Feasibility of an Intermodal Transport Solution Towards Northern Europe Using Portuguese Ports.

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ABSTRACT: The geographic location of Portugal and the respective ports of Lisbon and Sines on the Atlantic Coast imply strategic potential for maritime and terrestrial commerce as a gateway to Europe. The developments in rail infrastructure has been neglected in the past half century. The European commission development program aims at a revival in the sector. The developments related to Portugal is to have its regional ports be part of the unified Atlantic Rail Corridor which is a branch of the greater European unified and standardised rail network program with expectation of completion by the year 2030. The study aimed at developing an analysis of the competitive feasibility of transporting goods by intermodal transportation through Portuguese ports and onward to the German Hinterland as opposed to the transportation of goods directly to the Northern European ports from South African Ports, South American East coast ports and the North American Port of Newark. The goals would be to demonstrate the cost per containerised unit in TEU per prospective route by the combination of maritime and rail travel. The study additionally aims to analyse the effect of emissions along the combined intermodal routes and the overall time expected for each shipment to be delivered to the German hinterland. The study Also takes into consideration the status of rail infrastructure developments requirements to be made to meet uniformization and network completion and estimated investments for the respective sections

1 INTRODUCTION

Historical Background

Annual growth rate of container flows currently until 2020 is still expected rise, after the previous global slow down where a positive trajectory is expected in future years. High pressure on ports and on their hinterland connections are expected from the changes arriving from additional supply from the growth of shipping and as such infrastructure developments for ships and intermodal connectivity, highlights the need for forecasting tools and decision support systems. Continental regionalization is a more constant occurrence This is particularly true of Europe with the developments of the European Union. Ports are increasingly being regionalized particularly in the European framework for unified flow. This has led to Portuguese ports being regionalized in the greater supply chain, similarly with North-Western European ports. The ports are not in direct competition but for specific qualities, rather the terminals to gain its market share on the hinterland market. Directives of The European Union Commission is the development of a unified transport sector.

The Port of Lisbon is a large European port with an Atlantic orientation whose geo-strategic centrality gives it a high statute within the logistics chain of international commerce and in the main cruise circuits. The port is national leader in the movement of GT and the number of vessels occupying 1st place in the Portuguese national ranking of the handling of containerised cargo.

The Port of Sines is a leading the Portuguese port by the volume of cargo handled. The unique natural characteristics of an open deep-water sea port with excellent maritime access, without restrictions, allows the reception of any type of vessels.

The port of Rotterdam located strategically at the Rhine river mouth is the largest deepwater port in Europe. Sea) had a sea cargo handling of 7431548 containers and 12385168 TEU in 2016. (Port of Rotterdam, 2016)

Objectives and Structure

The objective is the demonstration of the feasibility of intermodal containerized freight transportation through Portuguese ports to the German hinterland by rail. The comparison is with vessels travelling to European ports and the containerised cargo then traveling by rail to the German Hinterland rail terminals

This work will be divided in 5 chapters. The Literature review will be presented in the second chapter. The review will be on the infrastructure investment requirements required along the Atlantic and Rhine Alpine Rail freight corridors. The third Chapter will elaborate on the process and methodology employed towards the calculation of the cost per route and containers unloaded per port and hence transported to the German Hinterland. It also further explains the procedures used to determine the emission calculations related to the maritime vessels and the rail component contribution. Here the calculated tariff per rail voyage will also be discussed. Chapter 4 covers the results of the cost of

2 LITERATURE REVIEW

The European Union and the Ports themselves respond to the expected growth of the market with large investments. These investments focus on the components of the transport chain, maritime access, port capacity and efficiency and hinterland transport. Developments in the maritime industry with increases in ship dimensions and hence the advantages of scale many ports in Portugal, need to deepen their maritime access to improve their accessibility for ships of over 8000 TEU and recently of 13500 TEU (ship Emma Maersk). This ongoing development and affects the competitive position of these ports to exploit their natural nautical conditions and level of investment in maritime access. The container handling capacity is growing fast in the Le Havre - Hamburg range, because of private investments in terminal capacity. Rotterdam, Antwerp, Bremen and Hamburg terminal capacity in these ports is planned to double, from 37 million TEU in 2005 towards 70-80 million TEU in 2020. (Hamburgsüd, 2015) (Zondag, 2008)

In the models in question, a specific instance of a maritime transport supply consists of two legs or a three legs segment when transporting freight from a port of origin to an inland destination. The first leg is the movement of the cargo from maritime ports of origin, transported along a maritime route to the destination port terminal. The second leg of the operation is the freight movement from the destination port terminal to the inland destination. The second option is a case of transshipment where there are two maritime legs from 2 ports and the final leg being the inland leg to the hinterland terminal. The inland legs of the transport operation are often referred to as the hinterland legs of the operation. Each of these segments requires the supply of a transportation service to accomplish the demanded cargo movement. The movement of goods between locations by freight transport, often involves the combination of different modes of transportation. These intermodal movements may apply multiple different modes of transportation, linked end-to-end, to move freight from a point of origin to a point of destination (Southworth) freight supply chains also incorporate the need for door to door supply which means that the entire systems can organize the transportation supply of goods from the point of origin to the final customer. Freight transportation is carried out on a global intermodal network composed of various actors that demand and provide transportation services. (Pfeifer, 2013). The freight movement include services by means of airplane, truck, train, or ship, as well as the transfers for moving cargo between the modes. There are also a variety of stakeholders that include customers, service providers, and governments each will have their own different interests that cause impacts on freight transportation networks and services. Complex relations also exist between the actors and the stakeholders involved. Therefore, it is important to consider freight transportation as an integrated system (Crainic).

Maritime transport is major contributing factor to global economic performance and elements that affect the supply and demand of trade which translate into the performance of the freight market. The freight market is the driving force of shipping markets is the freight market which at the current point in time of writing this thesis global freight rates have been low to the response in lower fuel and commodity prices. The new building and Sales and purchase market likewise will be affected by these events, which reflect the levels of supply and demand.

The New Building Market will be in particularly affected by supply and demand related to the freight markets which will be under a phase of the shipping cycles that affect the maritime economy. The current shipping cycle is in the trough cycle. After collapses from the great recession at the end of the last decade and the recent fall in oil prices and drop in commodity prices, reduced Chinese growth and political crisis in Brazil, since the previous year has led to from a collapse in the freight and charter rates.

Investments that are to be completed in the near and mid-term future related to maritime infrastructure that can exploit the market conditions in the future. Since the inevitable recovery and peak cycles will now follow this period, as such entities that have the infrastructure and systems in place to meet the increased demand post the current reduced economic activity will reap the most benefit.

The Atlantic Corridor, as defined in its alignment by EU Regulation 1316/2013, connects Europe's South-Western regions towards the center of the EU, linking the Iberian Peninsula ports of Algeciras, Sines, Lisbon, Leixões (Porto) and Bilbao through Western France to Paris and Normandy (up to the port of Le Havre) and further east to Strasbourg and Mannheim. It covers rail, road, airports, ports, railroad terminals (RRTs) and the River Seine inland waterway.

The population in the Atlantic Arc can be estimated at more than 80 million inhabitants (25% of the population of Eurozone) and is distributed around twelve urban agglomerations of more than one million inhabitants the corridor is the shortest itinerary to get to Paris, London, Berlin, Northern and Eastern Europe or Russia. From an economic perspective, the Atlantic Arc accounts for 30-40% of the GDP in the Eurozone: more than 2 trillion Euros' worth of GDP.

Currently there is considerable modal imbalance, which should lead to an equal share of transport modes (to the benefit of sustainable ones, particularly Railway and Port transport) As an example, we could say that approximately 50% of freight traffic between the Iberian Peninsula and the rest of Europe takes place along the Atlantic corridor. Only 1% of this traffic takes place by rail and 16% by sea, the remaining 83% by road. This has led to saturation in the road infrastructure and to the standstill and unsustainability of the system.

The goal of the Rail Corridor and to foster intermodal transportation.

- Coordinate the planning and implementation of the different actions in the corridor
- Improve the quality, competitiveness, and efficiency of the rail services
- Promote rail as an alternative mode of road transport
- Ensure interoperability in the rail transport of rolling stock, services and operators
- Boost the development and coordination of intermodal logistics centers and terminals

The Atlantic Corridor is characterized by an outstanding maritime dimension which is not yet fully exploited. Critical factors hindering interoperability and the seamless connection of modal networks lead to a situation of an unbalanced hinterland modal split, hindering the growth of the most efficient modes of long-distance transport. Important critical issues were identified at corridor level, largely related to the rail infrastructure, and notably:

- The missing link between Évora and Caia in the border Portugal-Spain;
- different track gauges;
- limited train lengths.

Moreover, improvements in landside access and last mile connections to ports are needed, with most of the existing bottlenecks being related to rail. The interconnecting nodes are also affected by limitations, thus artificially broadening the role and market share of roads. Airport connectivity with TEN-T rail is also limited. LNG availability at ports might limit the role of some Atlantic corridor ports in the future, if a proper plan is not rolled out, exploiting the potential of the existing LNG terminals along the Atlantic coastline. It is worth noting that Member States are already envisaging efforts in this domain (i.e. Portugal and Spain are working together on a project which is developing the LNG plan). (Secchi C. , 2016)

Shipping liners have had to adapt to change in market conditions from economic crises affecting Latin Americas largest economic power house Brazil which has had declining growth and heading towards recession from cumulative effects of Low commodity prices oil and lack of significant infrastructure developments in key sectors.

2.1 Terminal Characteristics

Lisbon port has a strong demand from its location inside the capital area with facilities along both banks of Tagus river. Centralization of many logistic chains for the entire country. Results of 2013, indicated that 11,9 million tons of cargo have been shipped of which 45% were containerized. Port of Lisbon has three container terminals with different characteristics and utilization levels: Alcântara terminal, deep sea and already with utilization above the 70; Santa Apolonia Terminal, short sea, with 50% and Poço do Bispo (mainly insular traffic) around 80% utilization rate. Although here is still available capacity in global terms (overall utilization is 60%), a bottleneck can be identified at Alcântara terminal. Strikes of stevedores also had influenced in the container terminals previous years´ throughput. On the other had the lack of a direct rail south connection to the Spanish border has a considerable detour (of more than 135km.)

The Container Terminal of Sines, called Terminal XXI, started operations in 2004, being operated under a public service concession regime by the company PSA Sines - Container Terminals S.A.

Sines Container terminal rail networks, are integrated into the Atlantic corridor of the Trans-European Transport Network. On the other hand, to respond to the growth projections, a plan for the evolution and expansion of road-rail accessibility is being implemented, within the framework of the Infrastructure Investment Plan - Ferrovia 2020, which will ensure correct intermodality for the connections with the interior of Spain, particularly in the region of Madrid. The increasing volume of containerized freight travelling within urban areas; the spreading of freight activity from city centers into suburban areas (Alho, 2011) This development has led to the increased completion of ports in a regional context to obtain a market share of the targeted hinterland markets for example Sines terminal XX1 and Lisbon´s container terminals.

In the context of Sines is to gain access to the market around Lisbon but be strategically place for future rail developments to be able to access the hinterland markets of Madrid and Europe by transfer of cargo to additional capacity at the Entroncamento MSC Terminal

Bremerhaven a modern and efficient hub for container transports into Europe and the whole world, Bremerhaven boasts a strategic geographical location directly on the North Sea and the longest container quayside in Europe. Offering rapid transshipment times for the world's mega container vessels, the port has a closely meshed network of feeder services and efficient transport connections to the hinterland for onward shipment of goods to the major economic centers of Europe. The world's biggest ocean carriers (>10,000 TEUs) are calling at Bremerhaven on a regularly.

EUROGATE Container Terminal Hamburg is characterized by a strong dynamic. The terminal is equipped with state-of-the-art container gantries and straddle carriers, permitting smooth and rapid handling. As one of northern Europe's main transport hubs, Hamburg also offers excellent road, rail and feeder connections to the economic centers of Scandinavia, central and eastern Europe and Russia. The Port of Hamburg lies 115 kilometers or 70 nautical miles inland from the North Sea on the River Elbe1. The eco-friendly inland location enables shipping lines and logistics providers to reduce transport times by road or rail.

PSA Antwerp has been constantly expanding the terminal, both in terms of surface area and handling equipment. In 2015/2016, the MSC PSA European Terminal (MPET), a 50/50 joint venture between TIL and PSA, moved its operations from the Delwaidedock on the right bank to the Deurganckdock on the left bank. In this context, this terminal has been expanded to a throughput capacity of 9 million TEUs annually

The terminal of Liscont was the terminal used for the container transfer at the port of Lisbon. The terminal allows for 630m of quay and maximum depth of 14.5m. The park area capacity is 7235 TEU and is Equipped with the Following: 2 post panama ship to shore cranes of 65 t and 51m reach,1 ship to shore crane of 45t lift and 39m reach, 10 rubber tire gantries of 40t seven rows and 6 stacking, 4 frontal forklifts of 45t 1 Ro-Ro forklift 2 reach 15yard truck and 16 chassis.

The terminal of Sines With a staged and sustained development plan, Terminal XXI offers natural depths of up to 17 meters ZH, allowing the large container ships of the transcontinental routes and the vessels of their feeder connections to dock Currently, with a berth length of 946 + 200 meters and equipped with 9 post-Panamax and super post-Panamax porches and 2 mobile cranes, the terminal has a storage area with 39.1 ha that allows a total capacity of 2,100 .000 TEU per year.

The port of Rotterdam ECT Delta terminal has a limiting depth of 16.65 m and 3.6km of quay and a yard area of 265ha. The Terminal is equipped with 36 STS cranes, 2 inland shipping cranes 38 straddle carriers 28 multitrailer tractors, 145 multitrains,9 terminal tractors and three reach stackers 265 AGV and 140 ASC`s and 4 RMGs

The PSA Terminal of Antwerp was depth limitation of 16.5m with quay length of 1780 and 1770.The terminal was equipped with the following: 2 RMGS and 2564 reefer connections. PSA DGD / MPET now features a total of 41 quay cranes across 9 berths, 200 straddle carriers and a quay length of 3,550 meters, which makes it the single largest container handling facility in Europe

The port of Hamburg has a quay length of 2080 m and a restrictive depth of 15.3m. the port is equipped with the following: 23 container gantries 95 3x stack straddle carriers 4X stack straddle carriers, 2 reach stackers and 8 RMGs

Port of Bremerhaven has a limiting draught of 16.5 m and quay length of 4.68m the terminal area is 2.9million m^2. The equipment at the terminal is the following: 13 container gantries 28 STS cranes and 67 4x stack 40t straddle carrier.

The port of Le Havre the quay length was 1050m the limiting depth was 14.3m 22000m^2 yard area. The port was equipped with 10 STS and 3 RMGs.

The South American Ports were ship loading crane details were as follows. The Ports of Rio de Janeiro Multirio terminal had a quay length of 800m and was equipped with 10 Ship to shore cranes. The terminal of Santos TPB is equipped with 8 STS cranes along a quay of 1108m. The port of Paranaguá has 9 STS cranes along a quay of 879m. The Port of Navegantes has quay length of 900m and the port of Salvador a quay length of 617, both had 6 STS cranes. The South African Ports were equipped with the following Cape Town had 6 STS cranes along a quay length of 2803m, Durban had 13 cranes along a quay length of 3899m, and port Elisabeth had 12 cranes along 925m. The North American port of Newark had 6sts along 1097m quay length. It was also equipped with 3 Rubber tyre gantries, 96 Straddle carriers 13 empty handler 5 reach stackers and 50-yard tractors.

2.1 *Rail corridor compliance*

The TEN_T European rail corridor network intends to have uniformization of all aspects of the rail network by 2030. The key factors that require that all sections of the European corridor are of the same standard. The following tables highlight the problems encountered along the Atlantic Corridor. The train length completion for Germany Netherlands and Belgium Is 100% completed. Germany has completed all freight lines to 100Km/h. Belgium and Holland have 835 and 81.6% respectively still to complete. The electronic rail traffic management systems are still required for Germany, Belgium and Holland whose completion is 0%,18% and 49.8% respectively (ERTMS) (European Economic interest group, 2015)

Germany is compliant with all other aspects Spain has 0% compliance with train lengths and Portugal is 72% compliant. France Spain and Portugal are nearly compliant by 93%, 99%,96% respectively. Spain and Portugal both still operate with Iberian track gauge and not UIC gauge. Spain has 25% compliance whereas Portugal has 0% electrification is the other region where Spain is only 68% compliant.

Table 1 Electric Voltage difference

voltage Difference		
Portugal	25	KV/AC
HS lines Spain	25	KV/AC
Northern France	25	KV/AC
Conventional lines Spain	3	KV/DC
Southern France	1.5	KV/DC
Germany	15	KV/AC 16.67HZ

Table 1 shows the different traction power and systems that occur along the Atlantic corridor currently. This proposes challenges for trains as there is greater requirements for transformers and rectifiers as a train cannot make a direct single journey in the current format.

Table 2 Sections along Atlantic corridor requiring electrification

Electrification	
France	definition
Gisors-Serqueux	bottleneck <Rouen Le Havre
Spain	
Medina del campo-Fuentes de Oñoro	Cross border Spain Portugal upgrading
Bobadilla-Algeciras	Conventional non-electrified
Madrid Badajoz	Conventional railway non-electrified cross border Portugal Spain

The principle problem is the lack of electrified track with respect to Portuguese ports are the Madrid Badajoz connection that will greatly enhance the port of Sines ability to gain access to the Madrid market and at Medina del Campo. This is currently inhibiting the prospective journeys of direct lines to the European hinterland markets

Table 3 Bottlenecks along Atlantic corridor route

Bottle necks	
France Spain	
Irùn-Hendaya	axle change and load transfer
	GPSO line improvement expected to create direct line to Bordeaux
Spain-Portugal	no electrification
	Planned no implementation
Vilar Formoso - Fuentes de Oñoro	
Caia-Badajoz	
Southern section	
Evora- Caia	MSC possible actual construction
Evora -Merida	missing links woks done

The bottle necks that will for the foreseeable future due to lack of electrification are at Vilar Formoso and Caia-Badajoz. These bottle necks are due to the need to change to diesel trains or hybrid inhibiting the possibility of a direct connection. The Bottleneck at Irun is due to the track gauge changes as France is already compliant with UIC gauge

Table 4 Sections requiring Trucks and Flatcar upgrade for axle weight TEN-T compliance

axle load 22.5t	
all core sections good	
Abrantes-Purtoal-lono	>22.5 axle trucks require up grading
Tours-Woipy	> 22.5 axle trucks on secondary route

Table 5 Rail Gauge along Atlantic Corridor

Gauge differences along the Atlantic corridor		
58% completed	1435	[mm]
France and Germany	1436	[mm]
Madrid-Antequera HS lines	1437	[mm]

Madrid-Antequera HS lines	1438	[mm]
None (Iberian gauge)	1668	[mm]
Iberian Gauge (Iberian gauge)	1688	[mm]

Table 5 displays the inconsistencies with track gauges and sections along the Atlantic Corridor.

2.2 *Portuguese Rail investments*

The investment estimates were obtained from European commission reports and in accordance with the sections requiring work which were found through the annual European commission reports estimated costs were calculated based on Professor Baumgartner method.

The effects of non-completion of rail corridor have direct and indirect effects upon the job market. Directly for the construction and infrastructure related jobs of implementation and operation of the new infrastructure. Indirectly from the new jobs created from the transportation opportunities from the newly connected network. The implementation of the core TEN-T network by 2030 would provide a substantial stimulus to the European economy, fostering both GDP and employment. They also suggest that the generated employment would benefit over-proportionally vulnerable groups, i.e. lower skilled workers. The highest economic multipliers were found for implementing the major cross-border projects along the nine CNC and for deploying innovative technologies. Implementing the core TEN-T network including the cross-border projects and the innovative technologies can thus be recommended as a suitable policy to combat the weak economic situation in Europe. (Schade. W, 2015)

Induced employment: jobs generated due to an increase in the demand for all goods and services, when construction and other supplying sector employees spend their (new) income. Then, it is needed to estimate a consumption multiplier, that is, the percentage of new income that is spent rather than saved by employees. (Schade. W, 2015)

Table 6 Estimated job creation loss

Estimated Job Creation		
Jobs created	20000	[Jobs]
Investment per 20K jobs	1000	[M€]
Estimated total investments on rail TEN-T	34547	[M€]
Jobs to be created	34.547	jobs/20k
Jobs to be created	690940	[jobs]

From the review of the European Commission reports from the information delivered from 2015 and reviews made by the Frauenhofer Institute where no further investments are made from 2015 with no further development until 2030 on the TEN-T transport network. Job projection relates that for every 1billion euros invested in the TEN-T network. The estimation is based on work done by W. Schade. Which affect both direct and indirect job creation. Directly by jobs in construction maintenance and repair of the Rail systems and infrastructure to be invested. In addition to jobs created by providing service in the newly developed rail sector. Indirect jobs from the flow of commerce generated by the new rail network.

3 METHODOLOGY

The study comprised of obtaining the costs for the maritime and rail components of three respective source maritime options that would have each respectively two maritime alterations. The maritime supply routes were from the South American East coast ports, the second was from South African ports, and lastly form the North American port of Newark. The rail would then take freight from either Portuguese ports or northern European ports to the German inland terminals.

3.1.1 South African maritime route

The Maritime route chosen is the Southern African route one which the shipping operator Maersk uses. The Route 1 consists of a northward leg that starts from Durban in South Africa to Rotterdam in the Netherlands. The northward leg has the following port calls Durban-Port Elisabeth-Cape Town, completing the African section. The ship continues to sail northwards up the Atlantic to make a port call at Rotterdam. The return voyage on the South leg which calls at Cape Town, Port Elizabeth, and Durban. The total route 1 length is 16184 nautical miles and the expected to have a fleet of 7 vessels, with a weekly call rate. The total round trip journey is expected to be 47 days. Route rotation is Durban-Port Elizabeth-Cape Town-Rotterdam-Cape Town-Port Elizabeth-Durban.

The route follows a timetabled schedule from Maersk Africa 1, in which the time in port and voyage time between ports is adhered to. The second route under investigation makes use of the vessels leaving South Africa from Durban and traveling from the same scheduled ports of South Africa. When traveling north along the Atlantic they head to the Portuguese Port of Sines, and then on to Lisbon. The vessels return on the South-bound journey making port calls at Sines before returning towards South Africa. The vessel Cargo quantities over the whole route are maintained to effect constant comparisons. The cargo heading northwards is 3344 TEU and southbound 2006 TEU. This gives a northbound cargo load ratio of 0.8 and southbound load ration of 0.48. Route 2 rotation is Durban-Port Elizabeth-Cape Sines-Lisbon-Sines-Cape Town-Port Elizabeth-Durban.

3.1.2 *Maneuvering*

The time in ports was related to the time of a vessel´s entry into port, to the time the vessel leaves port. The time taken for a vessel from the port entrance, to making berth was estimated considering speed variation due to incoming traffic and related regulations stipulated by ports regarding pilotage. This is the time reduced from port unloading and loading activities. The port time for effecting maneuvers is the time to approach the terminal docking bay. The first reduction in time spent in port is time taken to cover the distance where approach speed is required from port entry from the pilot boarding regulations of the respective ports. Where speed restrictions are imposed, these values are used, where there is no set speed restriction, then the average speed in ports to the terminal bay is used. The second element of the time consumed in port is for maneuvering this estimation goes in hand with the general distance associated with respective terminals for engaging in maneuvering activities

3.1.3 Loading and unloading container volume calculation

The analysis of the container quantities delivered and required at each port on the liner service was done by analysis of the Maersk schedule. The daily time was recorded per route section and time in port. The service time in port is the loading/unloading time required. The number of quay cranes required to service the container moving activities was thus calculated. The method employed was to first determine the available number of ship to shore cranes available. The number of ship to shore cranes enabled the calculation of the ratio of cranes per terminal quay length. The crane per meter ratio permitted the determination of the number of cranes servicing the vessel.

The number of cranes servicing the vessel multiplied by the respective cranes moves rate provided the number of moves per hour. The number of moves per hour possible provided a simplified approach to the number of containers offloaded. It was assumed that a move would constitute a complete offload of a container from the vessel. The move constitutes the complete movement of hoisting, trolling, gantry and idle positions of the crane movement the rate is based on the specified hourly movement rate of the respective cranes.

The number of containers moved in relation to international shipping is based on assumptions on the cargo load coming from South Africa. The vessel cargo quantities over the whole route are maintained to effect constant comparisons. The cargo heading northwards is 3344 TEU and southbound 2006 TEU. This gives a northbound cargo load ratio of 0.8 and southbound load ration of 0.48.

3.1.4 South African Port costs

The charging rates are similar for each of the South African ports and follow the charging fee principle from Transnet. The Port dues are associated with the costs per the first 24 hours related to a fee per gross tonnage and subsequent 24-hour berthing stay. Light dues are charged in accordance with the overall length of the vessel. There is also a further vehicle tracking system fee which is charged according to the vessel gross weight. Pilotage is charged at a base rate and a subsequent fee per gross tonnage. Tugs are required for these ports and 3 tugs per vessel are attributed in accordance with the vessels size. There is a fixed fee per tug and an additional charge per gross tonnage. (Transnet Port Authority, 2017). Handling fees are charged in relation to the terminal handling fee charges from Hamburg Süd per respective port with relation to imported or exported containers and likewise reefers.

3.2 *South American East Coast to Europe route analysis*

The objective is to demonstrate the difference between the cumulative costs of transportation of containerized cargo to the European hinterland of Germany. The comparison is for Route 1 which considers the status of ships traveling from South American East Coast to the northern European ports with the first port of call at Antwerp and continuing north until Hamburg. The quantity of cargo is then offloaded at these ports and is transported by freight rail to the hinterland. The cumulative value is compared to an alternative maritime route that makes a greater emphasis on rail transport by Goods coming to the Portuguese port of Sines and then northbound to Rotterdam and returning to Sines for a second stop before heading to South American east coast ports again

3.2.1 South America loading and unloading container volume calculation

The analysis of the container quantities delivered and required at each port on the liner service was done by analysis of the Hamburg Süd schedule. The daily time was recorded per route section and time in port. The number of quay cranes required to service the container moving activities was thus calculated. The method employed was to first determine the available number of ship to shore cranes available. The number of ship to shore cranes enabled the calculation of the ratio of cranes per terminal quay length. The crane per meter ratio permitted the determination of the number of cranes servicing the vessel. The number of cranes servicing the vessel multiplied by the respective cranes moves rate provided the number of moves per hour. It was assumed that a move would constitute a complete offload of a container from the vessel.

The move constitutes the complete movement of hoisting, trolling, gantry and idle positions of the crane movement the rate is based on the specified hourly movement rate of the respective cranes. The number of containers moved in relation to international shipping is based on assumptions on the cargo load coming from South America. The containers entering the Northern European ports are assumed as ports of predominately incoming cargo and as such have a 75% cargo offload to on load ratio. The vessel initially coming from South America is assumed at 100% full. The calculation of the cargo offloaded is done in an iterative fashion where each subsequent port of call on the northward journey. The international cargo delivered reduces to zero at Hamburg which is accounted by having A 45% offload at Rotterdam and 50% offload at Hamburg. This is a reasonable expectation as these ports are international recipient ports and Hamburg is the last port on the northward leg and would be expecting cargo to return Southbound.

It is assumed that the international cargo loaded begins once more at Le Havre with 50% of the loading attributed to International cargo. The iteration of Cargo loaded from the European ports is Iterative With 75% attribution to Lisbon and 50% to Sines. This will also imply a reduced cargo load heading to South America than that which came to Europe. The remaining containers on board are part of the rotational stock that must return and are empty.

In a similar fashion, the vessel that arrives at the South American Ports has their offload percentage done in an iterative form offloading at 80% at each port of call with Navegantes having an offload Percentage of 79. The result is all the remaining international containers are offloaded at the port of call at the southernmost point. The return journey northwards assume a 75% loading rate at the ports of call in South America for the return Journey Container Freight Station

3.2.2 South American Route Port Associated Costs

The port costs were found for each of the respective port dues on each maritime route in accordance with the charges laid out by the respective port authority and terminal operator. The Pilot and tug costs were charged in relation to each port´s specific pilot and tug operating guide or third-party service provider. The handling costs were calculated in accordance with each respective ports charges and fee schedule.

3.3 *North American route Analysis*

The study investigates the costs related to maritime container ship service traveling from the North American port of New York the shipping operator of Maersk uses, to the western European ports. The first route is direct to Rotterdam and the second is to the Portuguese ports of Sines and Lisbon. The Route consists of a Westward leg that starts from New York in the United States of America to Rotterdam Netherlands. The Eastward leg, returns to New York United States. The total route length is 6766 nautical miles and the expected to have a fleet of 3 vessels, with a weekly call rate. The total round trip journey is expected to be 22 days. Route 1 port rotation is New York-Rotterdam-New York. The route adheres to the timetabled schedule in which the time in port and voyage time between ports is adhered to. The second route under investigation makes use of the vessels leaving the United States port of New York to Portuguese ports of Lisbon and Sines. The return journey Westward to New York from the Portuguese Port of Sines. The vessel cargo quantities over the whole route are maintained. The East and West routes maintain a cargo transport of 3315 TEU. Route 2 port rotation is New York-Lisbon-Sines-New York.

3.4 *Fuel Costs*

The fuel consumption is further directly related to the specific engine used on the route which the fleet in question have all similar engine types in terms of engine specifications of Marine diesel fuel type power and stroke type.
Relating the fuel consumption in relation to the speed that the vessel travels is determined by the following formula

$$\sum F_j = F^* \left(\frac{S_j}{S^*}\right)^a \qquad (1)$$

F =The fuel Consumption

F*=The design consumption of engine also designated as the specific fuel oil consumption (SFOC) of the engine is

S=The course speed that the vessel undertakes per section of the voyage

a=3 - Specific engine type factor

j= Specific route between ports (Santos. T, Economics of Ship Operations, 2015)

3.2.2 *Auxiliary maritime fuel consumption components*

Auxiliary fuel consumption was also attributed to the associated number of auxiliary engines utilized during the voyage. The power of each auxiliary engine is 1176kW. There was additional 5.2kW attributed to each reefer with a Consumption rate of 0.23[kg/kWh] for frozen products per TEU**.** In port fuel consumption were associated with a standard hoteling rate of 4 tons per day (Cheaitou, 2012)

Auxiliary fuel costs were calculated by from the fuel consumption rates of specific equipment specifications from the ship´s description for the South American route analysis. These included the electrical power of generators. The power consumption from the electrical generators was estimated by simultaneous usage factors outlined for surface ships from the United States Navy (United Sates Navy,2012). Consideration of scenarios for waste incineration during the voyage allowed the calculation on the energy required by an incinerator per each section of the leg. Subsequent equivalent electrical energy consumption total was added to other energy consumption this would. Fuel consumption for electrical generation considers the ECA region where ULSFO fuel must be used in compliance with the sulphur reduction regulations imposed. The estimation of electrical consumption can be viewed in Appendix 2.

3.5 *Operating Costs*

Operating costs were estimated and calculated in accordance with formulae from professor Tiago Santos, economics of shipping operations. These values were compared with operating cost values found from the united states merchant Navy and Drewery consultants
The daily operational and periodic maintenance components are as follows:

- Ct – crewing (manning),
- Cal – Stores and consumables,
- Cmr – maintenance and repairs,
- Cs – insurance,
- Cad – administration,
- Cd – periodic maintenance costs.

3.6 *Capital Costs*

The purchase price of the vessel was found from Clarkson research

The monthly installment is found with the following formula:

$$P_i = s_o \left[\frac{\frac{j}{12}}{1 - \left(1 + \frac{j}{12}\right)^{-12n}} \right] \quad (2)$$

- P_i is the monthly installment
- j is the annual interest rate which is taken as 8% in this study
- J_i Is the interest parcel (The amount payable related to the specific time when a capital repayment is required)

$$J_i = \frac{j}{12} S_{i-1} \quad (3)$$

- S_o is the initial loan value which is assumed as the initial cost less down payment
- n is the number of years on loan (Ventura M, 2014)
- The number of years on loan 30 years at 8% interest

The depreciation of the vessel was calculated by straight line depreciation and the annual cost is associated with the first year´s value of depreciation for a new vessel. The useful life of the vessel is 35 Years.

3.7 *Rail costs*

The dissertation component calculations of the costs of rail transport include:

a) Average fixed costs (€) – is the costs associated with transportation of the type of goods associated with each type of product in the containers as such the products that are transported are laptops and shoes which are considered manufactured items which is attributed a fixed fee per ton-km

b) Variable costs (€) – the proportional part of the estimated maintenance costs found by expert estimations of Baumgartner and Delhaye as a percentage of the purchase price;

c) Driver's salary (€/hour)–A separate charge rate is associated with each country´s salary remuneration stipulation. The values are dependent on the permitted working hours of the driver in relation to the section of the route;

d) Traction energy (€/kWh)–is the costs associated with transportation of the type of goods associated with each type of product in the containers as such the products that are transported are laptops and shoes which are considered manufactured items which is attributed a fixed fee per ton-km

e) Charge for the transport route (€/km) – the related costs in relation to the tariff structures. A comparison of values is displayed with relation to CIS Software, Rail operator charge system calculations and charge associated with RNE timetable schedules.

f) The overhead cost of the current and projected routes – These costs are covered in the tariff structure by the respective operators.

g) The type of the rail freight wagon – the type used is a Greenbrier flat car double stacker;

h) Average time for one handling (hours) – is related to the handling time of ports and the handling times of available rail mounted gantries at the respective changeover terminals from electric to diesel and vice versa.

3.7.1 *Rail cost structure*

Direct costs are those in which the train incurs directly by its exploitation. These costs can be subdivided into the following categories.

In costs of access to infrastructure and operating costs of the service:

- Infrastructure use costs: all the fees that must be paid to ADIF for the use of the infrastructure.
- Operating costs: all costs related to traction and rolling stock.

Fixed costs are those that occur independently of the activity carried out by the train. They are "Periodic or hourly costs". These costs include:

- Depreciation of locomotive and rolling stock
- Financing of the locomotive and rolling stock
- Driving staff (salaries, social security)
- Insurance and taxes
- Other costs

Variable costs they vary proportionally to the activity of the train. The costs are related to the kilometres travelled by the locomotive. The following are included here:

- Fuel or energy consumption
- Drivers' and other assigned staff's allowances

Indirect costs are those not directly attributable to the operation of each train but occur by the normal operation of companies. They include the following concepts:

- Infrastructure costs: depreciation and financial expenses, or rental/leasing of facilities of the company, maintenance expenses and insurance of said infrastructure.
- Administrative &management costs: staff, office, communications and computer equipment.
- Commercial costs: personnel and commercial expenses.
- Other indirect costs

3.7.1 Rail tariffs

The tariff charges were calculated and the specific criterion and procedures to follow are laid out in Appendix 1 for each respective country through which the train path follows. The train path is from each respective port of call to the rail terminal in either Köln or Manheim with respect. In Table 19 the reviewed charges for each respective rail section of the overall route is determined the comparative values of the scheduled European rail network time table and path schedule, The European Network Rail charging information system (EICIS) and calculated values based on the tariffs of the respective countries rail operator as seen in Appendix 1 reference tariffs.

The Directive 2001/14 / EC indicates two different main economic philosophies, which may result in the definition of the infrastructure use rate: marginal cost (MC) and total cost recovery (CF), with each philosophy being able to undergo minor derivations. The marginal cost may be increased by a surcharge based on the operators' payment elasticity and thus reduce the state dependency (MC +). In turn, the principle of full cost recovery, i.e. the collection of all costs of maintenance and operation to the operator, can be changed to the principle of cost recovery fewer subsidies received through the pre-defined state contribution (FC-).

The recognition of the respective charging philosophy becomes difficult to determine, since this is not announced by the infrastructure managers, and can be the object of different interpretations by each author.

3.8 *Maritime Emissions*

Emissions from ships comprise the following chemical compounds:

Particulate matter (PM) (10-micron, 2.5-micron),
Diesel particulate matter (DPM),
Oxides of nitrogen (NOx),
Oxides of sulfur (SOx),
Hydrocarbon - total (HC),
Carbon monoxide (CO),
Methane (CH4).

Ocean going vessels emissions can be calculated by using energy-based emission factors together with activity profiles for each vessel. Emissions per ship call and mode can be determined using the equation below:

$$E = P \times LF \times A \times E \qquad (4)$$

where E = emissions (grams [g])
P = maximum continuous rating power (kilowatts [kW])
LF = load factor (percent of vessel's total power)
A = activity (hours [h])
EF = emission factor (grams per kilowatt-hour [g/kWh])

Load factors are expressed as a percent of the vessel's total power. At service or cruise speed, the load factor is 83 percent. At lower speeds, the Propeller Law should be used to estimate ship propulsion loads, based on the theory that propulsion power varies by the cube of speed as shown in the equation below.

$$E = P \times LF \times A \times E$$

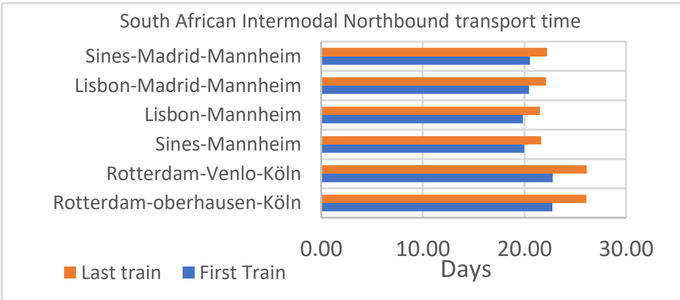
where LF = load factor (percent),
AS = actual speed (knots),
MS = maximum speed (knots), usually 1.064 times Lloyd's service speed.

The emissions of the vessel along both the projected route and the current timetable route were calculated with respect to each emission particulate type. The ocean-going vessels emission contributions were attributed in accordance with the load factor which had values associated with speed for speeds associated for voyages. The loading factor for Maneuvering and hoteling.

Rail emissions are accounted for in relation to ton/km of emission particulate generated per train per voyage. The calculations were done with respect to European commission values based on electric trains that are supplied by electric traction energy on route. The emissions for all the trains required to transport containers to the German hinterland were calculated.

4 RESULTS:

Time required for delivering North Bound Cargo is seen in Figure 1 shows the delay for each rail route. The time taken from port of discharge to German inland terminal is



shown.

Figure 1 South African Route inter modal north bound travel time

Figure 2 shows the last trains take longer form South African ports of origin than First train dispatches
The time required for delivering East Bound Cargo is seen in Figure 1 shows the delay for each rail route. The time taken from port of discharge to German inland terminal from Newark port of Origin is shown.

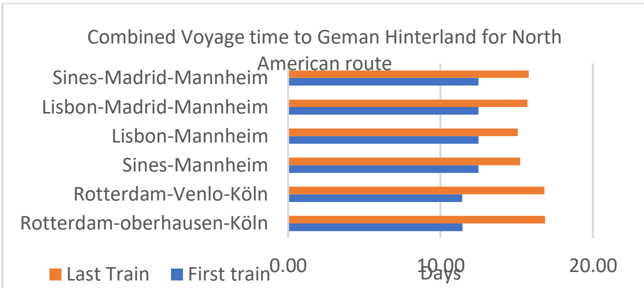


Figure 2 intemodal time East bound voyage North American Route to German inland terminals

Figure 3 displays the results for intermodal transport costs to German inland terminals from South African ports of origin.

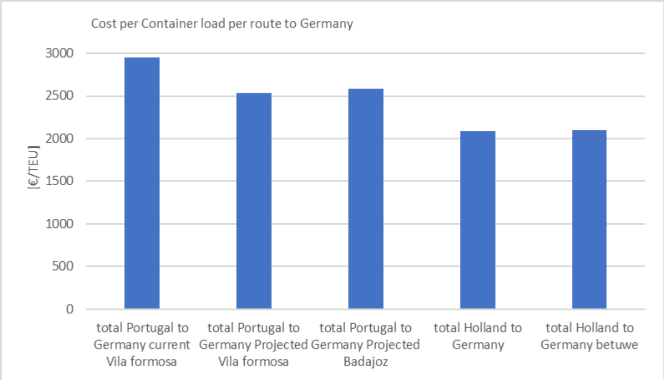


Figure 3 South African Intermodal unit costs to German in land terminals

Figure 4 displays the results for intermodal transport costs to German inland terminals from North American ports of origin.

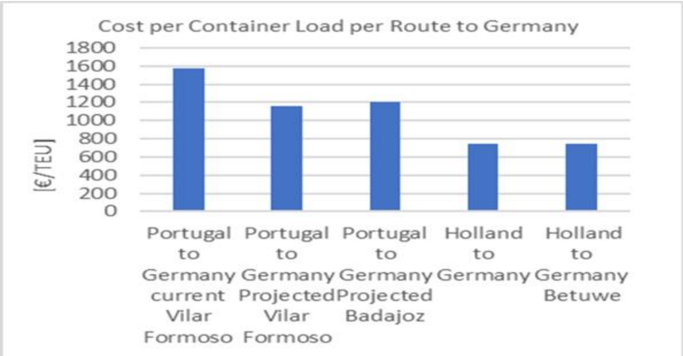


Figure 4 North American routes intermodal cost from Newark to German Hinterland

The figure displays the results for intermodal transport costs to German inland terminals from South American ports of origin.

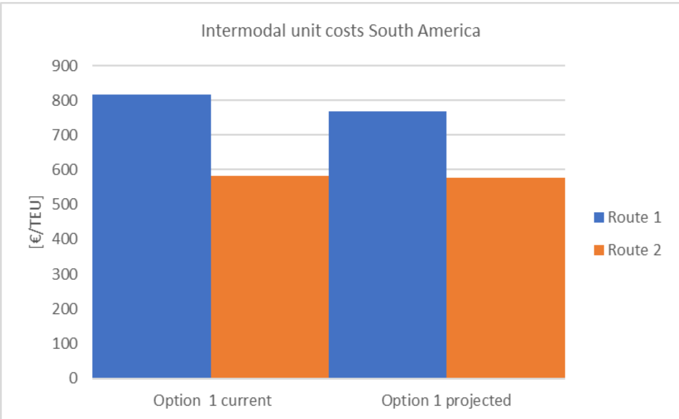


Figure 5 Intermodal costs to German inland terminals from South American Ports for two Maritime route options

Figure 5 Shows the rail options for the current and projected route costs, related to the two maritime routes. Route1 going to multiple Northern European ports is less than Route 2 intermodal costs. This is the same for projected routes using Betuwe line. similarly the use of the Badajoz projected route has the same effect.

5 CONCLUSION

In the analysis of routes from ports in South Africa and New York, United States through either Portuguese ports of Lisbon and Sines or the Port of Rotterdam and then by rail to German inland terminals. The intermodal transport unit cost was found to be higher traveling through the Portuguese ports, than the transportation of goods through the Port of Rotterdam. This is attributed to the greater distance travelled by rail from Portuguese ports to German inland terminals than from Northern European ports. This highlights the effectiveness of maritime transport that can make a large difference in the economies of scale. It requires many trains and nearly the entire weekly allowance of trains (using all allocated trains) to transport the quantities of cargo delivered by a vessel to a respective port.

The price sensitivity analysis of the total fuel consumed between the two maritime routes for South American East Coast goods transportation had the following outcomes. Route 1 to the Northern European maritime route is more expensive than Route 2. The sensitivity related to vessel speed shows that there is a variance in which route 1 is more expensive depending on the speed of the vessel. This occurs only for the vessel operating at maximum speed or at 15 kn. Along the South American maritime Route, 1 is less expensive for slow and super slow steaming, than route 2.

The combined costs of transporting containerized cargo through Northern European ports 1.4 times more expensive than the transportation of goods directly to respectively is Portuguese ports and short sea shipping to Rotterdam, and on to Mannheim and Köln. The emissions produced due to the speed of the vessel in relation to either South American maritime route. The carbon emissions are less for Route 1 traveling to northern European ports of call first. Route 2 traveling to Sines first and then on to Rotterdam returning to Sines shows an increase in carbon emissions as the speed increases. This is due to the addition of auxiliary equipment use in ports. This is also due to the increased speed the vessel undertakes to make the voyage.

The time in days expected from a voyage from South America for products to arrive in the German Hinterland. The time for the first train to deliver goods from the port of call shows that the fastest means is to send the products through lowland country ports of call. Transporting goods by Portuguese ports for the delivery of the first train load is 6 days slower than by Holland and the last train will be 8 days faster through Holland by either conventional or Betuweline.

The cost of transporting goods directly from South Africa through Rotterdam to Germany is cheaper by approximately a half of the cost of transporting goods through Portuguese ports. The difference in transportation costs by the Betuwe and conventional rail line through Holland by Venlo from Holland to Germany are negligible, in this case. In relation to the costs associated with projected costs to Portuguese ports. The results are found that it is cheaper to travel through Badajoz than to travel by Vilar Formoso. This is due to the lower tariff charges encountered in Spain.

The combined emissions of container transport from South Africa to Germany, that have rail routes going from Rotterdam to Köln Germany, produce the lower quantity of emissions. The second route that makes ports of call at Portuguese ports and then heads onward to Mannheim Germany. The second route produces a greater amount of emissions. Carbon emissions are four times greater for a route going through Portuguese ports and making use of projected Madrid route. The Current route going through Vilar Formoso must have more trains and a section requiring diesel hence a increase in Carbon emissions.

The rail contribution to the emissions is reduced along the Dutch rail options and as such the emissions produced from transporting goods by rail to Germany, from Portuguese ports is greater since the maritime influence between either distance does not have as great an influence, partly attributed to the ECA emission control.

The time in days expected from an East Bound voyage from Newark North America for products to arrive in the German Hinterland, by the first train to deliver goods from Rotterdam is 11.45 day. Transporting goods by Portuguese ports is 12.5 days. The time of delivery is negligible but for the last train delivered transporting goods directly to Portuguese ports results in 15.7-day time for delivery in Germany as opposed to 16.86 days when transporting goods through Rotterdam. The delay in waiting time for the trains to deliver from Rotterdam being attributed as the cause.

The North American combined route of transporting goods initially to Portuguese ports and then on to the German hinterland. When compared to the costs of transporting goods through Rotterdam is 2.1 times greater. The projected routes through Badajoz is 22% more expensive than goods traveling through Vilar Formoso this is due to the low cost of the tariffs and energy through Spain.

The combined emissions of container transport from North America to Germany that have rail routes going through Rotterdam to Germany produce the lower quantity of emissions. The second route that makes ports of call at Portuguese ports and then heads onward to the German hinterland produces a greater amount of emissions. Carbon emissions are over six times greater for a route going through Portuguese ports and making use of projected Madrid route. The projected route going through Vilar Formoso has a reduced distance to travel and hence a 13% decrease in carbon emissions.

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