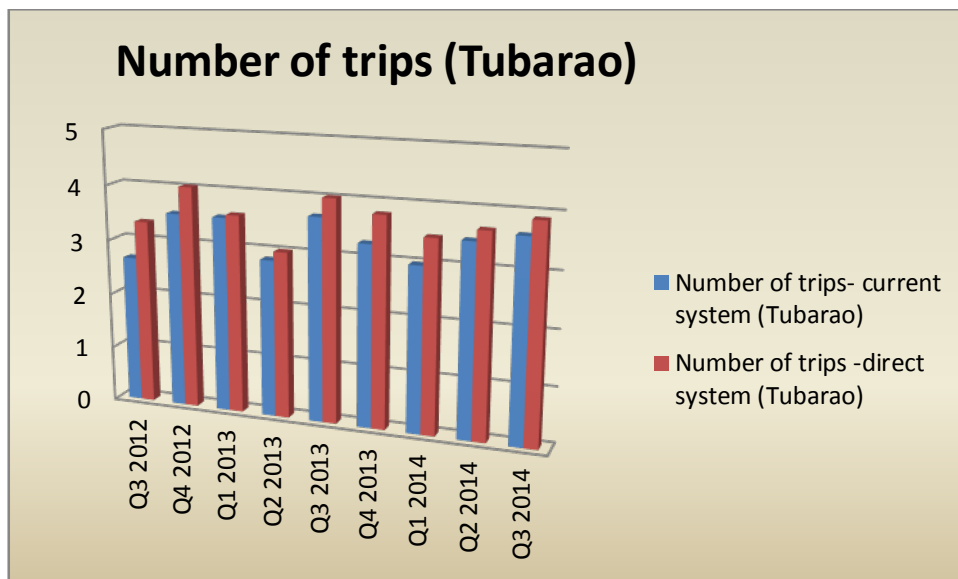
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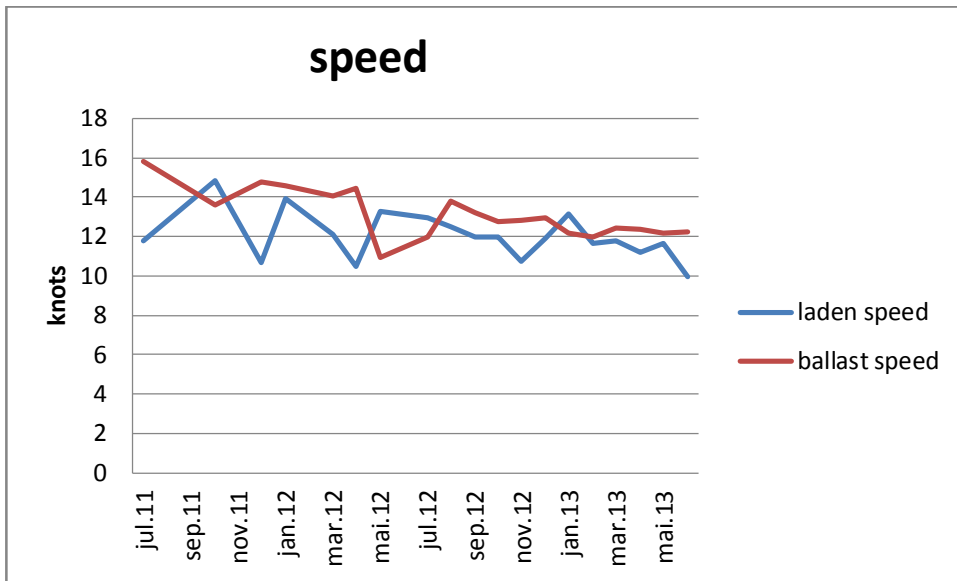
Appendix



(Graph 12: Number of carried out trips when Valemaxes load at the terminal of Ponta Da Madeira)



(Graph 13: Number of carried out trips when Valemaxes load at the port of Tubarao)



(Graph 16: Empirical speed of all the trips carried out by Valemaxes)