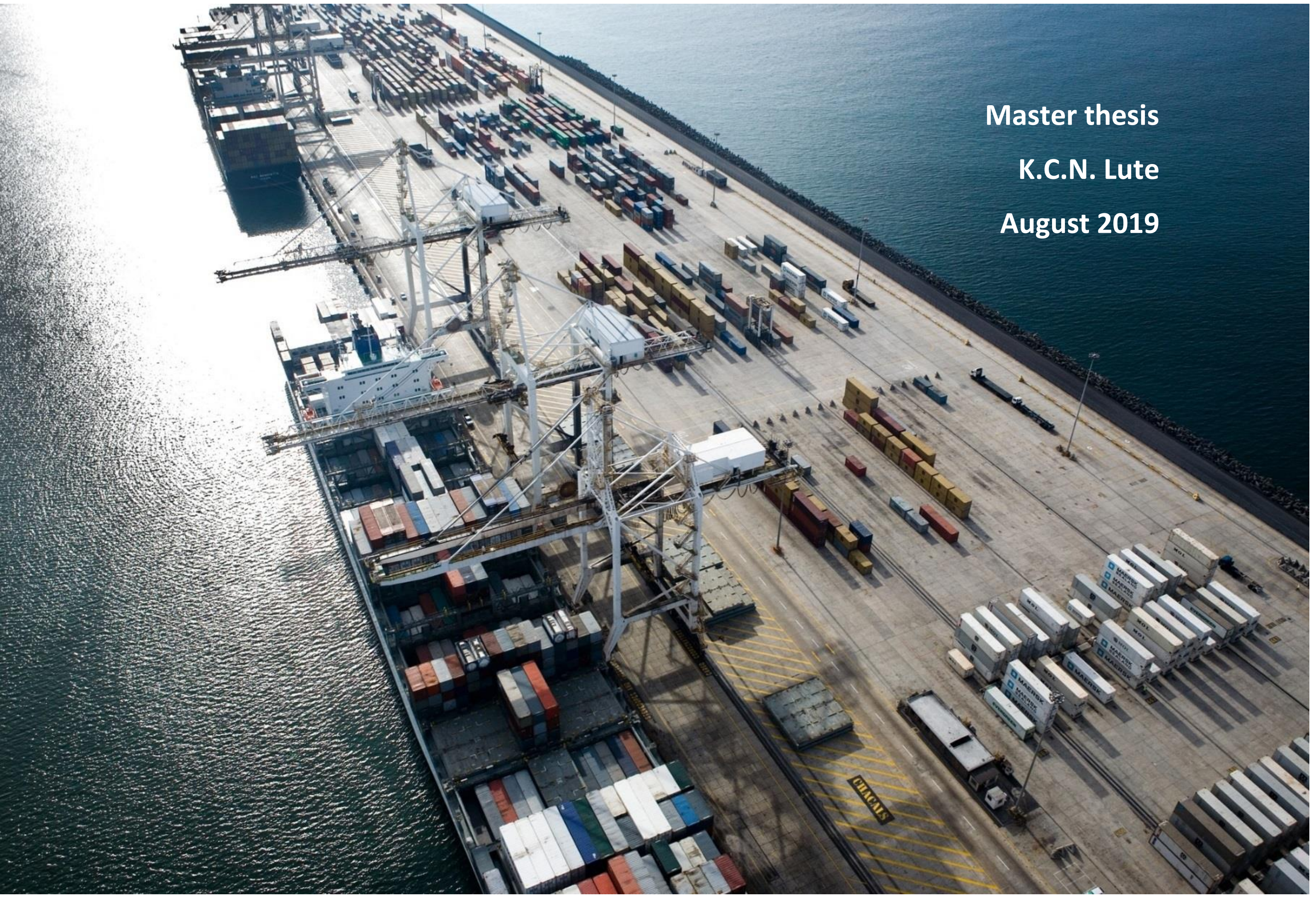
Assessing port competition via a cost-based logistic chain model

A transparent and generic approach.



Master thesis

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Royal HaskoningDHV
Enhancing Society Together

Assessing port competition via a cost-based logistic chain model

A transparent and generic approach

By

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TU Delft

Acknowledgements

More than a year has passed since I started the journey toward the completion of my master. This thesis resembles the conclusion of my academic career.

I started this graduation process with a goal: To understand the container shipping industry and to improve my programming skills while doing it. This thesis allowed me to fulfil this goal and in the process of doing so, I learned so much more.

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Kevin Lute

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SUMMARY

This study was conducted to address the lack of insight port authorities have in port competitiveness. The geographical area in which shipments originate (in case of export) or are destined for (in case of import) that pass through a port make up the ports hinterland. Insight in a ports hinterland and that of competing ports grands valuable information about the ports competitiveness. Port authorities do not have in-depth knowledge of the origin and destination of the containers moving through the port and thus information on the hinterland is not available. This knowledge gap is a result of the reluctance of data-owners to openly share the data of container transport.

In cooperation with Royal HaskoningDHV, this research is performed to reduce the knowledge gap of port authorities regarding the ports competitiveness. Royal HaskoningDHV is a major player in maritime consultancy services. The company delivers amongst other things, maritime market and due diligence studies for ports, port investors and policy makers. These studies often form a basis for investment or policy decisions for their clients.

Within this research a logistic chain choice model is developed from the ground up. This model allows to assess a ports competitive situation based on market shares within a bounded hinterland. Therefor the complete logistic chain is modelled between trading partners of the hinterland regions and the hinterland regions themselves. Using cost factors, the logistic chains are converted into a cost matrix. Using a Multinomial Logit function, the cost-based choice behaviour is simulated. This simulation enables the mapping of the hinterlands of the ports in the scope on a NUTS-3 level. The model identifies the key hinterland regions only for import and export container flows. The competitiveness of the ports is further quantified by performing a sensitivity analysis.

To test the model a subject area was chosen. The North of Italy was chosen with the six major container ports located there: Genoa, La Spezia, Livorno, Ravenna, Venice and Trieste. The main hinterland was identified as the north Italian regions, Austria and Switzerland consisting of 66 regions.

A sensitivity analysis was performed using the model. A port proved sensitive to price changes if the port doesn't have a clear generalised cost advantage and/or multiple ports have a comparable generalised cost in its key hinterland regions. For the subject area in the analysis showed that the port of Genoa has the best competitive situation of the ports. It has a leading position in all its key regions, most importantly Milan. The port of Ravenna, the smallest port in terms of throughput, proved to be most sensitive to price adjustments and overall has the weakest competitive situation as it lacks market share in its key regions.

Within this thesis a data-driven model is presented that allows to assess port competition within a bounded scope. This model is developed from the ground up and programmed in the Python programming language as a stand-alone solution. The model doesn't rely on extensive black-box models as often found in related literature. Due to its generic nature, the logistic chain choice model can also serve as a base model for different scenario analyses. Scenarios could include the change of ship-size, (oil) price or cost scenario's and future throughput forecasts. The model can provide insights regarding effective port investments and policy making.

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1 INTRODUCTION

The subject matter of this thesis is port competitiveness. The competition between ports cannot be classified by one single status as ports do not compete in a single market/region but in a large set of markets/regions with different features resulting from differences in location of origin and destinations of the cargo (Zondag, et al. 2010). It is therefore not correct to generally state that two ports are in competition and a more specific market definition is required. For example, the port of Genoa and the port of La Spezia are highly competitive for the container transport to and from the Milan region.

To be able to assess port competition and include the regional differences, a logistic chain model is created in this research. This chapter further introduces the thesis which is conducted in cooperation with Royal HaskoningDHV (RHDHV). The first section of this chapter begins with the impetus or motivation to research port competitiveness.

Due to developments in the sector and the world economy the level of competition between ports has increased. Because of this it is essential that port authorities understand their present competitive situation and the shape of their business environment.

The next section, added value for Royal HaskoningDHV, describes how RHDHV supports port authorities in understanding their competitive situation and what the model developed in this thesis can add to their methods. After this the objective function for this thesis is stated followed by the scope of the research and report structure.

1.1 IMPETUS FOR RESEARCH

Due to the heterogeneous distribution of economic resources, trading has always had an important part in the developed world. In the last couple of decades, globalization and integration of markets enabled the redistribution of labour and capital. In this environment, a standardised container proved to be a cheaper and more reliable alternative towards the conventional breakbulk shipping of general cargo (J. Rodrigue 2017). Demand for container handling in seaports has seen strong growth in recent decades. Worldwide container port throughput increased from 88 million TEU in 1990 to approximately 535 million TEU in 2008. After the 2009 dip, caused by the economic and financial crisis, growth resumed at a lower growth rate to 691 million TEU in 2016 (Drewry 2016).

The current business climate brings a number of challenges to (container) ports and container terminals. Obvious are the technical limits of the terminals, storage capacities of the quay etcetera. The technical and logistical properties of a port define the ports characteristics and limits when talking about container handling and processing. However, the logistics that come after the port are also of great importance to determine the success of a port. Good connection to the hinterland with enough capacity through highways, railways or inland waterway transport is essential (De Langen en Van der Horst 2008).

Due to benefits from economies of scale, container ship size, seems to be ever-increasing (Tran and Haasis 2015). Opposite to the advantages of scale are at sea, large ships have been claimed to suffer from diseconomies of scale in port (Yip, Lun and Lau 2012). Because of the high costs occurred in port, liners with large vessels have a preference towards terminals with high efficiencies in loading and off-loading large vessels. Sys, et al. (2008) stated that extended port time for ships destroys the rationale for bigger ships.

For a terminal to ensure this high efficiency, large investments are required. The increase in the physical dimensions of container ships has required container ports to provide deeper water, longer quays and cranes with greater outreach and height to allow for more containers across and higher stacks on deck. The number of containers that may be unloaded and loaded during a port call, the container exchange, has also risen significantly, increasing from a few hundred containers per call in the mid-1970s to several thousand in the early 2000s, to more than five thousand in 2015 (Martin, Martin and Pettit 2015). The peaks in container throughput that the hinterland and ports must handle keep increasing. These peaks can however be (partly) mitigated by increasing storage capacity and subsequently the dwell time of containers.

Not only recent developments in technical and logistical aspects put pressure on container ports, also the developments on the business side. The largest shipping companies have formed large alliances to further improve their own competitiveness, which effectively transformed the shipping sector into an oligopoly (OECD/ITF 2018). This means that more politics come into the field of container shipping as the already large shipping companies might join forces and therefor bargaining power towards ports and terminals. Certain shipping companies even have their own subsidiary companies that operate terminals. This can result in a preference for not only a port, but a certain terminal in a port. Even without these subsidiary companies in place, preferences and agreements will exist and influence the market.

Due to developments in the sector and the world economy the level of competition between ports has increased. In order for a port to survive and thrive, strategic planning has become essential. Strategy can only be successful if the current situation of the business is known. The port authorities need to understand their present competitive situation and the shape of their business environment to anticipate to changes in their competitive situation.

1.1.1 Added value for Royal HaskoningDHV

Ocean Shipping Consultants (OSC), the maritime economics & operations consultancy group of RHDHV, delivers consulting services in the maritime and infrastructural sectors. The services of the group include: cargo forecasting, market and technical feasibility studies, due diligence studies, transaction support, development of business models and financial planning. Currently RHDHV is focused on improving their service level by developing digital solutions.

For ports, it is not clear what their market share is for a certain region. This is a problem as profits are directly linked to hinterland market share and the resulting container throughput. This means that a knowledge gap exists of ports on their competitive situation. The competition between ports cannot be classified by one single status as ports do not compete in a single market/region but in a large set of markets/regions with different features resulting from differences in location of origin and destinations of the cargo (Zondag, et al. 2010). It is therefore not correct to generally state that two ports are in competition and a more specific market definition is required. For example, the port of Genoa and the port of La Spezia are highly competitive for the container transport to and from the Milan region.

Past studies with the goal of providing hinterland market shares required vast amounts of expert input and results are not specified up to regional level. This is a result of the inability to map the hinterland of ports as satisfactory origin-destination data is not available. Models that were previously build at Royal HaskoningDHV in order to do map the hinterland of ports proved to be too complicated to maintain. These models were reliant on assumptions that were unclear to the users, developers and clients and some viewed it as a black box.

To quantify the market share of a port and to determine its competitive position in a generic and data-driven manner, a model needs to be developed. This model should focus on logistic chain modelling in order to assess a ports competitiveness. The model should calculate the market share of ports, in a transparent manner within a certain bounded hinterland. In a transparent manner means that all the calculations and calculation methods are clearly described so the model doesn't become a black box. The methods and model results should be intuitive and accessible for engineers.

1.2 RESEARCH OBJECTIVE

The above described impetus and added value for RHDHV indicates the need for research of ports market shares and port competition. Ports authorities are especially interested in these subjects as they have to make critical decisions for long term investments and policy based on the available information. In order for Royal HaskoningDHV to provide consistent studies into this subject, a model needs to be required. In this research, this model is developed from scratch. The model is tested and calibrated by applying it on the north of Italy. Therefore, the research question is the following:

"Develop a cost-driven logistic chain model that enables the mapping of the hinterland of ports in a transparent manner to assess port competition."

1.3 SCOPE

Within this research a logistic chain choice model is created. Within the scope described in the following section the model is used to assess port competition. The scope is subdivided into different parts: port competition scope, ports and hinterland scope and the model scope.

1.3.1 Port competition scope

As described further in section 2.3 port competition is a complex concept and no consensus exists on the definition of port competition. (Van de Voorde en Winkelmans W. 2002) described that port competition is a complex concept that entails all relevant factors. Within this research the result of the port competition factors is analysed; the traffic or transport flows are simulated in order to determine the ports natural hinterland. This hinterland allows to assess which ports compete with each other for market share in a certain region. As the hinterland shows a ports ability to generate throughput, the market share of a port in a specific region represents its competitiveness for that region. Furthermore, the sensitivity of these market shares to deviations in (generalised) costs is an indicator of the level of competition in the hinterland and the ports ability to maintain its market share. The sensitivity is therefor also an indicator for a ports competitiveness. The competition in this research is further limited to inter-port competition.

1.3.2 Ports and hinterland scope

To calibrate and test the model a subject is chosen for the research. The subject area of this model is the north of Italy. The import and export flows will finalize and originate in the possible hinterland of the ports. The hinterland is limited to the north of Italy, Switzerland and Austria.

Switzerland and Austria are both landlocked, which turns them into highly contestable hinterlands that can readily switch among ports (Kashiha, Thill and Depken 2016). The north of Italy is chosen because the south of Italy is served by other ports located in the south; these southern ports have no significant hinterland in the north as previous studies have found out (Ferrari, Parola and

Gattorna 2011). The border of the North-South is set as to include the regions: Umbria, Marche and Toscana according to the NUTS nomenclature of the EU.
Italian ports struggle to gain market share in the French hinterland due to the French preference of Marseille as a port of entry and vice versa (Ferrari, Parola and Gattorna 2011). Therefor France and the port of Marseille are not incorporated into the model.

The larger ports that are in direct competition for the north Italian hinterland are investigated. For the north of Italy, the top six ports, based on container throughput of the last three years are considered, as shown in Figure 1 and Figure 2. The southern ports are not considered, as stated above these ports have a limited hinterland connection with the north. This limits the scope to the following ports: Genoa, La Spezia, Livorno, Ravenna, Venice and Trieste.

Figure 1: North Italian ports, with TEU throughput of 2017. Source: Authors elaborations on Assoporti data

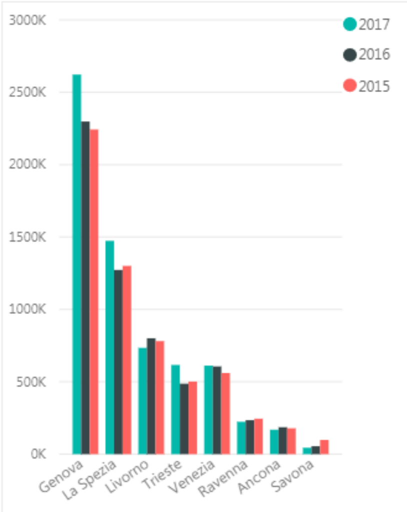


Figure 2: Graph of container throughput of north Italian ports in TEUs. Source: Authors elaborations based on Assoporti data

1.3.3 Model scope

A logistic chain choice model is created in this research. It is created from scratch using the python programming language. This research is focused solely on container trade; bulk and passenger flows are not taken into account. The model simulates the containers flows from the hinterland regions toward all trade partners of the country in which the region is located. In this simulation, the 'market share' of the logistic chains are based on a choice function (a multinomial logit function). This function calculates probabilities that a certain chain is chosen based on the cost difference of the different chains. This probability is then used as the market share for that logistic chain.

As the model is used to assess port competition based on regional market shares of the different regions, only the import and export flows are modelled. The empty container trade is a spatial allocation problem as described in section 4.1. This means that the logistic chains and/or transportation costs for empties are not quantifiable in this research and its model. Transshipment from ship to ship at the north Italian ports is also not incorporated as this practise is used by the container shipping companies to minimize their total cost and is thus a network optimisation problem as described in section 4.1. The model therefor only incorporates loaded container destined for import and export.

From the analyses of the data of the ports using the dashboard in chapter 4, it became clear that the smaller ports within the scope where partially or only served by small ships. In case of import flows, this means that cargo from afar is transhipped at a transshipment hub from a large vessel to a small vessel before the container reaches the final port. Large motherships sail the majority of the route and smaller vessels are used for the last part of the transport to distribute smaller bundles of containers to the different (small) ports. This phenomenon is incorporated in the model by including a route that includes transshipment at a fixed transshipment hub, namely Marsaxlokk, Malta. For every port in the scope, there is the option for the cargo to be transhipped at the port of Malta as described in section 5.2.2. Meaning that the choice set for every origin-destination pair consists of 12 different logistic chains.

A concession was made in the form of creating a static model based on data only from 2017. This is due to data availability and time constraints of this research.

1.4 REPORT STRUCTURE

The research will start with a literature review in Chapter 2. First the characteristics of the container shipping sector will be described. Next the definition of port competition is given and the port selection criteria are described. After it is established how ports are selected by container shipping companies, previous research on port choice modelling is described and a conceptual method is selected that is applied in this research.

Chapter 3 describes the methods and concepts used in this research. The model that is created in order to assess the port competition is a Logistic Chain Choice Model. First an overview is given of this model and the flowchart of the information flow within the model is given. Next, the methods used for the different internal steps of the model are described: port data analysis, chain generation, chain choice and port hinterland.

In order to calibrate and prove the effectiveness of the model, a subject scope is chosen in the form of the North-Italian ports and their hinterland regions. The largest 6 ports are used and the hinterland is bounded to North Italy, Switzerland and Austria. In Chapter 4 the port data is analysed. This data is used as input for the logistic chain model. Also, an analysis is performed on the liner services of the ports. From this analysis, dashboards are created. These dashboards are used to determine the final shape of the model regarding route choices and also delivers input data for the model. The results from this analysis are presented for the ports within the scope.

In Chapter 5 describes the logistic chain model. It starts with a detailed description how the model was developed. The next section describes how the model is calibrated. After the calibration of the model the results are shown. The model allows for the assessment of port competition on the level of the transport flows and the resulting hinterland shares and throughputs. Also, the sensitivity of the throughput for generalised cost changes can be determined. Next a scenario is described where the port costs of La Spezia are reduced and the effects of this change are described in detail.

In Chapter 6 conclusions will be drawn as well as recommendations on how to use the model and its limitations. Finally, recommendations on future research for the logistic chain model is given.

2 LITERATURE STUDY

This chapter describes the studied topics and the relevant literature. First the overall characteristics of the container shipping sector are described. This section also described why liners are assembling in alliances and how this influences the ports and their importance regarding the ports competitiveness. Then the definition and types of port competition are listed. After this an overview is given of the relevant literature on port choice and the different port choice factors are identified. Previous research on port choice modelling is then listed and the relevance and applicability towards this research is checked. Finally, conclusions are drawn and the final modelling choice is described.

2.1 CONTAINER SHIPPING MARKET

The container shipping industry is focused around shipping lines. Ocean going vessels that transit routes on a fixed and regular schedule. Hereby the ships sail a set route, calling on multiple ports. This is comparable to the regular and fixed schedule of public transportation systems (bus, train and tram) deployed in most developed countries. To ensure a high frequency of calls per port usually requires operating multiple ships on a single line. Most lines call on a port on a weekly or biweekly basis.

The very competitive nature of the business model of container shipping companies makes that cost plays an important role in the business model and cost optimisation is essential to maintain market share. The nature of container transport makes that possibilities for product differentiation are limited.

2.2 ALLIANCES

The nature of the maritime container transportation gives container liners limited opportunity to differentiate their core service, which is port-to-port shipping. This is because the cargo is standardized and homogenous. The price sensitivity of container shipping is also high since shippers usually look for the best price as they perceive the core product identical and switching costs are considered to be low (Lim 1998). According to Balci, Cetin & Tanyeri (2018), the differentiation options almost disappear due to the formation of strategic alliances.

Because of economies of scale, sailing with larger vessels has become the norm (Sys, et al. 2008). The purchase and operation of larger vessel has its challenges. Because the benefits of a larger ship are gained from its time at sea, the number of port calls is kept to a minimum, leaving connecting services to feeder vessels.

Though initial capital expense for a single ship is high, ships are often purchased in sets that will make up a complete shipping line. To ensure high utilization rates of very large ships, shipping companies have combined strengths and formed alliances. This allows a single company to participate in a line even though it would by itself not be able to deploy the required number of ships. It therefor enables the company to not only profit from economies of scale but also of economies of scope by extending its coverage.

Global alliances can be viewed upon as bundles of vessel sharing agreements (OECD/ITF 2018). Partners determine what they want to contribute to the alliance in terms of ships provided. The other partners can then charter slots on those ships. The idea is that the sum adds up to zero, meaning that all partners contribute equal to the system. Periodically any existing debts are settled.

Started mid-1990s, nowadays three alliances exist as shown in Table 1. These alliances consist of two or three very large companies. These companies agree on operational agreements that allow to coordinate utilization of ships, sailing schedules and itineraries. Cooperation via global alliances does not cover joint sales, marketing, pricing, joint ownership of assets, pooling of revenues, profit or loss sharing or joint management (OECD/ITF 2018).

Table 1: Global Alliances June 2018, Source: (OECD/ITF 2018)

Alliance	Carriers	Global market share (%)	Global carrier rank
2M	Mearsk	19	1
	MSC	15	2
Ocean Alliance	Cosco-OOCL	12	3
	CMA CGM	12	4
	Evergreen	5	7
THE Alliance	Hapag-Lloyd	7	5
	ONE	7	6
	Yang Ming	3	8

In ports with multiple terminal operators, often only one terminal is chosen by a single alliance. The rationale behind this is that using multiple terminals leads to a far more complex shipment network. More complex networks lead to operational challenges and costs and are therefore avoided. This means that there emerges a “winner takes all” situation, where only a certain terminal in a port is chosen by one of the three large alliances.

In the past, a larger number of shipping companies existed with smaller market shares. The terminal choice of a single operator didn’t result in large decline or increase of throughput. The fact that now only three alliances exist and the capacities deployed by these parties, make that large cargo shifts occur when an alliance decides to change terminal or port. This results in a strong position for liners in (price) negotiations with container terminal operators.

The volatility of cargo throughput has increased substantially with the increase in carrier and alliance size. This phenomenon is also represented in Figure 3. Decisions on terminal or ports are made by large alliances instead of a larger group of carriers (OECD/ITF 2018). To give a better image this image should show a fractional scale instead of an absolute scale, expected is that this would give a more moderate, but still convincing image.

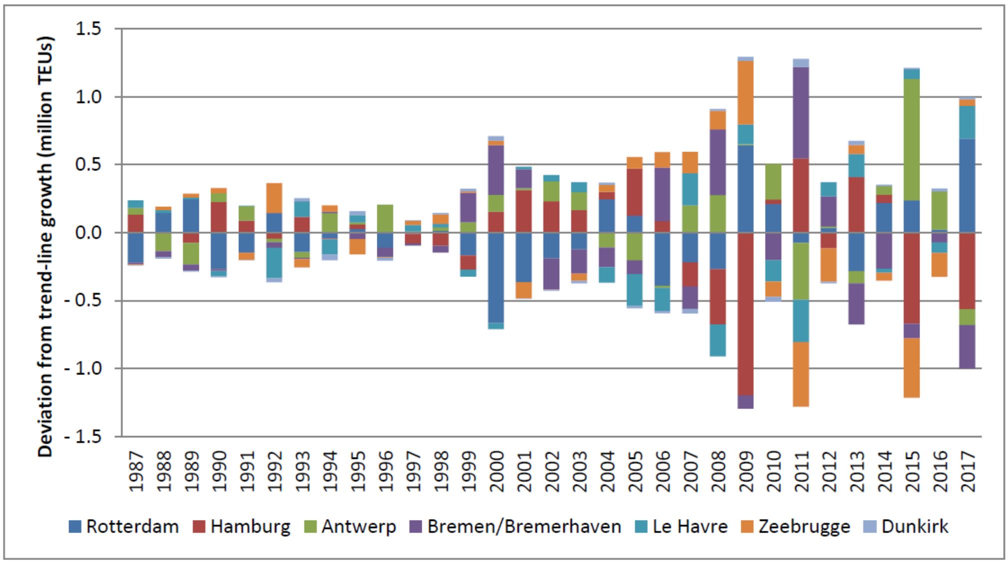


Figure 3: Volatility of Port Cargo in the Hamburg - Le Havre range, source: (OECD/ITF 2018)

As the number of clients of terminals decreases and their respective sizes increase, the influence of the container shipping lines on the competitiveness of ports becomes more and more important. Losing one shipping line as a client can mean that the terminal loses a considerable amount of throughput if not all.

2.3 Port competition

Due to the complex nature of seaport competition, no consensus on its definition exists. An early attempt at describing port competition was undertaken by Verhoeff (1981). He points out that seaport competition has a complex nature and that, because of this complexity, it is inappropriate to speak of 'the' competition. In the article, he further elaborates on why the issue of port competition is complex but fails to define port competition.

Van de Voorde & Winkelmans W. (2002) understood that the concept can be viewed upon from different angles. They argue that: “a modern definition of port competition should incorporate all aspects relevant to the constituting terms ‘port’ and ‘competition’.” They provide the following definition of seaport competition for their research:

“Seaport competition refers to the competition between port undertakings, or as a case may be terminal operators (...) in relation to specific transactions (the object, taking into account the origin and destination of the traffic flows concerned). Each operator is driven by the objective to achieve maximum growth in relation to goods handling, in terms of value added or otherwise. Port competition is influenced by (1) specific demand from customers, (2) specific factors of production, (3) supporting industries connected with each operator, and (4) the specific competencies of each operator and rivals. Finally, port competition is also affected by port authorities and other public bodies”.

When regarding a single type of traffic, in this case containers, there are three conceptual types of port competition according to Van de Voorde en Winkelmans W. (2002). Firstly the ‘intra-port competition at operator level’ refers to competition between different operators within the same port. An example of such operators are terminal operators. Secondly the ‘Inter-port competition at operator level’. This type of competition has a larger range than the previous as it entails the competition between operators located at different ports but contesting for the same hinterland.

This level of competition takes place at the regional or national level. Lastly the ‘competition between port authorities’, which can be on a local, regional or national level. This research will describe the competitive position of the individual ports in the north of Italy, therefor the focus lies on inter-port competition.

The hinterland of a port can be categorised as captive or contested. In a captive hinterland, only a single port exists with a substantial competitive advantage. This competitive advantage means that the generalised cost that is associated with the usage of this port is lower for that hinterland region in question (De Langen 2007). In contestable hinterlands, multiple ports compete for market share by providing competitive generalized transport cost. Zondag, et al. (2010) further recognised that containers are the least captive cargo of all traffic categories.

Within this research the result of the port competition factors is analysed; the traffic or transport flows are simulated in order to determine the ports hinterland. The information on the hinterland allows to assess which ports compete with each other for market share in a certain region. As the hinterland shows a ports ability to generate throughput, the market share of a port in a specific region represents its competitiveness for that region (Zondag, et al. 2010).

2.4 PORT SELECTION

Numerous previous researches have been performed on the subject of port selection and the corresponding port selection criteria. The different actors that are involved in the maritime shipping sector all have their own criteria in the port choice decision. The characteristics of the port, port’s rates, location of port, number of (maritime) shipping lines, geography of origin and destination of cargo and type of cargo are some examples of these criteria.

From the literature, different actors are identified that play a large role in the port selection process. According to Aronietis, Van de Voorde and Vanelslander (2011) the important decision makers can be categorised into three groups: shippers, shipping lines and the freight forwarders. Although there is no consensus on the real decision-maker, most literature describes the liner companies as the leading decision maker (Moya en Valero 2015).

The terminal operators are also recognised to be an important decision maker, but because the terminal operators port choice regards the to be implemented infrastructure that enable the flows of cargo instead of the actual flows it’s port choice criteria are not taken into account in this research. The decisions of terminal operators result in long-term commitments and usually entail large switching costs. These decisions result in infrastructure and are considered in this study as boundary conditions for transport flows.

Table 2 gives a summary of the literature that is reviewed concerning port choice factors.

Because of the abundance and variance in outcome of studies related to port competitiveness, Parola, et al. (2017) performed a systematic literature review of all papers published in leading journals between 1983 and 2014. It pinpoints the key-drivers that are identified in the papers and created a hierarchy based on the number of occurrences of every driver. This identified the following drivers to be leading, in order of importance: Port costs, hinterland proximity, hinterland connectivity, port geographical location, port infrastructures, operational efficiency, port service quality, maritime connectivity, nautical accessibility and port site.

All these port competition criteria value the characteristics of ports, while viewing the ports as stand-alone entities. The relevance can however be challenged as a port is merely a single shackle in the total logistic chain which makes it uncertain in what extent the port competition factors are influencing the transport flows. (Malaga en Sammons 2008) and (Zondag, et al. 2010) concluded that the choice of a port is a by-product of a choice of a logistics pathway in which the total logistics costs is a major supply chain consideration. These findings are supported by the previously described port choice factors that cannot be assigned to ports themselves but more to the transport chains; these factors describe characteristics of the hinterland, connectivity and location. Port competition has moved from competition between ports to competition between transport chains (De Langen en Van der Horst 2008).

The decision makers in this logistic chain were identified by Tavasszy and De Jong (2014). They state that the mode of transport is chosen by the shipper, while the routing decisions are left to the logistic service providers, such as shipping companies.

Table 2: Overview of literature port choice criteria

Author	Model type	Perspective	Determinants
Malchow and Kanafani (2001)	Multinomial logit model	Carrier	Port location, distance (land or sea)
Malchow and Kanafani (2004)	Discrete choice model	Carrier	Port location, distance (land or sea)
Lirn et al (2003)	Analytic hierarchy process	Shipping lines (transshipment)	Port characteristics, Port geographical location, Port management, Port Cost (from carrier perspective)
Tiwari et al 2003	Discrete choice model	Shippers	Port distance from shipper, distance to destination, distance to origin, number of berths, shipping lines fleet size, port congestion
Nir et al (2003)	Revealed preference multinomial logical model,	Shippers	Travel time, cost, previous choice
Velman and Bückman (2003)	Multinomial Logit model	Shipping lines	Cost and time, hinterland connections, frequency of service
Lirn et al. (2004)	Analytic hierarchy process	Shipping lines, port operators/authorities	Physical and technical infrastructures, geographical location, port management, port charges
Song an Yeo(2004)	Analytic hierarchy process	Shipowners, shippers, terminal operators, academics and researchers	Port location, port facility, cargo volume and service level
Tai and Hwang(2005)	Grey decision model	Shipping lines	Handling efficiency, port draft, cargo source of hinterland, frequency of routes, saving in operating cost
Ng.(2006)	Average significance scores, analysis of variance, t-test matrix	Shipping lines	Monetary cost, time efficiency, geographical location and service quality
Guy and Urli (2006)	Multicriteria analysis	Shipping lines	Port location, Infrastructure, service, monetary cost
Ugboma et al. (2006)	Analytic hierarchy process	Shippers	Efficiency, port charges, quick response to users' needs, reputation for cargo damage, adequate infrastructure and frequency of ship visits
De Langen (2007)	Survey	Shippers, freight forwarders	Port location, port efficiency, port infrastructure, frequency, hinterland connection, quality terminal operating companies

Tongzon and Sawant (2007)	Survey, Binary logistic regression and Model selection	Shipping lines	Port charges, port services
Chang et al (2008	Exploratory factor analysis;confirmatory factor analysis.	Shipping lines	Local cargo volume, terminal handling charge, berth availability, port location, transshipment volume, feeder network
Wiegmans et al. (2008)	Survey	Shipping lines	Hinterland connections, reasonable tariffs and hinterland size, proximity
Yeo et al (2008)	Factor analysis	Shipping lines, shippers, logistic related companies, freight forwarders	Port service, hinterland condition, availability convenience, logistics cost, regional centre, connectivity
Tongzon(2009)	Survey	Freight forwarders	Efficiency, geographical location, port charges, port services, connectivity, infrastructure, shipping frequency
Anderson et al (2009)	Nested Logit model	Shipping lines	Sea time, land distance, freight charge
Chou (2010)	Analytic hierarchy process	Shipping lines	Port charge, tax, rent and cost, port operation efficiency, port (un)loading efficiency, container yard efficiency and size, hinterland economy, transhipment, port location, depth
Tang et al (2011)	Network-based integrated choice evaltuation	Shipping lines	Port traffic, port calls, annual operating hours, depth, inter-modal transport, trade volume, ship turnaround time, port charges
Veldman et al. (2011)	Multinomial logit model, regression analyses	Shippers	Inland transport cost, maritime transport cost, hub-port effects
Onut et al. (2011)	Fuzzy analytic network process	Shippers	Port location, hinterland economy, port characteristics, port efficiency, cost
Steven and Corsi (2012)	Conditional logit model	Shippers	Freight charges, inland destination transit time, ocean transit time, size of the port as measured by the number of container berths
Yuen et al. (2012)	Analytic hierarchy process	Shipping lines, shippers, freight forwarders	Port location, costs at port, port facility, shipping services, terminal operator, port information system, hinterland connections, customs and government regulation
Lam and Dai (2012)	Analytic hierarchy process	Shipping lines	Port infrastructure, port charge, container traffic
Onwuegbuchunam (2013)	Survey, Multinomial logit model	Shippers	Shipper distance, ship-calls frequency, facility utilisation factor, crane efficiency, shipment size
Veldman et al. (2013)	Conditional logit model	Shippers	Inland transport cost, maritime transport cost, port specific effects, choice of coastline, inland transport cargo balance
da Cruz et al. (2013)	Analytic hierarchy process	Shipping lines	Vessel turnaround time, intermodal links, port facilities, proximity to import/export areas, depth
Nugroho et al. (2016)	Mixed Nested Logit	Shippers, freight forwarders	Cost of inland modes, inland mode time, greenhouse gas emissions, cost of port, number of ship calls, reliability of inland modes
Cantilo et al. (2018a,b)	Multinomial Logit	Shippers	Inland freight rates, maritime transit time, maritime transit rates, frequency of calls, trade agreements, GDP per capita

2.5 PORT CHOICE MODELLING AND PREVIOUS RESEARCH

An important part of this thesis consists of the construction of a port choice model. The research on the port choice criteria proved that the choice of a port follows from the choice of a logistics pathway, this means that the complete supply chain should be modelled. The ports should be viewed as elements or nodes in this chain (Robinson 2002). The complete supply chain is modelled by means of a multinomial discrete choice model. A multinomial discrete choice model is a model where a multitude of discrete or different choices are available in the choice set. The different choices are the different routes that are available to transport the cargo from point of origin to destination.

For strategic forecasting and planning purposes of this study, it is neither necessary nor possible to take all factors that determine logistic chain choice into account. Instead, an aggregate description of the system will be made, capturing the main flows and replicating behaviour of the main actors. For this purpose, it is assumed that the route choices are made on a cost-based level to maximize profit.
A multinomial logit function is used to describe the probability or extent to which a route is chosen. Zondag, et al. (2010) found that the inclusion of such a model is consistent with the economic theory, since higher costs result to lower volumes. The result of such a model is not an all or nothing route choice but results in percentages for the different routes or logistic chains. This way any existing route-preference and/or taste variation of shippers that deviates from the most logical choice is represented by a spread in choice. This spread can also result from the be an unconscious choice for a sub-optimal choice by the shipper caused by a lack of information or faulty information.

Previous literature has also addressed the problem of port competition and the corresponding hinterland overlap of the different ports. Zondag, et al. (2010) represented in their paper a new port forecasting approach. Previous models comprised of fixed hinterland or didn't incorporate OD data, as container transport proves to be one of the least captive cargo types, a new approach was required. This approach models the port competition explicitly, via a logistics chain approach. The study was limited towards the ports of Antwerp, Rotterdam, Bremen and Hamburg. The hinterland region studied comprised of The Netherlands, Belgium, Luxembourg, Germany, France, Austria, Switzerland, Czech, Slovakia and Poland. The study further assumed that the ports are only competing between themselves and no other ports, to make this assumption only a part of certain countries' trade is taken into account. The method to calculate this share is not described. One of the simulated measures was the increase of road transport costs within a specific country. These scenarios are not within the scope of this research, however the approach of a complete logistics chain approach based on costs is similar. The limited scope hinterland approach also proved to grand valid results and this is also reused for the model developed in this research. The database and trade model used in this approach is not freely available nor up to date, which makes it not compatible with the model created for this research.

Another comparable discrete choice model was developed by Tavasszy et al. (2011). The objective of this study was to model the complete seaborn container shipping industry in order to allow to run different scenario's. This resulted in a general high-level approach covering the world. Only the main shipping lines where modelled. Despite the general approach this resulted in the more than 800 liner services and 400 ports. The model's focus laid on the maritime side of the transport chain. The focus and extensiveness of the model did not allow for a detailed analysis of the hinterland. The hinterland costs where not specified on a per country basis and OD data is only specified on a country level. Considering the importance of hinterland in the highly competitive scope of our research, the methods used in this approach are insufficient. However, the data used in this research is both freely available and up to date. The data used are the UNComtrade and Eurostat data.

Also other theoretical frameworks have been used to analyse port competition. To analyse the port choice in combination with the hinterland, the Spatial Interaction Model (SIM) approach is used in multiple researches. Moura et al. (2018) recently used this approach to evaluate the effect of the geographical pattern of countries foreign trade on the inland distribution and the use of infrastructure. The hinterland in this study consists of the Spanish peninsula and the focus for trade is on Asia and the US. The model proves to deliver a good fit of the parameters involved. The data used in this study is gained from port authorities on the port throughputs. Data of the size of flows is also gained from the Spanish tax agency. The SIM approach turns out to be reliant on this flow data and is therefore not broadly applicable. Not every tax agency or national statistics agency publishes these data; for the case of North of Italy these flow data or OD data is not available. As the model of this research is meant be generic and universally applicable, this approach is not achievable.

2.6 CONCLUSION

This chapter described the studied topics and the relevant literature. First the overall characteristics of the container shipping sector were described. The competitiveness of a port is described as the extent to which it succeeds in obtaining a share of the container traffic within a certain region.

The very competitive nature of the business of shippers and container shipping companies makes that costs play an important role in the business model and cost optimisation is essential to maintain market share. The nature of container transport also makes that the possibilities for product differentiation are very limited. This results in that the companies mainly compete on costs. Currently liners are improving their competitive position by the formation of alliances. The concentration in market share of the liners gives them a stronger position at (price)negotiations and this puts added pressure on terminal operators.

The port choice criteria are evaluated, these criteria value the characteristics of ports, while viewing the ports as stand-alone entities. The relevance can however be challenged as a port is merely a single shackle in the total logistic chain which makes it uncertain in what extent the port competition factors are influencing the transport flows. Therefor the total chain needs to be modelled. The most important decision makers in this chain are identified as the shipper for the mode of transport and the shipping company on the routing of the maritime leg.

Various previous research relies on external models to generate input data such as OD-data, however these models are not described nor is the interaction between the models. This lack of transparency creates a Black box effect where the internal workings of the model are not clear. For this research, this will be avoided by creating a transparent stand-alone model.

The Discrete Choice Modelling approach is identified as the best option to model the problem. Furthermore, the route choices will be modelled with a Multinomial Logit Function. If previous research is a valid indicator, this model specification allows for the modelling of the logistic chain and the resulting port choice and hinterland with a bounded scope in a generic and universally applicable manner.

3 Modelling methods

In this chapter, the methods of modelling of the research are described. It starts off with an overview of the research and the modelling approach of the logistic chain model. The model used is compared to the classical four-step approach and a complete flow-chart of the whole logistic chain model is shown including all the required inputs. Next the methods used in the different steps to develop the model are described. This starts with the analysis of all port data, which delivers the input variables for the model and the shape of the shipping network can be deducted from the analysis of the service lines. Next the different steps of the logistic chain choice model are described in detail.

3.1 Overview

Within this research a model is developed from the ground up that can be used as a platform to perform port competition studies. A schematic overview of the model is depicted in Figure 4.

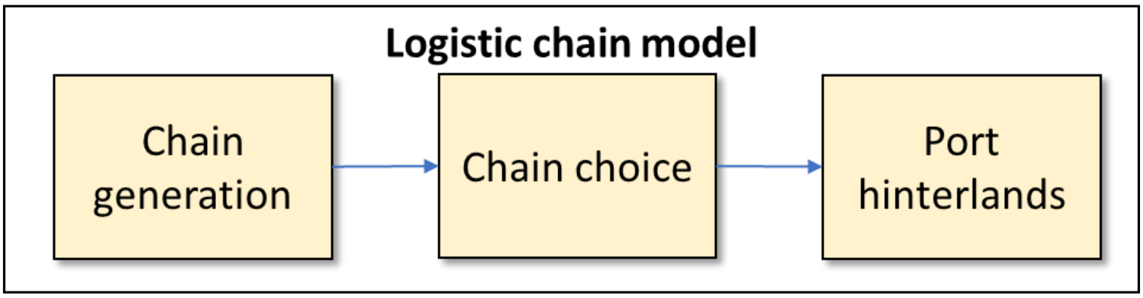


Figure 4: Conceptual overview of the logistic chain model

The model consists of a logistic chain model which determines the market shares of the ports in their hinterland regions.

To model the market shares, first the total logistic chain is modelled for both import and export in as shown in the “Chain generation” step. For the import case, the chains originate at a trade partner of the subject area. The subject area in this case is the north of Italy, Austria and Switzerland and the trade partner can be any of the trade partners of these countries for example Mexico. The chain originates at a trade partner; it ends at the hinterland of the north-Italian ports. For the export case, the origin and destination are reversed as shown in Figure 5.

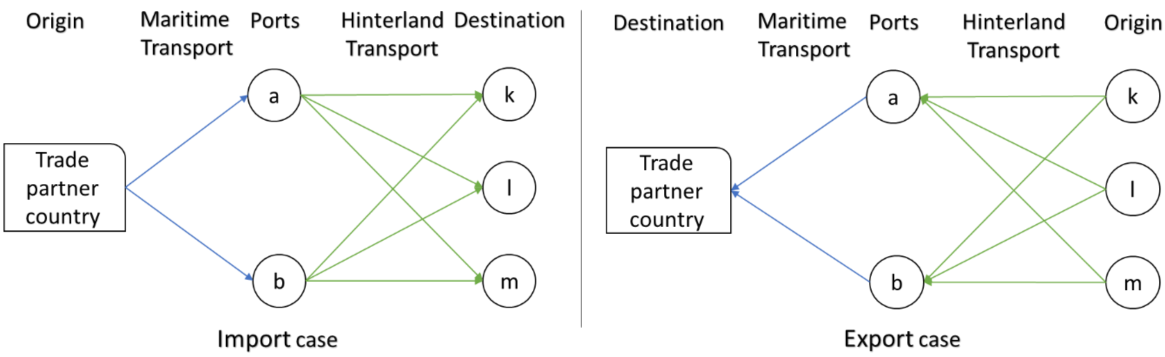


Figure 5: Conceptual representation of logistic chain options

A Discrete Choice Modelling approach is used, which means that for every origin and destination pair (OD-pair), a number of discrete logistic chain options are available; for every OD-pair a route\chain is available through all the different north Italian ports.

The costs of the logistic chains are determined, including the maritime and road parts. The actual choice or market share for the different logistic chains is determined using a Multinomial Logit Function which compares the costs of the chains with the same origin and destination and returns the probability that a certain chain is used. This probability is then used as the (market) share for that chain. To gain the total regional hinterland (market) share of a port, all the chains for that region that go through the port are summed.

Modelling and all data-processing is performed using the Python programming language. This is chosen as it has extensive data-science modules in place. Furthermore, the varied applications of the language in scientific environments guarantee that this research is not limited by the programming language. For data visualisation and other visuals, the Microsoft Office package is used. Interactive dashboards are created with Microsoft Power BI because this integrates well within in the Office environment.

3.1.1 Modelling approach logistic chain choice model

For the modelling approach of the logistic chain choice model, inspiration is drawn from the classic transport model, also known as the four-step model (Ben-Akiva en Lerman 1985). The four consecutive steps originated in the 60's when the first attempts at modelling transport were made and it has been widely used since. It provides researchers a framework to analyse and model passenger transport flows at any spatial level. The four-steps of the model are trip generation, trip distribution, modal split and trip assignment as depicted in Figure 6.
This means that first the transport demand is determined which results in the number of trips. The trips are then distributed over the area resulting in a Origin-Destination matrix. After this the trips are assigned to the available modes and finally the trips are assigned to the logistical or infrastructural network.

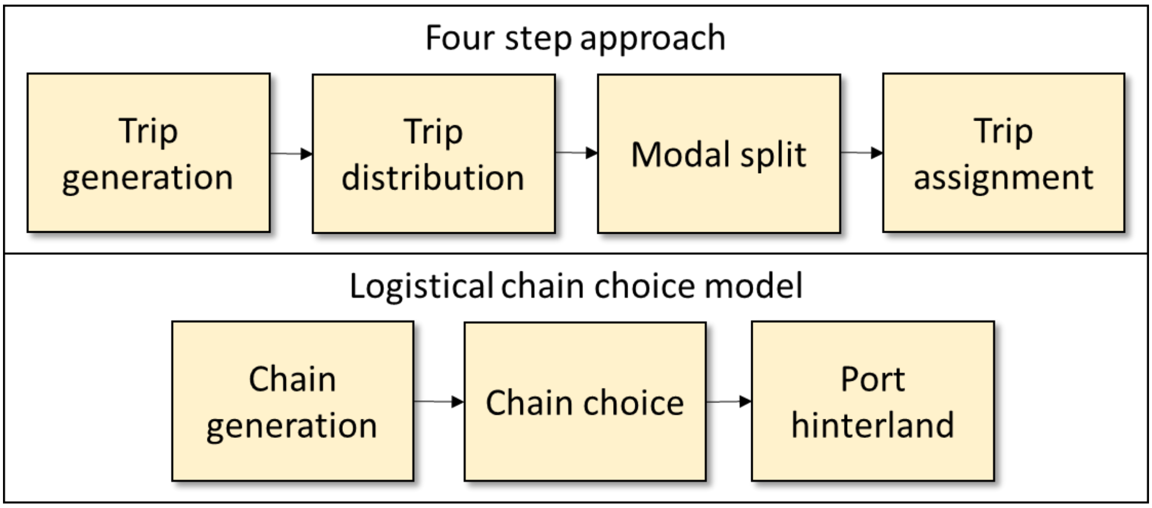


Figure 6: The classical Four-step approach and the logistic chain choice model

For this study, there are no passenger trips but container flows and the trips are not distributed but instead a choice is made between logistic chains.

For this study, the four-step is not suitable. In the four-step approach, the demand for transport is determined in a very elaborate manner that allows for scenario analyses. The generation of trips depends on numerous spatial variables. In these scenarios changes are made in these variables resulting in shifts in trip demand. For this study, container flows are the result of international trade. The international trade is taken as an exogenous variable and is converted into containers to determine the transport demand.

Within the first step, “Chain generation”, the chains that lead from the origin of the transport to the destination are determined as well as their corresponding costs as further described in section 5.1. The interest of this research lies in the hinterland of the subject port and therefor the overseas inland route is not explicitly modelled.

The next step, “Chain choice”, the market shares of the different chains are determined. Within the four-step approach, the trip distribution and modal split are performed sequentially. In the model the choice is made on a cost basis of the different logistic chains as further described in section 5.2.

The last step, “Port hinterland”, the market shares of the logistic chains are combined with the transport demand to calculate the hinterlands of the different ports. These are then calibrated towards the actual throughputs of the ports as further described in sections 5.3 and 5.4.

3.1.2 Flow chart of model

The overview of the complete model is shown in Figure 7 with corresponding section numbers. The different inputs for the model are shown in blue. All the port related data is analysed in chapter 4. The results from this analysis serve as inputs and boundary conditions for the logistic chain model. The cost factors and the distance matrices are described in chapter 5, where the logistic chain model is described. The calculations and methods used in the different steps of the logistic chain model are described in the following sections of this chapter and where applicable, the results are shown in the sections listed in the figure below.

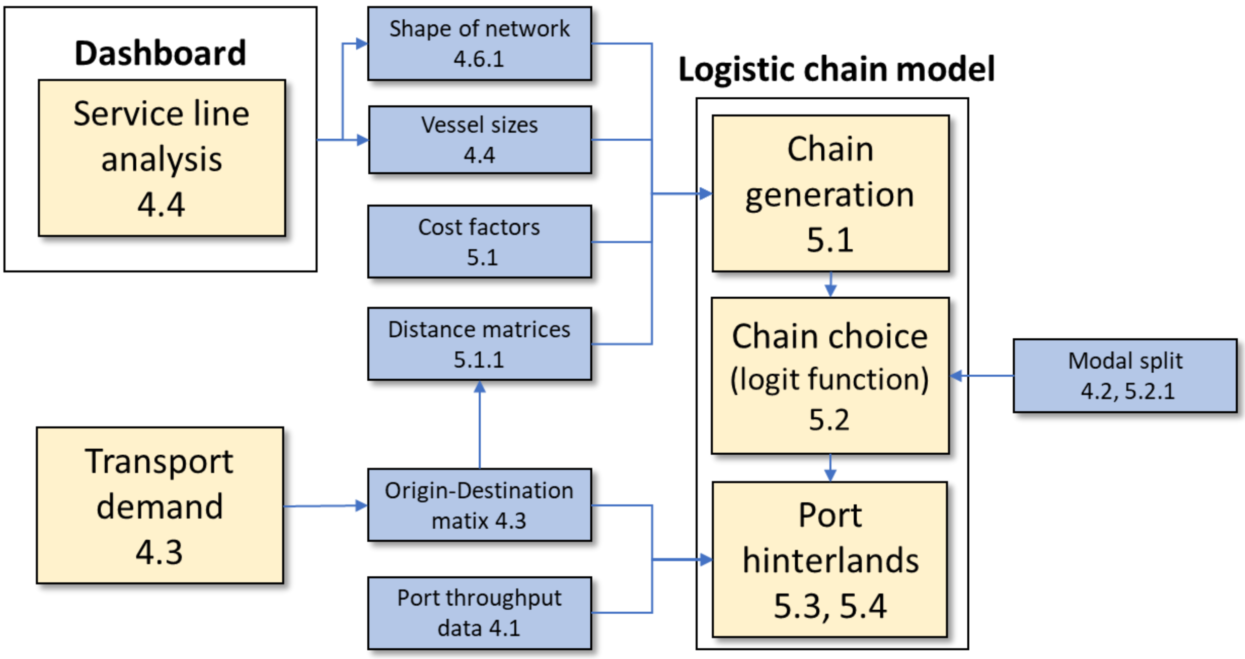


Figure 7: Flow chart of the different parts of the model, with corresponding section numbers below

3.2 Port data analysis

This step in the analyses, which is described in Chapter 4, gives a better understanding of the to be modelled port and sets the boundary conditions and inputs for the logistic chain model. First the throughput data is gathered and discussed, these values are eventually used in the logistic chain model to calibrate the flows. Other inputs consist of the modal split and the trade demand. A very elaborate analysis is made of the service lines in order to get information on the shipping lines and their activities in the north Italian ports. From the service line analyses dashboards are created. These are built to be able to determine the shape of the shipping line network in the logistic chain model as well as to determine the size of the ships that are deployed at the ports.

Because the model is intended to be bounded, first a scope needs to be set. The contested hinterland of the subject port will determine the scope of the ports. Port that compete for this contested hinterland should be included in the analyses. Paradoxically the output of the model is to gain hinterland market share information. This means that this can be approached iteratively. For a first-time research into a subject port, the client might have data that describes the (past) hinterland which can be used as a starting point. If this is not available an expert can be conducted on the subject. In this case a consultant from Royal HaskoningDHV was consulted, who has performed previous studies on the subject.

3.2.1 Liner capacity deployed

To analyse how the north Italian ports are used by the shipping companies the liner services are investigated. This is required in order to determine the shape of the shipping line network in the logistic chain model and for the determination of the size of the ships that are deployed at the ports.

This section describes how the capacity that liners deploy is calculated. As most ports only publish the aggregate container throughput, data on shipments is not provided or available. This means that origin, destination, shipping company of the shipment is not known. The terminals and shipping companies have the data available for their own shipments but this information is not shared because it can be valuable information for competitors. In order to quantify the share of the different liners, an analysis of the ship capacities that the liners deploy can be made. This capacity is assumed that this has a direct relation to the call size of that liner. Capacity is treated as an indicator for transport activity or call size.

To investigate if this is a valid statement for the ports in the scope and the ships that call in the ports, a linear regression analysis is performed. The routes that liners sail is open information as freight forwarders and shippers want to know when ships depart and arrive and what the duration is of their shipment. The Danish company eeSea collects all shipping service related data in extensive datasets. These datasets include all container services data of planned services including, proforma port calls, ship capacity, shipping companies, alliances and more. The data formats are consistent and updated on a monthly basis. This makes it possible to do future data analyses by using the standardised Python scripts developed in this research. As eeSea was established late 2015, they only started mapping container services data from 2015 onwards. Correspondence with eeSea shows that the data is correct and complete on a global scale from the first quarter (Q1) of 2017. Therefor the current situation is analysed from the first quarter of 2017.

Results are shown in Figure 8 and Table 3. As expected there seems to be a relation between the capacity deployed and the throughput regardless of the specification of this throughput. The throughput is divided into four categories, namely: total loaded containers without transshipment, total loaded containers including loaded containers that are transhipped, total containers that include empties but without transhipment and finally total containers that include empties with transhipment. All four sets investigated give comparable results: the slope indicates that for every 3-5 TEU capacity results in 1 TEU throughput. The capacity needed for one throughput TEU decreases as the slope increases per category. This seems logical as more throughput is considered per category and the capacity deployed stays constant.

Table 3: Regression analysis results on Capacity vs Throughput. Source: Authors elaborations on eeSea (service) and Assoporti (throughput) data

	Slope	Intercept	R^2 value	p-value	Standard error
Total loaded excl. transhipment	0.209243	-8620.230	0.969505	0.001381	0.026446
Total loaded incl. transshipment	0.245567	25340.300	0.960037	0.002364	0.035794
Total excl. transhipment	0.274964	3809.321	0.964445	0.001874	0.037674
Total incl. transhipment	0.316750	41134.010	0.971542	0.001203	0.038613

As for this analysis only the year 2017 and the six ports under investigation are used, no hard conclusions can be drawn from the statistical tests as the sample size is not adequate (Dupont en Plummer 1998). Analysis performed on a single period in time are called cross-sectional analysis. For future investigations into this relation, it is recommended to use larger datasets. As different types of ships are likely to have different relative call sizes per port call, a more extensive statistical analysis might be required with disaggregate data.

For this study, it is assumed that the capacity of a ship deployed at port has a constant relation to the call size. Therefor capacity deployed per port has a direct relation to the throughput. The statistical analysis performed in this research does not indicate that this assertion is wrong as all statistical parameters indicate that there exists a direct relation between the two variables.

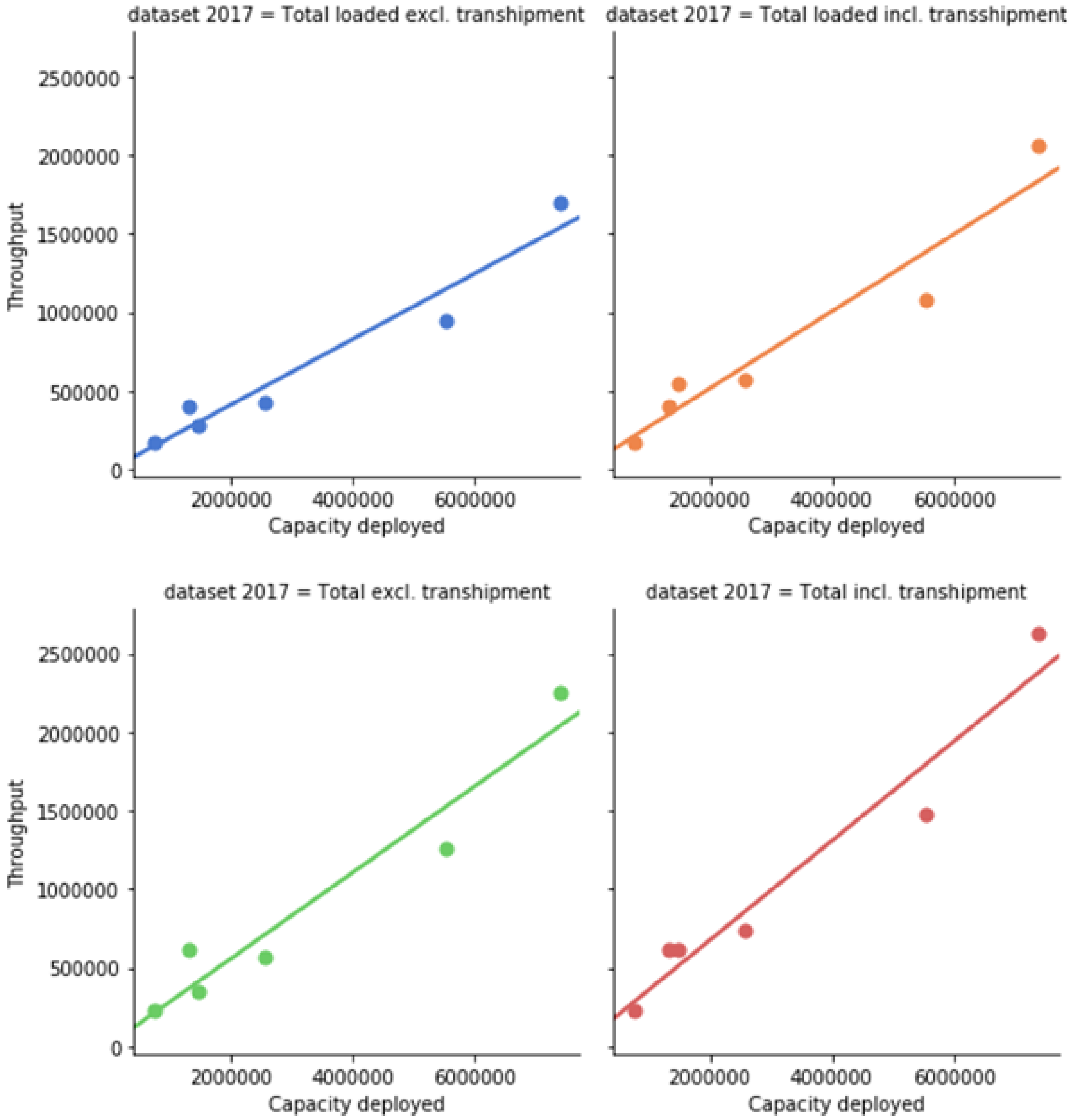


Figure 8: Linear regression of capacity deployed vs throughput for the North Italian ports for 2017. Source: Authors elaborations on eeSea (service) and Assoporti (throughput) data

From the result of the analysis of the service line data, a new dataset is created. To present this data interactively, a dashboard is created for every port. A dashboard allows to create an extensive overview of data in a visually clear and structured manner as shown in Figure 10 and Figure 9. This dashboard is easily manipulated into the required format and can display statistics in all formats.

From the container services data, the total container capacity deployed per service the desired time frame can be calculated. As shown in Equation 1, the capacity, in TEU, deployed per service equals the average capacity of the ships deployed per service multiplied by the frequency of call for the service within the timeframe.

Equation 1

$$for\ service\ s: \qquad Capacity_s = Frequency_s * Shipcapacity_s \tag{1}$$

The frequency of call for the service is required to calculate the capacity. The calculation of this frequency is shown in Equation 2. The frequency is the total number of calls in the time frame without a unit. The timeframe and the interval between calls are both in days. Often liners address each port in the service on a weekly or biweekly basis meaning that the interval between calls for a liner service is 7 or 14 days.

Equation 2

$$for\ service\ s: \qquad Frequency_s = \frac{Timeframe}{Interval\ between\ calls} \tag{2}$$

In order to get to calculate the total capacity deployed for a port, Equation 3 is summed over all services in that port.

Equation 3

$$for\ services\ t\ at\ port\ p: \qquad Capacity_p = \sum_{s=1}^{t} Frequency_s * Shipcapacity_s \tag{3}$$

Total capacity deployed per company and alliance is also determined. The average ship size and average feeder size are also determined by using the capacity as the weights. The results are visualised on the port specific dashboards.

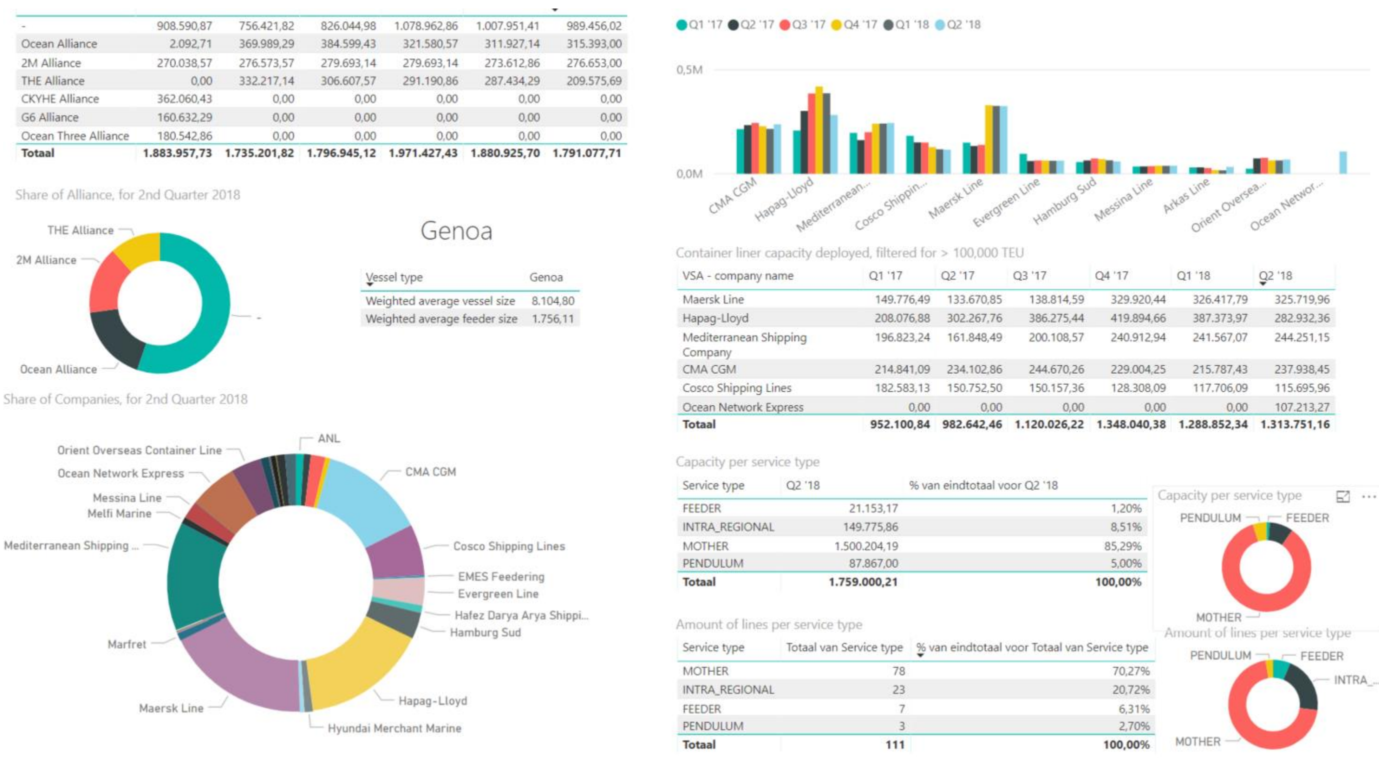


Figure 10: Dashboard example for the port of Genova. Source: Authors elaborations on eeSea data

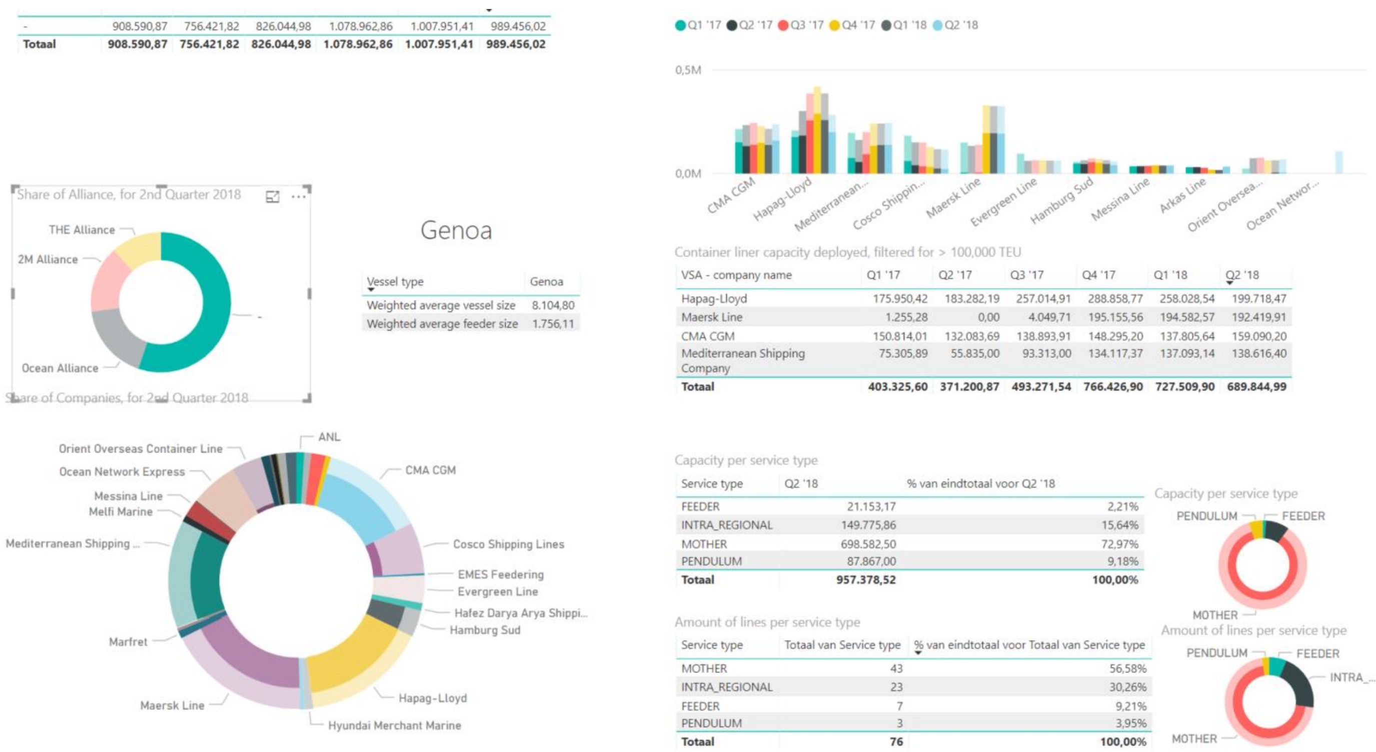


Figure 9: Example of the dashboard functionalities, highlights the services not directly bound to any alliance. Source: Authors elaborations on eeSea data

3.2.2 Trade demand

As input for the logistic chain choice model, the size and origin and destination of trade must be evaluated. An overview of the flows of data for this step is shown in Figure 11. The result is a origin destination matrix that lists the flows in TEUs.

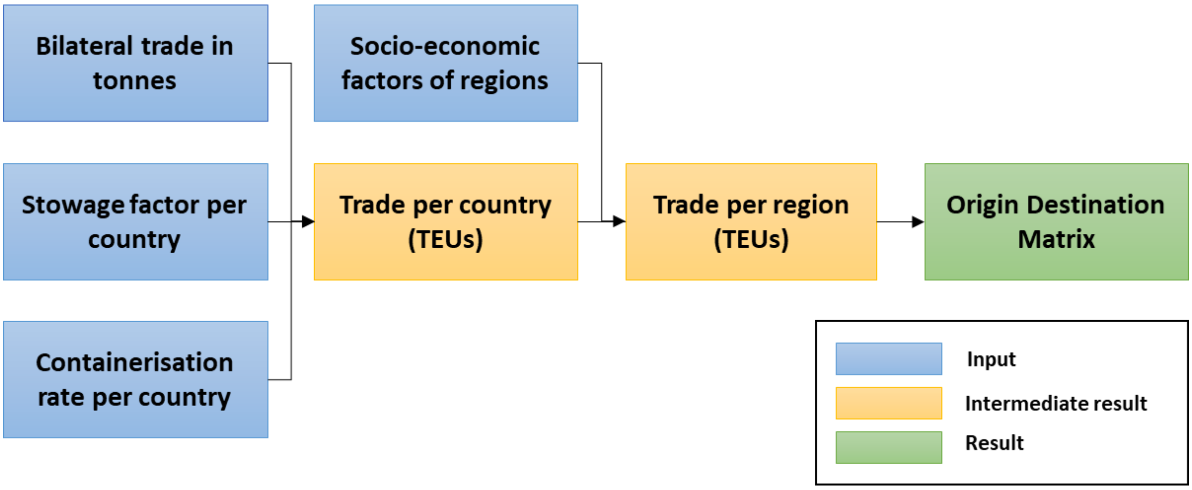


Figure 11: Determining container demand per hinterland region

Bilateral trade volumes

The demand of transport is a derived demand for goods (Rashed, et al. 2018). Therefor the base of the model is the bilateral trade between the hinterland of the ports in question and their trading partners. This bilateral trade data is obtained from the UNComtrade database. In this model, the trade isn't generated but set as an exogenous variable. The trade of a region or country is made up of import and export, and a research has been performed on the factors that determine bilateral trade volumes.

Areas are split into different zones to be able to appreciate regional peculiarities as well as to understand the contribution given by each zone to the gateway throughput of individual ports. For this purpose, a widely applied and recognised territorial unit of analysis, the Nomenclature of Units Territorial Statistical(NUTS) is used. In the captive market of the north Italian ports a detailed level of analysis is applied with the NUTS-3 classification (i.e. provinces) while in the other countries the NUTS-0 scale is used (i.e. countries). As described in the scope: the captive market consists of the North of Italy and Austria and Switzerland and the trade partners are analysed on a NUTS-0 scale. All trade partners that trade with the hinterlands of the north Italian ports are included in the analysis.

Data describing trade is only available on a country level. However, to model port competition between ports in the same country, regional statistics are required. Because these statistics are not available, they are simulated.

A widely used model to evaluate (bilateral) trade empirically is the gravity model of trade, which has the same form as Isaac Newton's law of gravity (Bergstrand 1985) (Baier en Bergstrand 2009). In this model trade flow is analogous to a gravitational force between countries (which is, as in Newtons law, a function of distance) and socioeconomic factors play the role of mass. As distance will be the main variable in the route generation step, it is not taken into account for the trade demand distribution. Therefor only the socioeconomic factors are used to divide the total TEU demand of a country into regional TEU demand.

Much literature exists on this subject: (de Groot, Linders en Rietveld 2003), (Hausman, Lee en Subramanian 2005), (Baier en Bergstrand 2009) and (Stack 2009). Using statistical analysis in their research, the authors have all focused on explaining bilateral trade volumes using different factors.

Both (de Groot, Linders en Rietveld 2003) and (Hausman, Lee en Subramanian 2005) describe in their research that the factors GDP, GDP per capita and distance between two regions explain up to 70% of bilateral trade. For this research, it is assumed that these parameters provide the weight factors needed to allocate parts of the trade of a country towards the different regions as shown in Table 4.

Table 4: Fractional weight factors

	Groot et al. (2004)	Hausman et al. (2005)	Average log	Fractional weight
Log GDP importers	0.86	0.915	0.89	0.79
Log GDP per capita importers	0.11	0.358	0.23	0.21
Log GDP exporters	1.20	1.201	1.20	0.78
Log GDP per capita exporters	0.15	0.535	0.34	0.22

Transport demand

The bilateral trade between two countries or the import and export between two countries is only described by UNComtrade in tons, however we are interested in TEU. Because of this the amount of trade for countries in TEU must be estimated. For this study, this is done by using the data from Eurostat on maritime trade. Two factors are used to establish an estimation for the amount of TEU, the containerization rate and stowage factor.

The containerization rate describes the amount of trade that is shipped in containers. The unit is ton/ton. It is calculated by dividing the containerised trade in ton with the total maritime trade of a country in ton as shown in Equation 4.

Equation 4

$$for\ trade\ partner\ i: \qquad f_{containerization,i} = \frac{Containerized\ maritime\ trade_i\ [ton]}{Total\ maritime\ trade_i\ [ton]} \tag{4}$$

The stowage factor describes the amount of trade in tons that goes into a single TEU. The unit is ton/TEU. It is calculated by dividing the total containerised maritime trade of a country in ton with the volume of containerised trade in TEU as shown in Equation 5.

Equation 5

$$for\ trade\ partner\ i: \qquad f_{stowage,i} = \frac{Containerized\ maritime\ trade_i\ [ton]}{Containerized\ maritime\ trade_i\ [TEU]} \tag{5}$$

Both the containerization factor and the stowage factor are calculated solely with data from Eurostat to ensure data cohesion. This data is based on all cargo handled in ports in a certain country, not only the cargo destined for that country. It is assumed that the containers handled in ports in a country with a different destination does not significantly affect the calculated average. This assumption can be made as the destination country will likely be in close proximity to the port and country, and therefor has comparable trade/logistic characteristics.

Finally, the total trade demand per country is determined by summing the above calculated parameters for the different trade partners with the respective amount of trade in tons as shown in Equation 6.

Equation 6

$$for\ tradepartner\ i: \quad D_{country} = Trade\ in\ Tons_i * \ f_{containerisation,i} \, / \, f_{stowage,i} \qquad (6)$$

3.3 Chain generation

The next step to set up the logistic chain or routes that are available for the container transports. The output of this step is to create the cost matrix. This matrix contains chains in which a container can be transported and the corresponding cost. To be able to create this the distance matrix needs to be created as well as the cost factors that need to be addressed. The conceptual steps are shown in Figure 12.

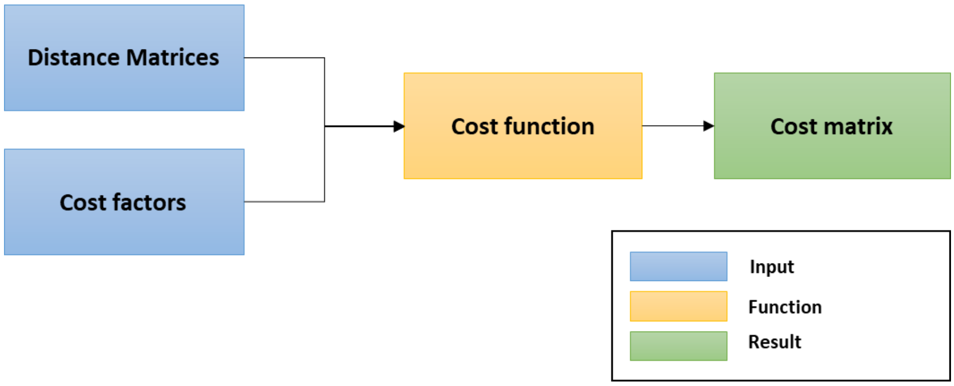


Figure 12: Determining the cost matrix

The basis of this model is the origin and destination matrix that is established is the former step. The values that are given for the transport flows, or the flow quantity between the origin and destination, are not of interest in this step. The actual origins and destinations are used to determine the logistic chain in-between. Every container can travel though every port in the scope. This means that every OD-pair gets different routes through the different ports as shown in Figure 13.

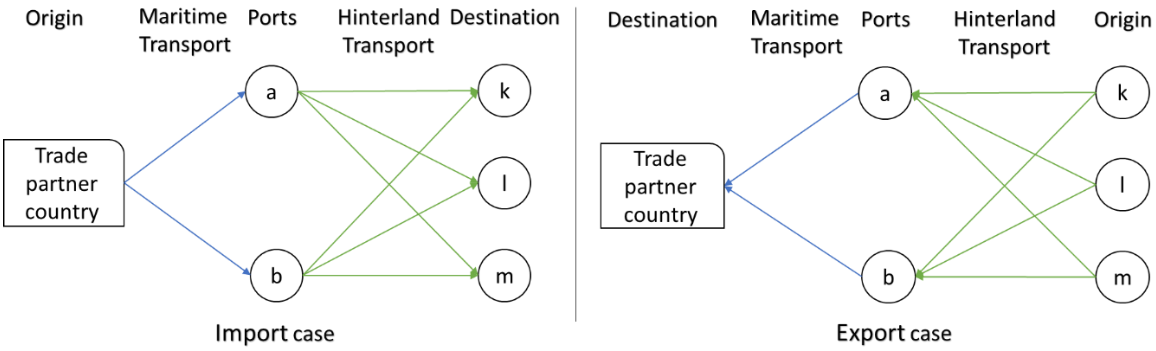


Figure 13: Transport flow conceptual overview

The distances of the different modal legs have to be determined separately. For the hinterland transport leg, this is done by implementing the Google maps API into the script. This allows to extract the distance from the Google database between every region and every port in an efficient way. For the maritime transport leg, the maritime distances where extracted from (SeaRoutes 2019). The routes resulting from this website are the actual used routes for merchant vessels.

The next step is to convert the distances to costs by using several cost factors. All cost-factors are descripted into detail in section 5.1. The costs are determined on a per container basis. The costs factors are used to convert the distances matrix to a cost matrix as shown in Equation 7, divided into constant cost and variable costs for both the maritime and the hinterland leg separately. The maritime factors included are the operating costs, vessel costs, fuel costs and the terminal handling costs and port charges. All these costs are dependent on the average size of the ships with the exception of the terminal handling costs which are charged per container regardless of size. Further information on the costs factors and chain generation is given in section 5.1

Equation 7

$$C_r = mar_{vc_r} * mar_{time_r} + mar_{cc_r} + hint_{vc_r} * hint_{dist_r} + hint_{cc_r} \tag{7}$$

$mar_{vc_r} = \text{ the maritime variable costs } [\frac{€}{TEU \ * \ day}]$

$mar_{vc_r} = Operating\ costs + \ vessel\ costs + \ fuel\ costs$

$mar_{time_r} \ = \ maritime\ time\ [days] = \ maritime\ distance\ [nm]\ /\ vessel\ speed\ [kn] * \frac{1}{24}$

$mar_{cc_r} \ = \ maritime\ constant\ costs\ \left[\frac{€}{TEU}\right]$

$mar_{cc_r} \ = Port\ dues + \ terminal\ handling\ costs$

$hint_{vc\_r} \ = \ hinterland\ transport\ variable\ costs\ [\frac{€}{TEU * km}]$

$hint_{dist_r} \ = \ hinterland\ distance\ [km]$

$hint_{cc_r} \ = \ hinterland\ constant\ cost\ \left[\frac{€}{TEU}\right]$

3.4 CHAIN CHOICE AND PORT HINTERLAND

Both the transport demand in the form of a OD-matrix and the costs of the routes in the form of a Generalised cost matrix have been created in previous steps. This last step will allocate the transport onto the logistic chains or routes. This is done by implementing a Multinomial Logic function. This functions' input is the costs of the different routes and its output is the probability that a specific route is chosen. This probability is assumed to be the market share of that logistic chain. Next, the OD-matrix can be projected onto the chains to gain the flow size. These flows can be aggregated based on the port it flows through to gain the hinterland market shares of the ports in the different regions and the port throughputs. The flow diagram for the chain choice and the resulting port throughput is shown in Figure 14.

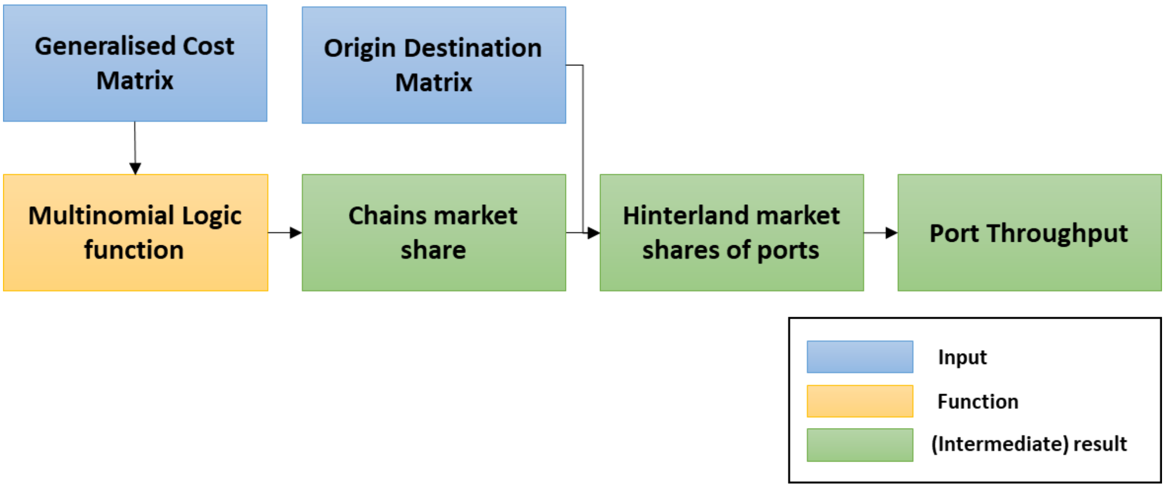


Figure 14: Determination of chain choice and the following market share and port throughput

3.4.1 **Logit function**

The Multinomial Logit (MNL) function is used to model the choice behaviour for logistic chains. The result of such a function is not an all or nothing choice but results in percentages for the different options. The multinomial logit function gives the probability that a certain route is chosen given its generalised cost. The resulting probability gives a gradual change in chain preference instead of an all-or-nothing assignment to accurately model choice behaviour.

An example of the S-shaped curve resulting from a logit-function is shown in Figure 15 for a two option case (binomial logit function). This way any existing route-preference and/or taste variation of the decision maker that deviates from the optimal route is considered. The optimal route represents the route with the lowest cost. This spread can also result from an unconscious choice for a sub-optimal option by the decision maker caused by a lack of information or faulty information.

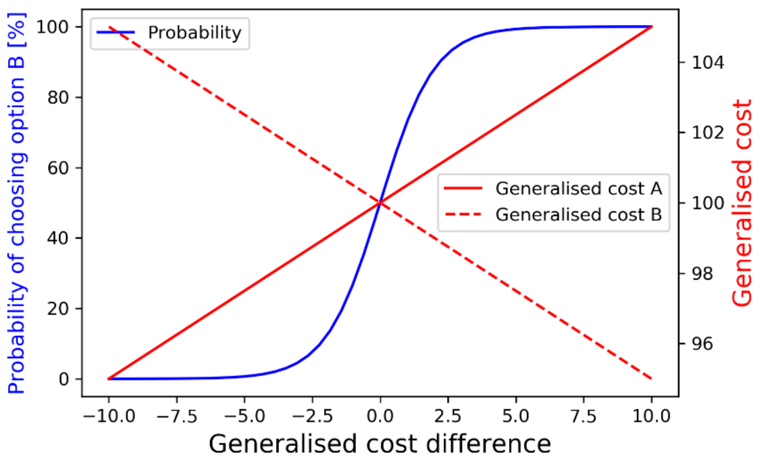


Figure 15: Example of a logit function for a two option case.

The probability of choosing a specific chain or route is described in Equation 8. This probability is used as the 'market share' for that chain which is the percentage of containers that is transported using that chain.

Equation 8

$$P_r = \frac{e^{GC_r}}{\sum_{h=1}^{n} e^{GC_r}} \tag{8}$$

$P_r = Probability\ of\ chosing\ route\ r$
$GC_r = Generalized\ cost\ of\ route\ r$
$h = route\ out\ of\ choice\ set\ of\ routes\ from\ origin\ to\ destination$
$\varepsilon = error\ term$
$\mu = logit\ scale\ parameter\ or\ cost\ co\ddot{e}fficient$

The choice for a certain logistic chain is traditionally a trade-off between lead time and the transport costs involved (Fazi 2014). The lead time is negatively correlated with the cost of the shipment, thereby influencing the chain costs of the total chain of transport. Because of this interaction, the choice is made to only model the transportation costs without the inclusion of a value for time. The value for time is different for every actor. Important factors influencing the value of time are the value of the cargo and the internal structures or requirements of companies or corporations. Since too many assumptions where needed to address the value of time accurately and no consensus exists on the determination of the value of time (Dekker 2005), it is chosen to leave it out of the costs function. Value of time is however included indirectly as the cost-functions of the ships are dependent on time.

As the actor wants to maximize profit it will want to minimize cost. Following this approach, the chains are compared based on their generalised cost as shown in Equation 9.

Equation 9

$$GC_r = -\mu * (C_r + \varepsilon_r) \tag{9}$$

Here the (logit) scale parameter μ can be seen as the cost coefficient, the importance of cost in the choice for a route. For large values of μ small differences in costs give large differences in the probability of choosing a certain route. When a very small value is used for μ only large differences in costs result in a larger share for the 'better' option.

The C_r is the cost value listed in the Cost matrix. The error term ε_r represents measurement errors and choice factors that are not directly modelled. These error terms can be used for calibration purposes. Because the calibration is performed on real throughput numbers the resulting error term will not only incorporate factors with a monetary (cost) value. As identified in the literature study, factors like terminal productivity, available facilities and corporate preferences also play a role. All these factors that cannot be incorporated in monetary value but instead are aggregated into the error term. Because of this error term, the result from Equation 9 is called the Generalised Cost (Bruzelius 1981).

4 PORT DATA ANALYSIS

In this chapter, data describing the north-Italian container ports is addressed. This data is processed to serve as inputs and boundary conditions for the model.

To be able to determine the shape of the shipping line network in the logistic chain model and to determine the size of the ships that are deployed at the ports, the service line data is analysed. The results from this analysis are presented in the form of dashboards. These dashboards allow to gain insight in the way the shipping companies use the ports within the scope and to what extent.

First the throughput data is gathered and filtered towards the values that are applicable for the model. Secondly the modal split of the ports is determined and an approach for modelling the hinterland modes is chosen. Next the transport demand is determined. This is done by first dividing the total bilateral trade of Italy and its trading partners over the different regions.

The scope in this research consists of multiple countries, but not all containers are shipped through ports within the scope. Next, the options to overcome this problem are described and an approach is chosen and executed that includes the analysis of the US Bill of Lading of 2017.

Next the liner service analysis is described and the dashboards are presented. The (numerical) results from the analysis of the selected ports are then described on a port for port basis and finally conclusions are drawn.

4.1 THROUGHPUT DATA

Data regarding throughputs is gathered from the respective port authorities involved. Detailed data for the Genova port is gained for 2017 (Ports of Genoa 2018). It provides detailed data on import and export for both empties and loaded containers as shown in Table 5.

Table 5: Detailed throughput port of Genova for 2017. Source: Ports of Genoa

	Import loaded	Import empty	Import total	Export loaded	Export empty	Export total	Total loaded	Total empty	Total
TEU's	264.771	65.570	330.341	291.837	39.101	330.938	556.608	104.671	661.279
FEU's	288.482	191.917	480.399	465.583	34.472	500.055	754.065	226.389	980.454
Container total	553.253	257.487	810.740	757.420	73.573	830.993	1.310.673	331.060	1.641.733
TEU equivalent	841.735	449.404	1.291.139	1.223.003	108.045	1.331.048	2.064.738	557.449	2.622.187

This data allows to calculate the TEU-ratio, this is the TEU equivalent unit per container. For the port of Genova this value is 1.59 for import and 1.60 for export. For the other ports in the scope data on the amount of TEU's versus FEU's is not available. The average TEU ratio for the major European ports is 1.6 which corresponds to the found values for the port of Genova (ESPO 2017). In this research, 1.6 TEU equivalent unit per container is used for all container flows.

Because of trade imbalances between two countries or regions, there will always be an empty container trade. The model deployed in this research is not able to implement empties. This is because the empty container trade is basically a spatial allocation or relocation problem where the provider of the containers needs to balance out the demand and supply of containers for every location (Stopford 2009). This means that the route or transportation costs for empties is not quantifiable in this research and its model. Empty container flows are consequently not considered. All the container throughput data that is used consists of full/loaded containers. For the other ports in the scope, data is available on the amount of loaded and empty containers on a TEU equivalent basis (Assoporti 2018). This is shown in Table 6.

Table 6: Throughput data of ports of North Italy 2017 in TEU's, transshipment is excluded: Source Assoporti

Port	Import loaded	Export loaded	Total loaded	Import empty	Export empty	Total empty
Genova	659.039	1.044.466	1.703.505	445.001	104.101	549.102
La Spezia	323.378	620.746	944.124	301.879	16.061	317.940
Livorno	190.370	239.689	430.059	93.426	40.459	133.885
Ravenna	67.279	99.873	167.152	45.843	8.774	54.617
Venezia	131.569	274.952	406.521	193.085	11.780	204.865
Trieste	140.419	142.487	282.906	27.371	38.760	66.131

The transshipment volumes are also reported. These are listed in Table 7. These values are further discussed in section 4.5 where the results of the port analysis are given. Because transshipment is in essence a network optimisation problem of the shipping lines (Meersman and Van de Voorde 2013), transshipment throughput numbers are not explicitly incorporated in the model. However, the route that containers have taken cannot be deducted from mere throughput figures. Shipments could already be transhipped before arriving at the port in question. Therefor this routing option is taken into account in the model and will be further discussed in section 5.1.

Table 7: Transshipment at ports in 2017. Source: Assoporti

	Total Hinterland [TEU]	Total Transhipment [TEU]	Transshipment [-]
Genova	2.252.607	369.580	0.14
La Spezia	1.262.064	211.507	0.14
Livorno	563.944	170.141	0.23
Ravenna	221.769	1600	0.01
Venezia	611.383	0	0.00
Trieste	349.046	267.110	0.43

4.2 Modal split

For the hinterland leg, the modal split is of importance. The modal split is the split of the cargo throughput over the different transport modes. Three different options are available: Road, Rail and Barge. For the Italian peninsula, no evidence is found that barges or inland water ways are used for container transport in any port. This might be a result that due to the shape of the country, the hinterland is relatively close to a port and the north is closed off by the Alps. Inland shipping or barge transport is very dependent on the rivers available and their accessibility. For the north or Italy only one river can be used, which is the Po river. For 2014 the number of containers transported over the Po river was less than 25000 (Observatory of European Inland Navigation 2015). As the usage of barge transport within the scope is neglectable it is not modelled.

Port specific modal split is not widely available. For four ports in the region the split of modalities is listed for the year of 2014 in Table 8. It can be concluded that road is the major mode of transport for these ports.

Port	Road	Rail	Barge
Genova	0.8	0.2	0.0
Livorno	0.9	0.1	0.0
Trieste	0.6	0.4	0.0
Venezia	1.0	0.0	0.0

Table 8: Modal split data for 2014. Source: OSC

In Europe, the breakeven price for intermodal transport that includes a rail leg lies between 500-750km (J. Rodrigue 2017). Within the scope, all distances from the origins/destinations of trade towards the ports are less than this range. Therefore, the most cost-effective transport mode is the road direct approach. For further modelling of the hinterland regions within the scope it is therefore assumed that the origin or destination of the containers using the rail-modality lies outside the geographical scope and throughput figures are altered accordingly. The available modal split data from 2014 is used and the rail throughput amount is deducted from the total throughput for the respective ports.

For the ports that in reality have a large share of rail transport, the resulting market share in hinterland regions with good rail connection might be under-estimated in the model. The extent of this deviation is however unknown and can only be assessed with a complete set of OD-data. This should be kept in mind when analysing the results. For the ports in the scope this will have consequences for the port of Trieste in particular, as this port has a large share of rail transport. As the breakeven distance for rail is however larger than what is possible within the scope of this research it can be assumed that this has minimal consequences for the model.

The model described in this research, is meant to be generic, which means that it should be applicable to every hinterland case. For the case modelled it is chosen not to model all modes for above mentioned reasons. For future use of the model in areas with higher rail utilisation, barge container shipping or larger scopes, it is highly recommended to incorporate the modes that are applicable to approximate the real world more closely.

4.3 TRADE DEMAND

The trade demand result from the bilateral trade volumes of the hinterland of the ports. First the total amount of containers generated by the bilateral trade of the countries in the scope is determined. Secondly the trade of countries is divided into regional trade demand.
The scope in this research consists of multiple countries, but not all containers are shipped through ports within the scope. Lastly, the options to overcome this problem are described and an approach is chosen that includes the analysis of the US Bill of Lading of 2017.

4.3.1 Total trade countries

The methodical flow of the calculation is as depicted in Figure 11 and described in detail in section 3.2.2. First the total trade per country is calculated. This requires three inputs, the bilateral trade on a country level and both the stowage factor and the containerisation factor for that country.

The total bilateral trade in tonnes for the three countries specified by direction can be found in Appendix A. This shows that for Italy the largest trading partner for import is Russia with 12.7% based on weight. This probably has some correlation with the fact that Russia is a large exporter of commodities such as oil and gas (The Observitory of Economic Complexity 2019). The market shares of the different countries are not that high and the second largest is Germany with 7.2%. The third is Algeria with 5.4%. The largest export partner of Italy is Germany with 12.9%, followed by France with 12.0%. and Spain with 7.2%.

The data on export and import of Italy clearly shows that the bilateral trade is very varied and no single country is dominant. The major trading partners being are geometrically close but not overly represented. Also a lot of countries that are only available by water/air have a large market share, such as the UK, USA and Libya. This is however very different for Austria and Switzerland. Austria's import and export is dominated by Germany with 32.5% for import and 31.7% for export. The same goes for Switzerland where 40.1% is imported from Germany and 29.7% is exported to the same country. From the list, it is clear that most trading occurs with neighbouring countries, which is explained by the lack of a domestic port. (Limao en Venables 2001) found that landlocked economies are disadvantaged, as transports cost are generally 50% higher and trade volumes 60% lower than their coastal counterparts. A substantial part of this disadvantage can be mitigated by infrastructure improvements in both the landlocked and the transit country.

The stowage factor and containerization factor are calculated as previously described in section 3.2.2. To calculate these, data from Eurostat on the maritime trade are used. The data from Eurostat should be accurate and reliable, however some inconsistencies were encountered as some stowage factors exceeded the maximum payload limit of 28 tons (CMA CGM 2019) for a single TEU. Instead of using the assumed to be false value or the logical maximum possible value, the weighted average was used for the year and direction applicable to that trade flow. This is done because it is unknown what is part of the data is missing and making assumptions will deteriorate the data consistency. Only limited instances of this data inconsistency were encountered. In cases where it wasn't possible to obtain the factors from the Eurostat data, because the data of maritime trade not available, the weighted average was used as well for the year and direction applicable to that trade. From this analysis, the stowage factor for all import and export going through Italian ports is determined. This is 13.19 t/TEU for import and 13.86 t/TEU for export in 2017. For the same year the containerization factor is 0.14 t/t for import and 0.28 t/t for export.

The stowage factors can be validated with the data from the north Italian ports.
For the norht italian ports, Assoporti (Assoporti 2018) also provided information on the weight of goods transported in the containers. From this the stowage factor is calculated as previously described Equation 5. This data was adjusted for transhipped cargo. Calculating the weighted average based on throughput of the ports, this results in the average stowage factor at 13.61 t/TEU for import and 12.56 t/TEU for export for 2017. Results are shown in Figure 16.

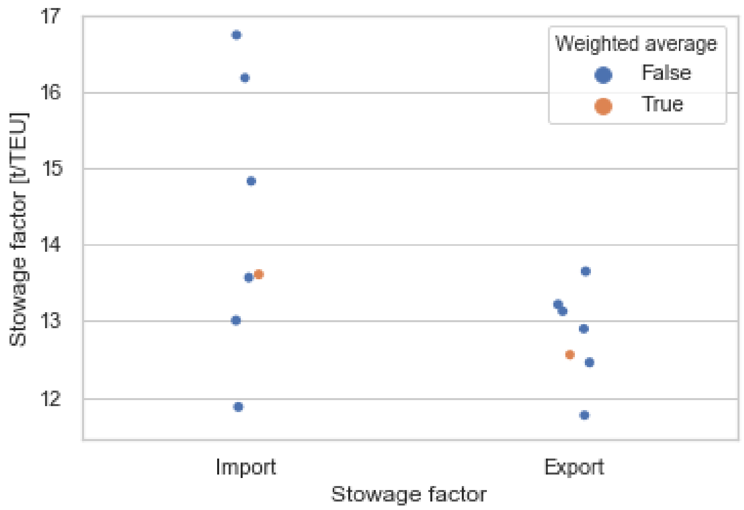


Figure 16: Stowage factor per port. Source: Authors elaboration on Assoporti data

These values are comparable to the found values for all Italian ports and therefor suggest that these values are in line with the expected values.

The bulk of the container throughput at the north Italian ports originates or is destined for the hinterland located in the north of Italy. The estimated total trade demand from Italy, or bilateral trade in TEU, is shown in Table 9.

Table 9: Estimated bilateral trade in TEUs for Italy 2017

Italy import			Italy export		
Partner country	**Estimated trade in TEU**	**% of total**	**Partner country**	**Estimated trade in TEU**	**% of total**
Saudi Arabia	621310	12.87%	France	1294185	22.69%
China	505828	10.48%	USA	397703	6.97%
Spain	440316	9.12%	Spain	379109	6.65%
France	437648	9.07%	China	247239	4.34%
Belgium	273915	5.68%	UK	237854	4.17%
Azerbaijan	208813	4.33%	Turkey	176474	3.09%
Austria	184535	3.82%	Switzerland	156656	2.75%
Slovenia	162415	3.37%	Austria	154904	2.72%
Iraq	148114	3.07%	Germany	144596	2.54%
USA	120973	2.51%	Slovenia	141774	2.49%

4.3.2 Regional trade

As previously described in section 3.2.2, the trade is split into regional specific container demand to appreciate both regional peculiarities as well as to understand the contribution of each zone to the throughput of the individual ports. The amount of trade is allocated to the different regions by using socio-economic indicators that describe the specific region. The result of this is shown in Figure 17. Differences between the import and export distribution prove to be marginal and the figures are identical. It should be pointed out that the legend of the figure is not linear. This figure shows that there is a large difference in containers attraction between the different zones on a NUTS-3 level the different regions and their codes are listed in Appendix A. It Is clear that the most important hinterland regions lie in the north part of this scope, with Milan being first on the list with almost 12% of all Italian trade. This also explains why there is limited containers mobility between the north and south parts of Italy as the middle part of the country lacks economic activity (Ferrari, Parola en Gattorna 2011).

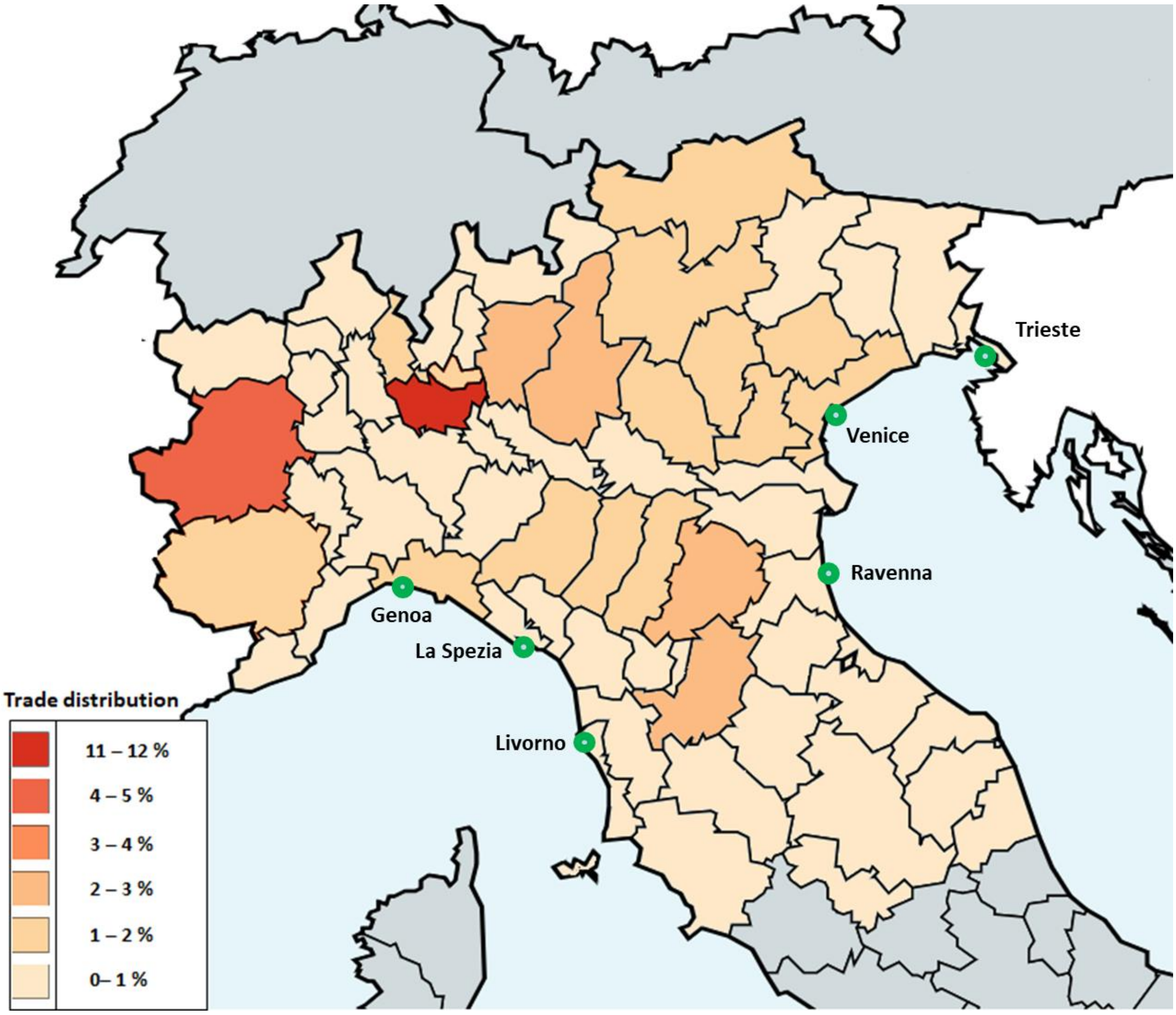


Figure 17: Trade distribution Import or Export for Italy on a NUTS-3 level, source: Author

4.3.3 Competing ports outside scope

Both Austria and Switzerland do not have access to the open sea or ports, they are landlocked. Therefor the handling of most bilateral trade over longer distances is executed at ports located in other countries. Some of this trade will pass through ports in the scope of this research and a part will pass through ports that are not in the scope. To determine the trade demand for the ports within the scope an assumption must be made about the amount of containers from Austria and Switzerland going through Italian ports instead of the Northern European ports. The main competing ports with their hinterland in Austria and Switzerland are Rotterdam, Antwerp and Bremen (De Langen 2007). These ports are located in the so called, Hamburg-Le Havre range. To determine the percentage of trade for the North Italian ports and thus for the trade demand for this research a number of options or approaches are available.

The first option is to model the out of scope competing ports. This means that the model should include the whole shipping network of the competing ports including the maritime distances, road-distances, port-costs and specifications. To calibrate the model on the total throughput of these ports requires to model their complete hinterland. This will increase the complexity of the model greatly. A compromise can be made by partially modelling of these competition ports. This means that the ports are modelled but not the complete hinterland. This option is not considered as this will also mean that the scope is extended and will create too much uncertainty in the model as calibration is not possible.

Another method is to set a fixed percentage of trade going through the Italian ports. In order to do this a source is required. As no complete dataset is available on the route of shipping of bilateral trade for the countries in the scope, a diversion is required towards a partial dataset. In previous researches on port hinterland, a partial dataset has been used to generate the OD data. In (Kashiha en Thill 2013) and (Kashiha, Thill en Depken 2016) the Bill of Lading of the US import has been used for this purpose. The methodology of these studies is applied to the Bill of Lading of 2017 (US Customs 2018). This dataset, containing 36 million rows was analysed and this resulted in a percentage of 0.96% for Austria and 5.20% for Switzerland.

It was expected that the market share of the ports in the Hamburg-Le Havre range would be large but the found percentages were larger than expected (Ferrari, Parola en Gattorna 2011). As the data analysed is only for the export destined for the US, some things should be considered. As all trade is moving westward, this connects better to the shipping lines that sail on the ports of the Hamburg-Le Havre range. The Italian ports located in the Adriatic Sea do not have any large lines connected to the US and the route possible requires a detour when destined for the US. The ports located in the Ligurian sea should however be able to acquire market share as they are closer to Austria and Switzerland. Generally, the geological location of the main trade attracting regions of these countries are located north of the alps. This makes that trucks are facing tunnels and elevations in order to reach the Italian ports which leads to congestion and higher costs. It is expected that trade from other trade partners that are located in the Mediterranean and the (far) east will generate a higher share of transport going through the Italian ports as the route to the Hamburg-Le Havre range requires extra sailing around the Iberian Peninsula. As trade to Mediterranean ports is over short to medium distances this is most cost effectively done by small to medium sized ships. This type of ships sails from the (north) Italian ports in large numbers. Therefor the amount of trade of Austria and Switzerland destined for the Mediterranean is likely to be larger. For the trades going to the Far east, larger vessels are most cost efficient and mostly deployed, as these ships sail from both the ports in the Hamburg-Le Havre range as well as the North-Italian both options should be comparable in attractivity.

This hypothesis is supported by data on the ports for Austrian import and export (Seehavenbilanz 2018). For the year 2017 the port of Trieste was used for 2.8% of the import and 5.06% of the export. This 5.06% is substantially larger than the 0.96% found for the US alone.

This means that the total export of Austria is 5.06/0.96= 5.27 times larger than the analysis of the US Bill of Lading. For this study the fraction of trade of the Swiss and Austrian hinterland that travels through the North Italian ports are estimated based on the ratios between the available data. The assumed values are: 2.79% for the import and 5.06 for the export of Austria and 15.11% for the import and 27.41% for the export of Switzerland. Although the found values might seem low, when compared to another study from 2011 on the hinterland regions of the North Italian ports, the found values in this study are in fact higher (Ferrari, Parola en Gattorna 2011).

4.4 SERVICE LINE ANALYSIS

This section analysis the service lines that the different liner companies deploy at the North Italian ports. This is done to be able to determine the shape of the shipping line network in the logistic chain model and to determine the size of the ships that are deployed at the ports. Also the dependencies of the ports on the different companies and alliances can be easily evaluated. The different container companies and their capacity deployed is a indication in how the port is able to obtain its market share. The results from this analysis are presented in the form of dashboards. These dashboards allow to gain insight in the way the shipping companies use the ports within the scope and to what extent.

These are calculated as previously described in section 3.2.1. For all the ports in the scope an interactive dashboard is created in PowerBI. For the port of Genova, a full-sized representation of this is shown in Figure 18. The other dashboards can be found in Appendix C. With these dashboards, the structure of and the dependency of the port on its (liner) clientele can be evaluated in a convenient manner.

The data from the dashboard is divided in quarters to be able to view throughput growth over the last 1,5 years. Graphical tools that show the divisions, such as alliances shares, are based on the last quarter. The first table of the dashboard, represents the throughput of the different alliances that are present at the port. The fact that liner companies are part of Alliances doesn't mean that all services they operate are under the alliance flag. For example, not all ships of Maersk are labelled as part of the 2M alliance. Only for certain services the alliance partners have vessel sharing agreements. The partners contribute to this service by providing ships or by chartering slots on those ships as explained in section 2.2. The donut chart under the table shows the percentage of capacity from the services that are supplied by the different alliances for the last quarter. The '-' indicator means that the service does not belong to a specific alliance and is performed by a single liner.

The different companies that sail on the port are listed in the right graph and the corresponding table under it. The amount of liner companies and the size of their respective capacity deployed gives insight in the dependency of a container port and its terminals on the different liner companies. As the different quarters are shown, a quick assessment of the growth of throughput per company can be made. The distribution of the companies and the capacity they deploy for the last quarter is also shown in the donut chart in the bottom left corner.

From the dashboard, it is also possible to determine if the port is a major gateway port, a transhipment hub or a regional port. For a major gateway port, the majority of shipping capacity will be supplied by large motherships coming from major production areas such as China. For a regional port however, services will be performed by smaller ships namely intra-regional ships and feeder ships. The share of service types is shown in two tables and two corresponding graphs in the bottom right of the dashboard. Both graphs are needed to show the full picture as a single mothership can have more than 10 times the carrying capacity of a feeder.

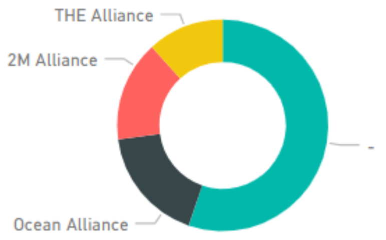
For the different ports, the maximum vessel size and average vessel size are listed in Table 10. The average is the weighted average with ship capacities used as weights.

Table 10: Vessel sizes per port

	Maximum vessel size [TEU]	Average vessel size [TEU]
Genoa	14507	8716
La Spezia	14725	10914
Livorno	8980	5199
Venice	6817	3139
Trieste	12409	7323
Ravenna	2605	1778

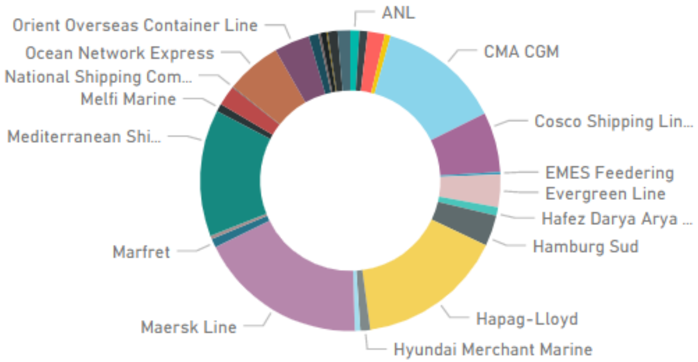
Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
-	908.590,87	756.421,82	826.044,98	1.078.962,86	1.007.951,41	989.456,02
Ocean Alliance	2.092,71	369.989,29	384.599,43	321.580,57	311.927,14	315.393,00
2M Alliance	270.038,57	276.573,57	279.693,14	279.693,14	273.612,86	276.653,00
THE Alliance	0,00	332.217,14	306.607,57	291.190,86	287.434,29	209.575,69
CKYHE Alliance	362.060,43	0,00	0,00	0,00	0,00	0,00
G6 Alliance	160.632,29	0,00	0,00	0,00	0,00	0,00
Ocean Three Alliance	180.542,86	0,00	0,00	0,00	0,00	0,00
Totaal	**1.883.957,73**	**1.735.201,82**	**1.796.945,12**	**1.971.427,43**	**1.880.925,70**	**1.791.077,71**

Share of Alliance, for 2nd Quarter 2018

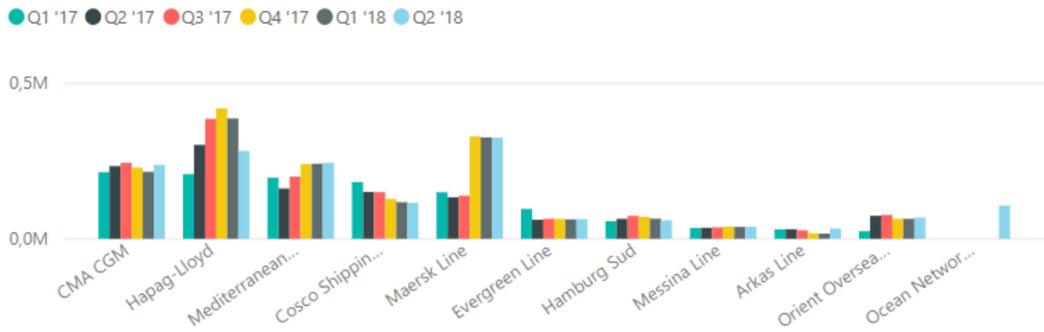


Genoa

Share of Companies, for 2nd Quarter 2018



Container liner capacity deployed, filtered for > 30,000 TEU



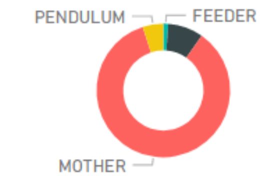
Container liner capacity deployed, filtered for > 100,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
Maersk Line	149.776,49	133.670,85	138.814,59	329.920,44	326.417,79	325.719,96
Hapag-Lloyd	208.076,88	302.267,76	386.275,44	419.894,66	387.373,97	282.932,36
Mediterranean Shipping Company	196.823,24	161.848,49	200.108,57	240.912,94	241.567,07	244.251,15
CMA CGM	214.841,09	234.102,86	244.670,26	229.004,25	215.787,43	237.938,45
Cosco Shipping Lines	182.583,13	150.752,50	150.157,36	128.308,09	117.706,09	115.695,96
Ocean Network Express	0,00	0,00	0,00	0,00	0,00	107.213,27
Totaal	**952.100,84**	**982.642,46**	**1.120.026,22**	**1.348.040,38**	**1.288.852,34**	**1.313.751,16**

Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
MOTHER	1.500.204,19	85,29%
INTRA_REGIONAL	149.775,86	8,51%
PENDULUM	87.867,00	5,00%
FEEDER	21.153,17	1,20%
Totaal	**1.759.000,21**	**100,00%**

Capacity per service type



Amount of lines per service type

Service type	Totaal van Service type	% van eindtotaal voor Totaal van Service type
MOTHER	78	70,27%
INTRA_REGIONAL	23	20,72%
FEEDER	7	6,31%
PENDULUM	3	2,70%
Totaal	**111**	**100,00%**

Amount of lines per service type

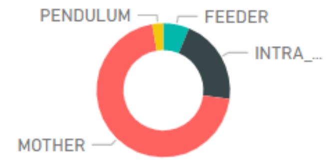


Figure 18: Full-sized dashboard for the port of Genova

4.5 INDIVIDUAL PORT ANALYSIS

This section describes the ports in this research by processing all the data from both the dashboards and the throughput numbers. First all the numbers are extensively listed for every port separately without drawing conclusions. For the conclusions please refer to section 4.6.

How much a port depends on a single liner is also discussed in the following section, here it should be kept in mind that large dependencies are the norm in the current container shipping industry. A low dependency in the current container shipping industry is probably describes as a high dependency in other businesses, as described in section 2.1. This dependency can be viewed upon as an indicator for the redundancy of the port. Also the number of shipping lines give an indication of the relative competitiveness of the ports, as shipping lines will establish themselves in ports that are part of logistic chains with good characteristics.

4.5.1 Genova

The port of Genova is the largest port in the scope and located furthest west in the Ligurian Sea. It's total throughput for 2017 was 2.622.187 TEU. Of this number 2.252.604 TEUs where destined for the hinterland and 369.580 TEUs where transhipped to other ports. The share of transshipment is 14% of total throughput.
Of the 2.252.604 TEUs destined for the hinterland, the share of empties is 24%. Which is about average for the ports located within the scope of this research.

More than 30 liner companies are present in the port, but only 11 have more than 30.000 TEU capacity deployed in the last quarter. The port has a large number of liner companies that sail on the port and large dependency on a single liner company is absent. However, the four top liners still represent more than half the total capacity. Maersk is highly present in the port with over 300.000 TEU ship-capacity in the last quarter, which represents 18% of the total.

More than half the services are executed by a single liner without alliance assistance. The rest is performed by all three major alliances with an almost even share.

From the data and dashboard, it follows that the port is a mainly used by the large shipping companies as a deep-sea gateway port. Most lines, about 70%, which representing 85% of capacity, consists of large motherships. Only a small part consists of feeders and intraregional, which is supported by the 14% of transshipment. This is also represented by the maximum size/capacity of vessels of 14.507 TEUs and an average size/capacity of 8.716 TEUs. These are the second largest in the scope.

The port has an import to export ratio of 0.63 which means export is dominant. Consequently, this is reversed for the empties trade. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Figure 18.

4.5.2 La Spezia

The port of La Spezia is located only 80 kilometres to the south east of Genova and is the second largest port in the scope. It's total throughput for 2017 was 1.473.571 TEU. Of this number 1.262.064 TEUs where destined for the hinterland and 211.507 TEUs where transhipped to other ports. The share of transshipment is 14% of total throughput. This transhipment share is identical to that of Genova. Of the 2.252.604 TEUs destined for the hinterland, the share of empties is 25%. Which is about average for the ports located within the scope of this research.

More than 25 liner companies are present in the port, but only 10 have more than 30.000 TEU capacity deployed in the last quarter. The port has a large number of liner companies that sail on the port, but market shares are limited for most of them. The top 2 liners represent more than half the total capacity. MSC and Maersk are both highly present in the port with over 450.000 TEU and respectively 200.000 TEU ship-capacity in a quarter. This means the port is very dependent on these two liners. MSC uses the port for its intraregional services and deploys motherships, which might indicate that MSC uses the port for transshipment. Maersk only deploys motherships at the port.

With 36% the 2M alliance performed most services by capacity. About a third or 34%, of the services are executed by a single liner without alliance assistance. This means that the port is highly dependent on a single alliance and its members.

From the data and dashboard, it follows that the port is a mainly used by the large shipping companies as a deep-sea gateway port. Most lines, about 71%, which representing 82% of capacity, consists of large motherships. Only a small part consists of feeders and intraregional, which is supported by the 14% of transshipment. This is also represented by the maximum size/capacity of vessels of 14.725 TEUs and an average size/capacity of 10.914 TEUs, which are the largest in the scope.

The port has an import to export ratio of 0.52 which means export is dominant. Consequently, this is reversed for the empties trade. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Appendix C.

4.5.3 Livorno

The port of Livorno is the third highest port in the scope, however the throughputs are only half of the second port, La Spezia, and much more comparable to Venezia and Trieste. It is the smallest port in the scope located in the Ligurian Sea. It's total throughput for 2017 was 734.085 TEUs. Of this number 563.944 TEUs where destined for the hinterland and 170.141 TEUs where transhipped to other ports. The share of transshipment is 23% of total throughput.
Of the 734.085 TEUs, the share of empties is 24%. Which is about average for the ports located within the scope of this research.

More than 14 liner companies are present in the port, but only 7 have more than 20.000 TEU capacity deployed in a quarter. The port has a number of liner companies that sail on the port but a large dependency on a single liner company is present. The largest capacity is deployed by MSC, as this company solely deploys 30% of total capacity. The second and third are CMA CGM and Hapag-Lloyd with both 19%. This means that there is a large dependence on three liner companies. These three companies only deploy motherships with the exception of CMA CGM which has half its capacity in Intraregional services, which strongly suggests that CMA CGM used this port for transshipment purposes.

More than 79% of the services are executed by a single liner company without alliance assistance. The remaining share is divided by the 2M alliance and THE alliance.

From the data and dashboard, it follows that the port is a mainly used by the large shipping companies as a deep-sea regional port with more focus on transshipment. Most lines, about 62%, which representing 78% of capacity, consists of large motherships. The rest consists of intraregional, which is supported by the 23% of transshipment. Of the larger shipping lines, CMA CGM and Hapag-Lloyd both deploy mother vessels and intra-regional, therefor they use Livorno as a transhipment hub. The ports focus is also represented by the maximum size/capacity of vessels of 8980 TEUs and an average size/capacity of 5199 TEUs.

The port has an import to export ratio of 0.79 which means export is dominant. Consequently, this is reversed for the empties trade. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Appendix C.

4.5.4 Ravenna

The port of Ravenna is the smallest port in the scope. Located in the Adriatic Sea it's total throughput for 2017 was 223.369 TEU. Of this number 221.769TEUs where destined for the hinterland and only 1600 TEUs where transhipped to other ports. The share of transshipment is 0.01% of total throughput.
Of the 221.769 TEUs, the share of empties is 25%. Which is about average for the ports located within the scope of this research.

In the port 11 liner companies are present, but only 6 have more than 10.000 TEU capacity deployed in a quarter. The port has a low number of liner companies that sail on the port and large dependency on a single liner company. MSC is responsible for 56% of all throughput.

All the services are executed by a single liner without alliance assistance. This means that no alliance is present in the port.

From the data and dashboard, it follows that the port is a used by as a regional port only. No motherships call at the port. This is supported by the fact that there is no significant transshipment. Most lines, about 88%, which representing 94% of capacity, consists of intraregional. The rest consists of feeders. The ports use is represented by the maximum size/capacity of vessels of 2605 TEUs and an average size/capacity of 1778 TEUs which is the lowest in the scope.

The port has an import to export ratio of 0.67 which means export is dominant. Consequently, this is reversed for the empties trade. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Appendix C.

4.5.5 Venezia

The port of Venezia is a medium sizes port within in the scope. It's total throughput for 2017 was 611.383 TEU. Of this number 661.383 TEUs where destined for the hinterland and none where transhipped to other ports. The port of Venezia is the only port in the scope that is not used for transshipment at all. Of the 661.383 TEUs, the share of empties is 34%. Which is the highest for the ports located within the scope of this research.

There are 17 liner companies are present in the port, but only 4 have more than 20.000 TEU capacity deployed in a quarter. The port has a number of liner companies that sail on the port but a large dependency on a single liner company is present. MSC is responsible for 33% of the throughput.

About 73% of the services are executed by a single liner without alliance assistance. The rest is performed by the Ocean alliance.

From the data and dashboard, it follows that the port is a mainly used by the large shipping companies as a regional port but it has some deep-sea gateway activity. Most lines, about 78%, which representing 69% of capacity, consists of intraregional, MSC the main player in this port only has ships of this type in this port. The port is also use for relatively low scale deep-sea, with Cosco, CMA CGM and Evergreen all calling with motherships, of limited size. The motherships represent 16% of the services with a capacity of 27%. The ports use is also represented by the maximum size/capacity of vessels of 6817 TEUs and an average size/capacity of 3139 TEUs.

The port has an import to export ratio of 0.48 which means export is dominant. Consequently, this is reversed for the empties trade. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Appendix C.

4.5.6 Trieste

The port of Trieste is a medium sized port within the scope. It's total throughput for 2017 was 616.156 TEU. Of this number 349.046 TEUs where destined for the hinterland and 267.110 TEUs where transhipped to other ports. The share of transshipment is 43% of total throughput, the highest of the ports investigated. Of the 349.046 TEUs, the share of empties is 19%. Which is the lowest value for the ports located within the scope of this research.

Only 8 shipping companies are present in the port, but only 5 have more than 20.000 TEU capacity deployed in a quarter. The port already has a small number of liner companies that sail on the port and is also highly dependent on a number of specific liner companies. The highest share of the capacity consists of MSC with 46%. The next is Maersk with 23%. Combined the two shipping liners that make up 2M have over 77% of the capacity.

As mentioned 2M has a large influence in the port, however 'only' 41% is sailed under the alliance label. The Ocean alliance accounts for 23% of capacity. The rest is not labelled as alliance but performed by single companies.

From the data and dashboard, it follows that the port is used in different ways by the different liners. The 2M alliance deploys large pendulum ships. These ship account for 22% of the lines and 41% based on capacity. The Ocean alliance deploys relatively small motherships at the port of Trieste. These lines account for 28% of the lines and 23% based on capacity. The rest consists of intraregional deployed by MSC and Evergreen. The ports use is also represented by the maximum size/capacity of vessels of 12409 TEUs and an average size/capacity of 7323 TEUs.

The port has an import to export ratio of 0.98 which means that export and import are in balance. For the empties trade the export is dominant. More detailed information and visual representation can be found in the dashboard for this port, which is shown in Appendix C.

4.6 Conclusion

In this section, conclusions are drawn from chapter 4. First the data is that is used as input variables for the model and its boundary conditions are described. Next, the shape of the shipping network in the logistic chain model is determined based on the analysis of the shipping network. Last the dependencies of the port on the different shipping lines is determined.

4.6.1 Model inputs and boundary conditions

This chapter delivered an overview of the ports in the area. All the data of the port concerning container throughput is discussed. A distinction is made between the import and export flows of both the empty containers and the loaded containers. For the logistic chain choice model discussed in the next chapter, this analysis delivered certain boundary conditions. The first is that the model will only incorporate loaded containers. This is because the empty container trade is a spatial allocation or relocation problem and no quantification of this trade can be incorporated in this model. Therefor the model will be calibrated on throughput values of loaded containers.

Because transshipment is in essence a network optimisation problem of the shipping lines, transshipment throughput numbers are not explicitly incorporated in the model. However, the route that containers have taken cannot be deducted from mere throughput figures. Shipments could already be transhipped before arriving at the port in question. Because the empties trade and transhipped containers are not considered in the model, only loaded containers that have their destination or origin in the hinterland are used to calibrate the resulting model.

Also, the stowage factors of the individual ports are calculated. The weighted average stowage factors for the import and the export are used to validate the stowage factors used to calculate the total trade demand following the method described in section 3.2.2.

The modal split is determined for the scope. Inland shipping in the scoped region is very limited, as only the river Po is suitable in the north of Italy. On the Po river, less than 25000 containers are shipped annually. Because of the very limited usage of inland shipping it will not be modelled in this research. Regarding the rail modality, it is established that for Europe the break-even distance ranges from 500 to 700km. Within the scope, all distances from the origins/destinations of trade towards the ports are less than this range. Therefor it is chosen only to model the road mode. The road modality accounts for 86,4% of all hinterland shipments in Italy.

4.6.2 Conclusions port analysis

The ports in the scope are all analysed based on throughput numbers and the service lines that are calling at the ports. All ports in the scope handle more export than import. The relative size of the north Italian container ports is small as for example the port of Rotterdam has a throughput that is higher (more than 14million TEUs) than the combined throughput of these six ports (less than 6 million TEUs).

Ports are used in different ways by the liner companies. The largest ports in this scope are found in the Ligurian Sea. From large to small these are Genova, La Spezia and Livorno. Because of the geographical shape of the Mediterranean, large ships make a detour of the main shipping routes in order to access the Ligurian ports. The ships can continue their journey towards the coast of France and Spain or in other direction towards the South Italian ports. With this route, a large hinterland area/container demand can be accessed without a large detour from the main shipping routes as shown in Figure 19.

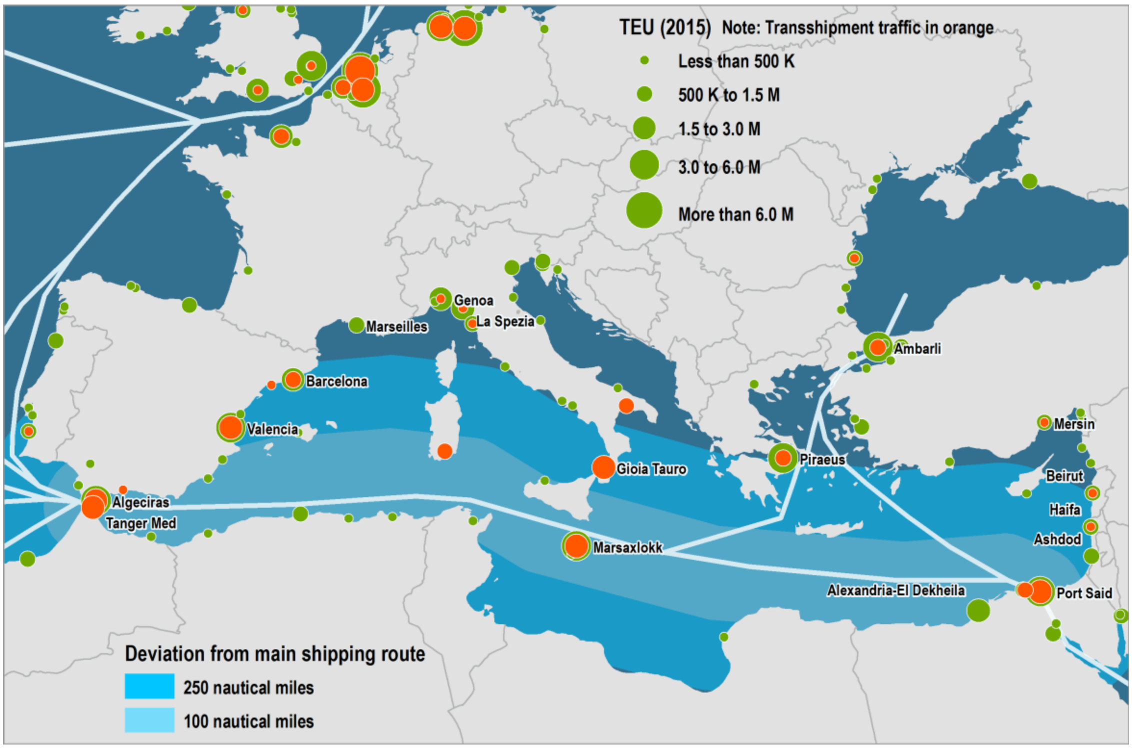


Figure 19: Deviation from main shipping route mediteranian container ports. Source: Rodrigue, J-P and T. Notteboom (2010) "Foreland-Based Regionalization: Integrating Intermediate Hubs with Port Hinterlands", Research in Transportation Economics, Vol. 27, pp. 19-29

Because of this, large ships that sail on the main shipping routes call on Genova, La Spezia and Livorno and use the ports as deep-sea gateway ports. This is represented by the fact that in these ports, the share of motherships lies around 80% by capacity. The ports are not used as transshipment hubs as the ports are not on the main shipping routes. (Rodrigue and Notteboom 2010) identified the distance from the shipping lines as one of the key port selection criteria regarding transshipment. The fact that the ports are not used as transshipment hubs is represented by a relatively low transhipment share of these ports, 14% for both Genova and La Spezia and less so for Livorno with 23%.

Genova has a relatively good spread in its liner company clientele, and no clear company or alliance dominance is visible. However, in the port of La Spezia, both MSC and Mearsk are highly present as the combined capacity deployed accounts for more than half the total capacity.

The port of Livorno is used more as a deep-sea regional port with more focus on transshipment. This is shown by the fact that the port has a good portion of transshipment (23%) but relatively low throughput values of around 600.000TEUs. The port has a large dependence on three liners. MSC with 30%, CMA CGM with 19% and Hapag-Lloyd also with 19%. These three companies only deploy motherships with the exception of CMA CGM which has half its capacity in Intraregional services, which strongly suggests that CMA CGM used this port for transshipment purposes.

The ports in the Adriatic Sea have a disadvantage over the ports in the Ligurian Sea, as a large detour is needed if the ports are called upon by the large motherships that sail on the main shipping routes. This results in the fact that only Trieste is called upon with a single service with large vessels of around 12.500TEU. This service is a pendulum service, which means it only calls on a very limited amount of ports. Pendulum services are known to have norm deviating routings.

The port of Ravenna has the lowest throughput in the analyses and is only used as a regional port. This is shown by the low throughput of about 200.000 TEU and all services consist of small feeder or intraregional ships. The port is highly dependent on a single line, as MSC is responsible for 56% of all throughput.

The port of Venice is of average size in the scope with around 600.000TEU. It is mainly used by the large shipping companies as a regional port but it has some low scale deep-sea gateway activity with motherships with less than 7000TEU capacity. The port is highly dependent on MSC, who are responsible for 33% of the throughput. It uses the port for intraregional services.

The port of Trieste has the largest share of transshipment in the scope, 43%. This is mainly because the MSC uses the port for the transshipment of its pendulum service that sails with around 12.000TEU ships. This pendulum service sails under the 2M alliance. The dependency on this pendulum service and the companies that perform this are evident as they have a 77% market share in the port.

The North Italian ports are very dependent on only a limited number of liners, with the MSC being by far the largest. It has the largest share in 5 of the 6 ports. Only the port of Genova has limited dependence on this liner with 14%. It should be however considered that this analysis is performed on a port level. The same analysis on a terminal level can give a different perspective. The size of the ports does seem to have a relation with the number of liners that call at the ports, where small ports only have a limited number.

4.6.3 Conclusions on shipping network

From the above conclusions from the analysis of the ports it is clear that the smaller ports in the scope are predominantly served by feeder and intra-regional shipping line types. These vessels have higher per TEU sailing costs than larger vessels. As described in section 3.3, the costs for the maritime part of the logistic chain in the model are based on the average ship size for that chain. This means that for the smaller ports, the cost for maritime transport would be very high if cargo would come from afar, for example China. This would mean that smaller ports don’t get a share of shipments from trade partners located far away. In reality, these smaller ports do get part of the shipments as container are transhipped in a ship to ship fashion before being distributed by these smaller vessels. The ship to ship transshipment needs to be modelled in order for the smaller ports to get a realistic market share. The modelling approach to include this type of transshipment is described in section 5.1.2.

5 LOGISTIC CHAIN MODEL

This chapter describes the logistic chain model. The model is developed in clearly defined steps. First the different logistic chains or routes are determined. This is done by first making route consideration and then applying the cost factors onto the routes. Secondly the discrete choice is modelled by applying the multinomial logit to the different chains. Because not all factors are implemented into the model, there will be an offset of the real-world throughput of ports. The next step is to calibrate the model towards the real-world throughput values. Next a sensitivity analysis is performed. This determines the sensitivity of the ports to changes in the cost functions. Lastly the conclusions are drawn from the model.

5.1 CHAIN GENERATION

The chain generation step sets up the logistic chains or routes that are available for the containers. As the choice for logistic chains are based on the monetary costs the result of this step is the cost associated with each route listed in a matrix format. The methodical flow is as described in section 3.3. First routing considerations should be made and the distances need to be determined for every route. Secondly, the costs are calculated based on ship size.

5.1.1 Route considerations

In order to calculate the distances first the distances to calculate have to be determined. For the road distances, the Google Maps API is implemented into the model. This makes it possible to extract distances from all the ports to the different hinterland regions. It is assumed that routes have the same properties both ways. As for some countries, maritime trade is not the only option, also the road distances to European countries are incorporated. For countries, the capitals are used as the node.

For the maritime distances data, a shortest path algorithm was modelled based on a GIS map. However, this method didn’t produce adequate results. Shipping routes are not only based on the shortest available sea route containing water, as depth of the waterways is a major determinant for routes. This proved to be mainly the case for the shorter distances and routes that involve close to shore sailing. As an alternative, the maritime distances where extracted from (SeaRoutes 2019). The routes resulting from this website are the actual used routes for merchant vessels. All distances where extracted manually, but for future researches it is advised to use their paid API service.

The bilateral trade is taken as an exogenous variable in this study. This means that for the import case (and inversely the export), the first part of the route is of low interest and distances can be approximated. The deviation in routes starts in the second part of the maritime leg. This results in the first differences in costs for the various hinterland areas.
The maritime leg starts at the main port in the trade partner country or a neighbouring country in case the country is landlocked. For the transport of the TEU from the origin towards the port a fixed distance is taken of 100km by road transport.

5.1.2 Transshipment and ship size considerations

Within this research, transshipment is defined as transfer of a container at an intermediary port from a ship to a ship. This definition is used unless explicitly mentioned otherwise. According to (Meersman, Van de Voorde en Vanelslanders 2016), the transshipment volumes have less or even no link at all with available cargo volumes in or to the hinterland of the concerned port, but depends on strategic location of the port in international networks and chains, and on specific features of the port, such as available capacity, efficiency of operations, price levels, etc. Transshipment volumes are determined by optimising maritime trade flows by shipping companies. This research focusses on the socio-economic properties of the hinterland and no attempt is made to optimise a shipping companies shipping network. Therefor the hub-role of the ports in this research is not considered and transhipped containers throughput volumes are deducted from the total.

As transshipment can have large cost benefits for long distance shipping is included into this research. To model this Malta is assumed to be the fixed transshipment hub for the ports in the scope. It is possible for both the Ligurian ports as well as the Adriatic ports to have their transshipment their regardless of the east or west orientation of the route taken. Malta is found in the service schedules of all interregional sailing vessel for the different ports. It is assumed that while other options might also be available, they are all similar in cost respect as transhipment throughput is known for its price sensitivity (Chen, et al. 2017).

For every route two options are possible, direct shipping or transhipped shipping with the transshipment taking place in Malta. The direct route will be performed by the average ship size of the ports while the transshipment will be performed by the average ship size of the feeder or intraregional vessels of the ports in combination with a 18000 TEU mothership as shown in Figure 20.

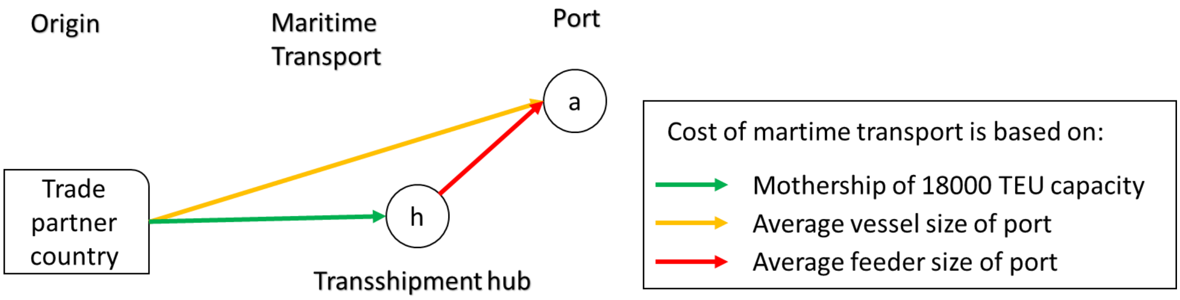


Figure 20: Maritime cost based on different shipsizes

5.1.3 Maritime costs

The maritime cost need to be calculated on a per TEU basis. The main input variable for this section is the maritime distance of the route.

The maritime transport cost consists of the total costs incurred by the carriers. Normally the freight rates of the carriers cover these costs. However, these freight rates prove to be very volatile, and are mainly driven by supply and demand in the shipping sector (Stopford 2009). Freight rates are not always transparent, multiple shipping lines deploy extensive additional charges systems. These charges range from “Peak Season Surcharges” to “Carrier security Fees” (Hapag-LLoyd 2019). Another issue with using the freight rates is that the ports of shipment and the ship size are not specified. Freight rates are not used.
For this study the maritime costs are approximated for different ship sizes and are dependent on time. In order to assess the maritime cost (Stopford 2009) has created a classification system. This approach divides the costs into five categories:

- Operating costs, these are costs made regardless of the operations performed with the ship. It includes crew, stores and maintenance.
- Periodic maintenance costs, these are costs incurred when the ships undergo major repairs.
- Voyage costs are the variable coast that are dependent on the specific voyage of the ship. These include fuel, port charges and canal dues.
- Capital costs are the costs that are made to finance the ship.
- Cargo handling costs, represent the charges that liners pay for the loading/unloading and stowing of the cargo.

To estimate the cost directly associated with operating a ship, a model of OSC is used. This model is based on data of container vessels that were built in the last 10 years. The costs included in the model are the operating costs, capital costs and the fuel. The result of this model is the cost per slot for different vessel sizes as required. The distribution of these costs is shown in Figure 21. The underlying data table can be found in Appendix D.

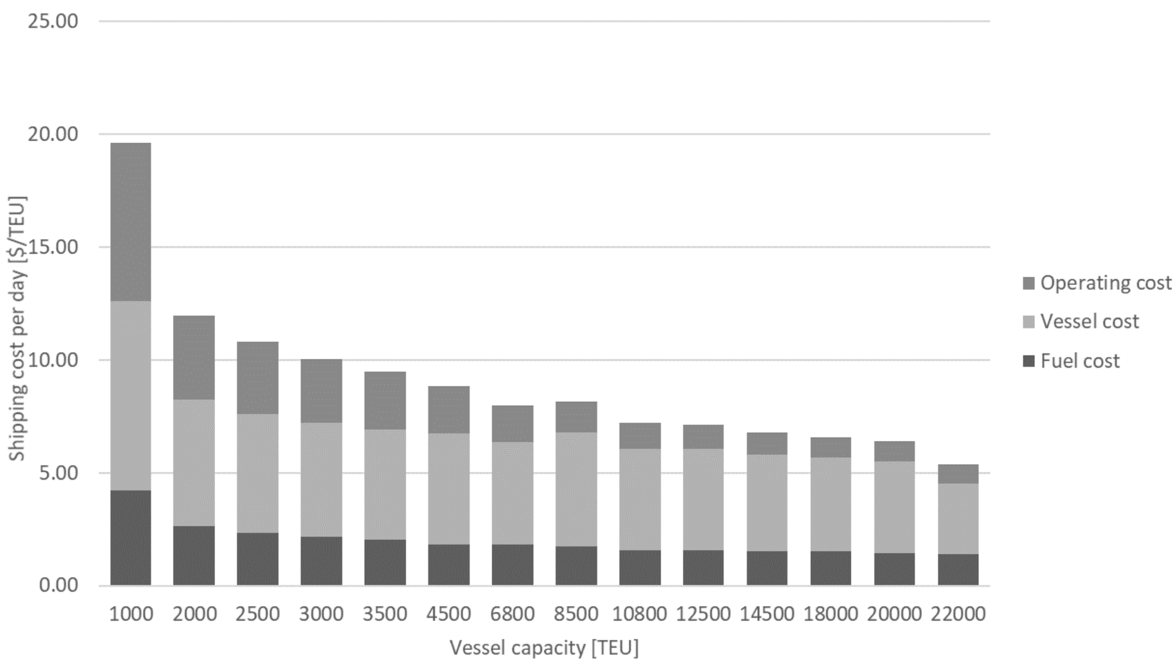


Figure 21: Shipping cost per day per slot. Source: Royal HaskoningDHV

The capital costs are based on the costs of a newbuild ship. The newbuild price varies from vessel to vessel and is dependent on the size of the ship and economic circumstances. Due to economic circumstances, the demand and supply for new ships varies through time and so does the price of new vessels. Normally the price of larger vessels is higher. Because however all 22,000 TEU vessels were ordered in times of with high yard supply and vacant orderbooks, the price was lower than 18,000 TEU ships build a couple of years earlier. This results in even lower than expected capital cost on a slot basis.

The fuel costs are based on both the specific fuel consumption of the ship and the fuel price. The specific fuel consumption of a ship has relation to the ship speed of the third power (Klein Woud en Stapersma 2008). To determine the specific fuel consumption the average speed of container ships for the different ship sizes is determined. An analysis is performed on all container line services of 2017 (eeSea 2018). This leads to an average ship speed of 13knots for ships up to 5000TEU capacity and 14knots for 5000TEU and above. The specific fuel consumption for the different vessel sizes can be found in appendix D.

5.1.3.1 Terminal handling charges

Terminal handling charges (THC), are the charges that are incurred for the loading and unloading of a vessel. This is a cost that is charged per container by the terminal operator company and is cargo dependent. These charges are billed towards the carrier of the ship. However, these are usually passed on to the shipper, which in turn sets its own price on this. As described in section 2.2, shipping alliances have considerable bargaining power over terminals. This fact is supported by the results by the different dashboards of the ports within the scope; Genova is the only port that has a varied clientele. The large shipping companies use this bargaining power to sign long standing contracts with the terminals, which include price agreements (OECD/ITF 2018). The details of such agreements are not publicly available. However, to approximate the value, the surcharge of shippers is used. For the whole of Italy this was 178€ for both handling a TEU or a FEU (Hapag-LLoyd 2019) for 2017. It is expected that this number includes (profit) margin(s), the real value might be lower. The rate OOCL charges is also found for the port of Genova, which is 170€ for both a TEU or a FEU (OOCL 2016), this gives the appearance that values don't differ much between shippers or the Italian ports. An extensive report on THCs by the EC shows that this was indeed the case in 2009 (EC 2009).
For this research, a value of 178€ per container is used for all ports. This is chosen as values for ports other than the North Italian ports are not available and not relevant as they will not determine route differences.

5.1.3.2 Port charges

Port charges are the fees that the operator of the ship needs to pay to use the facilities and services provided by the port. These charges can include: pilotage, towage, mooring, admin fees. With the different service providers and the port authorities there are numerous different pricing policies. The different parties also employ various discount factors and surcharges. This makes prices dependent on specific individual characteristics. Prices can be based on cargo weight, gross registered tonnage, net registered tonnage or deadweight (Stopford 2009). Because the exact properties of the ships are unkown and prices not transparant, prices are ussually approximated in studies. For this study a model of OSC is used, which approximates the port charges based on ship size as shown in table Table 11. As the average ship size is used to calculate the costs for every logistic chain the port charges are different for every port, however the same pricing structure is used model wide.

Table 11: Port dues per ship size, Source: RHDHV

Ship size [TEU]	4500	6800	8500	10800	12500	14500	18000
Port dues [$]	54,725	99,500	107,750	117,750	127,750	140,560	157,500

5.1.4 Road transport costs

The cost for road transport were determined by analysing data that was available at RHDHV, the dataset contains 86 quotes made for road transport of both TEU's and FEU's from Rotterdam to its hinterland. As data on the hinterland specific region is lacking it is assumed that the costs for transport in the scope of the hinterland is comparable to the price asked for the transports in this dataset.

To determine the cost of road transport per km a linear regression analyses is performed on the value for containers, this value is obtained by implementing the TEU-ratio as described in section 4.1. This ratio is 1.6 TEU equivalent unit per container. The results from the regression analyses are described in Appendix E. The resulting constant cost are €76.22 per container and the variable cost are €0.93 per kilometre per container.

5.2 CHAIN CHOICE

The chain choice is determined in two stages. Both stages encompass a discrete choice between chain options. The first stage is the choice for a mode of transport. As this model is created on the bilateral trade of the hinterland countries also other options for the transport of containers are available. In this study, the modes of transport in the hinterland are reduced to road only as described in section 4.2. This means that the choice for modality is reduced to two, the direct road route and a route that includes a maritime leg. As determined in the literature study the decision maker for this stage of transport is the shipper of the cargo. If the decision is made to use maritime transport a second choice-set is available. This choice set contains the different maritime routes that are available. The decision maker for this stage was identified as the shipping company that tries to minimize its cost. For every port in the research two options are available: the direct shipped option and an option where transshipment is used.

5.2.1 Modality choice

The first stage is the choice for the mode of transport. It is assumed that shippers determine the choice of the modality of the transport as stated in section 2.3. The choice set is limited to two options. The first option is the maritime modality. The second is the road-only route option. The road-only option is calculated by using the fastest route from origin to destination and no further discrete choice modelling is required. The maritime option is calculated based on the average maritime costs for the respective OD-pair or transport flow as shown in Figure 22.

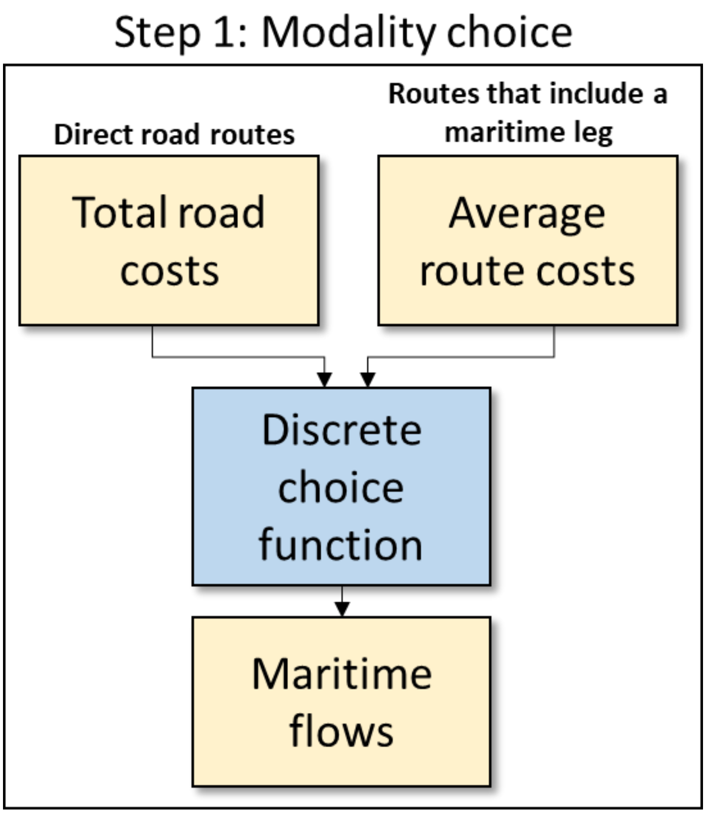


Figure 22: First step of route choice

5.2.2 **Maritime route**

The second step is the choice of the maritime route. For the six ports in the scope two options are available, the direct route and the transshipment route as described in section 5.1.1. Therefor for every origin and destination within the scope of this research, a choice set of twelve routes are available to choose from.

For every port two separate logistic chains are in place to perform this transport. One is directly shipped and the other is transhipped at Malta, which is the fixed transshipment hub for this model as determined in section 5.1.2. For example, the import of goods in containers from Mexico to Italy. In the model, there is a logistic chain that goes directly from Mexico to Livorno. There is also a chain that goes from Mexico to Malta on a large mothership and the container is then transhipped onto a smaller feed vessel that sails from Malta to Livorno. The routing options are shown in Figure 23, the flow in the model is shown in Figure 24.

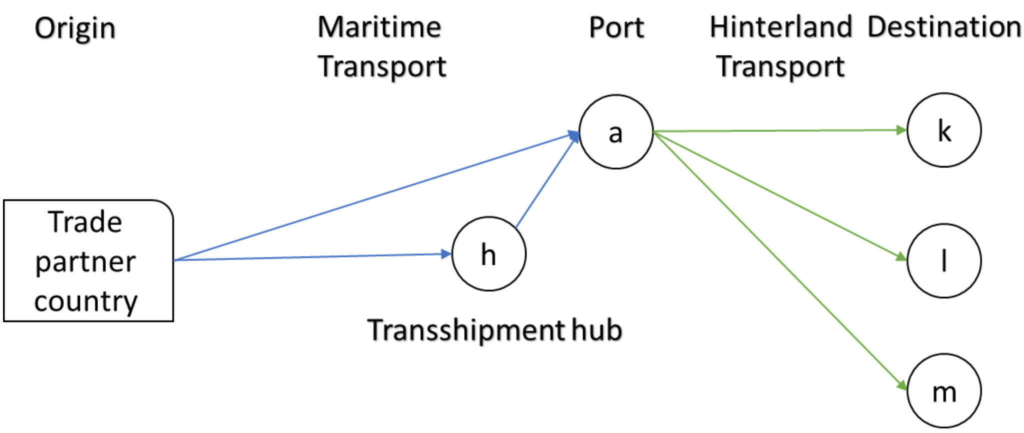


Figure 23: Routing options maritime part of logistic chain

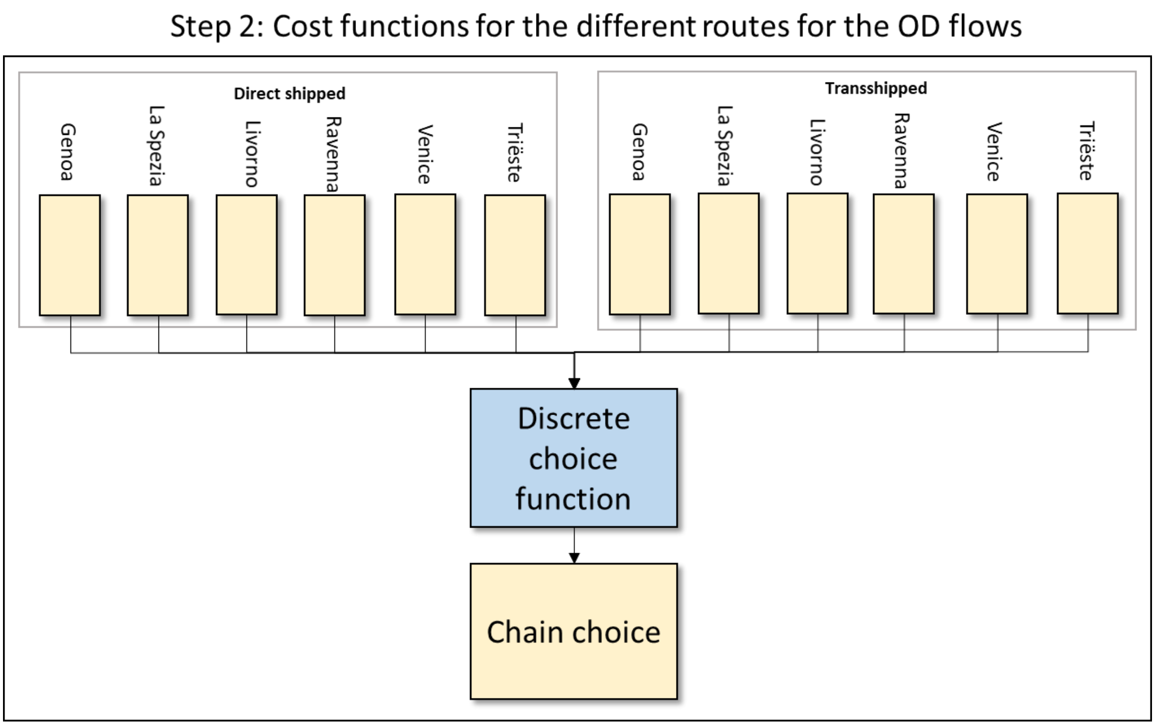


Figure 24: Second step of route choice

5.2.3 Scale factor

The discrete choice function that is used for this research is the Multinomial logit function as described in section 3.4.1. The logit scale parameter μ (mu) that is used in the cost function describes the slope of the curve of the logit function It can be viewed as a cost coefficient. When a large value for μ is used the choice function will simulate an all-or-northing assignment for the different choices. This means that for large values of μ small differences in costs give large differences in assigned volume, as the result of the function is a probability. When a very small value is used for μ only large differences in costs result in a larger share for the 'better' option.

The value for μ, is model specific. The larger the modelled choice areas are the lower the value, which means lower cost sensitivity, should be. An indication of its value can be gained from available literature on comparable applications. The research by (Tavasszy, Minderhoud, et al. 2011) was calibrated towards a μ of 0.0045. According to (Veldman en Buckmann 2003) values between 0.0016 and 0.0045 were applicable. However, these all incorporated (much) larger choice areas than this research. Values mentioned in (Jin 2010) range between 0.007 and 0.015. The Rhumb model of Royal HaskoningDHV uses a scale factor of 0.01. The parameter value used in this study is estimated using a calibration method.

5.3 CALIBRATION

This section described the calibration process followed. The calibration is done for both parts of the chain choice described in the previous section. The first stage is the calibration of the modal choice. This is required as the cost scaling coefficients and the maritime error term of the cost functions are unknown. These values are calibrated on data from Eurostat on the total maritime container transport. This results in the fraction of trade using a logistic chain that includes a maritime part.

The fraction of trade using a logistic chain that includes a maritime part is used as input for the second step. As the decision maker is different in this step as described previous, the cost scale factor could be different and is therefore unknown. Within this step the error term is port specific, this error term incorporates all the non-monetary factors that might explain a preference to a port or logistic chain and may correct any mistakes made in the cost assessment of the model. Both variables are calibrated on the actual port throughputs.

5.3.1 Calibration of modal choice

The first stage choice set consists of the road direct approach and the maritime shipping approach. To calibrate the part of trade that uses the maritime shipping approach a selection was made of nine countries for which both options are viable alternatives. The countries used for calibration are: Albania, Belgium, Denmark, France, Germany, Netherlands, Slovenia, Spain and the United Kingdom. The total amount of containers available for trade is determined as described in 4.3 and the total containerised trade of the countries is extracted from the Eurostat database (Eurostat 2019). This results in the fraction of trade that uses a maritime route.
For this fraction, the weighted average of the countries is used instead of individual fractions in order to mitigate the effect of transshipment activity as well as the use of foreign ports. For import this fraction is 0.45 and for export this is 0.38.

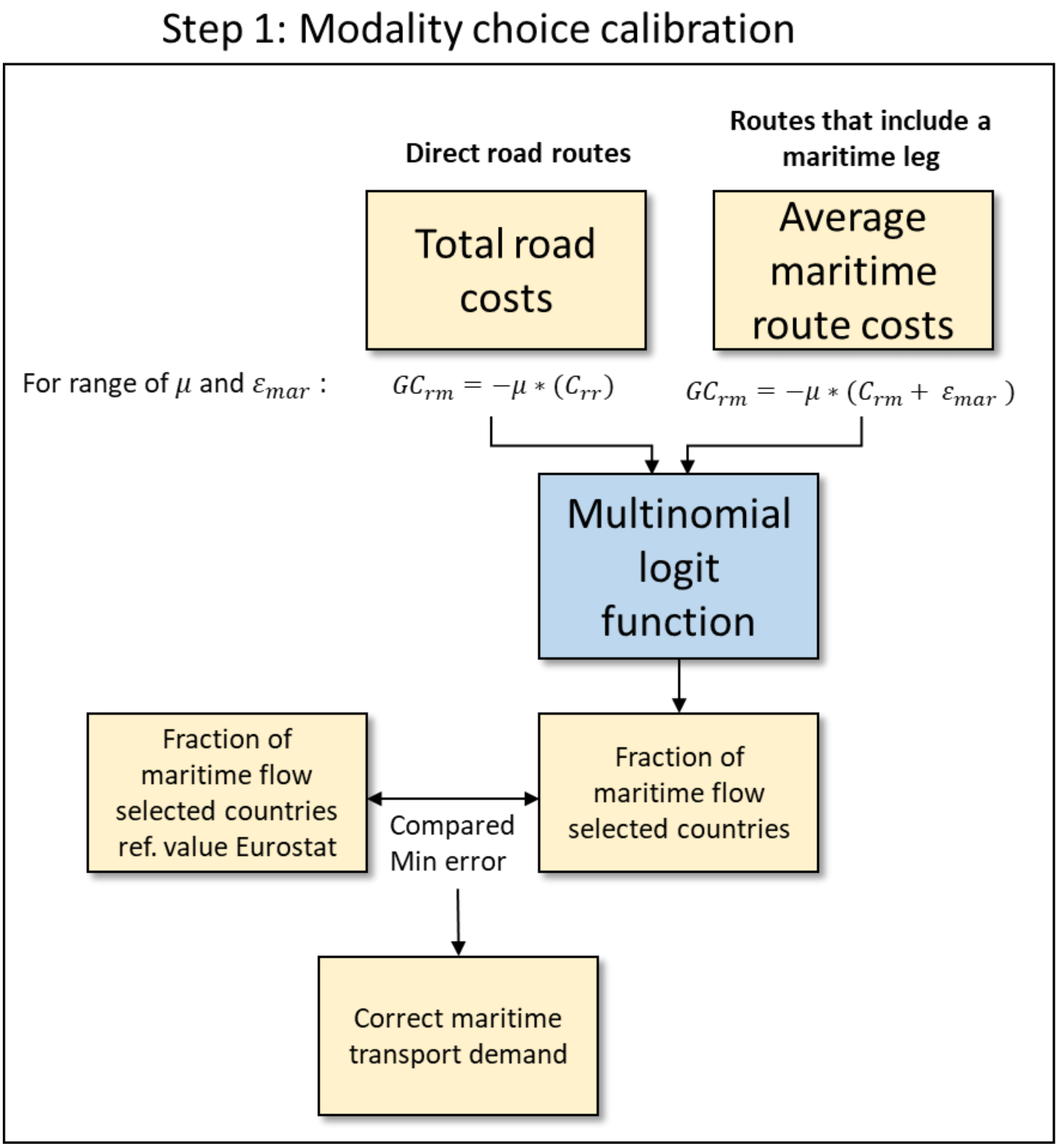


Figure 25: Calibration of step one, flow diagram

The maritime cost used is the average maritime costs for the respective OD-pair or transport flow. Both the cost scale factor (μ) and the maritime error coefficient (ε_{mar}) are unknown. Both these values are determined using complete enumeration within the range of cost scale factors described in section 5.2.3. The flow diagram of the calibration is shown in Figure 25.

The value of mu is determined by minimizing the square of the error terms also called the least squares method by combining both the import and the export. This resulted in a cost scale factor of 0.01. The maritime error term was determined for both import and export separately as the value for which the error first switched from negative to a positive error, meaning that the lowest positive correction factor is used. Resulted in a maritime error coefficient of 244.5 inwards and 270.5 outwards.

5.3.2 **Calibration of maritime route choice**

In this calibration step the second chain choice step Is calibrated. From the previous step the total maritime transport is determined. As the decision maker is different in this step as described previous, the cost scale factor is also different and therefor unknown. Within this step the error term is port specific, this error term incorporates all the non-monetary factors that might explain a preference to a port or logistic chain and may correct any mistakes made in the cost assessment of the model. Both variables are calibrated on the actual port throughputs. The flow of this calibration step is shown in Figure 26. As shown first the cost scale parameter is determined, this is done by using complete enumeration within the range of cost scale factors described in section 5.2.3. Then the value with the minimum error for the throughput is chosen.

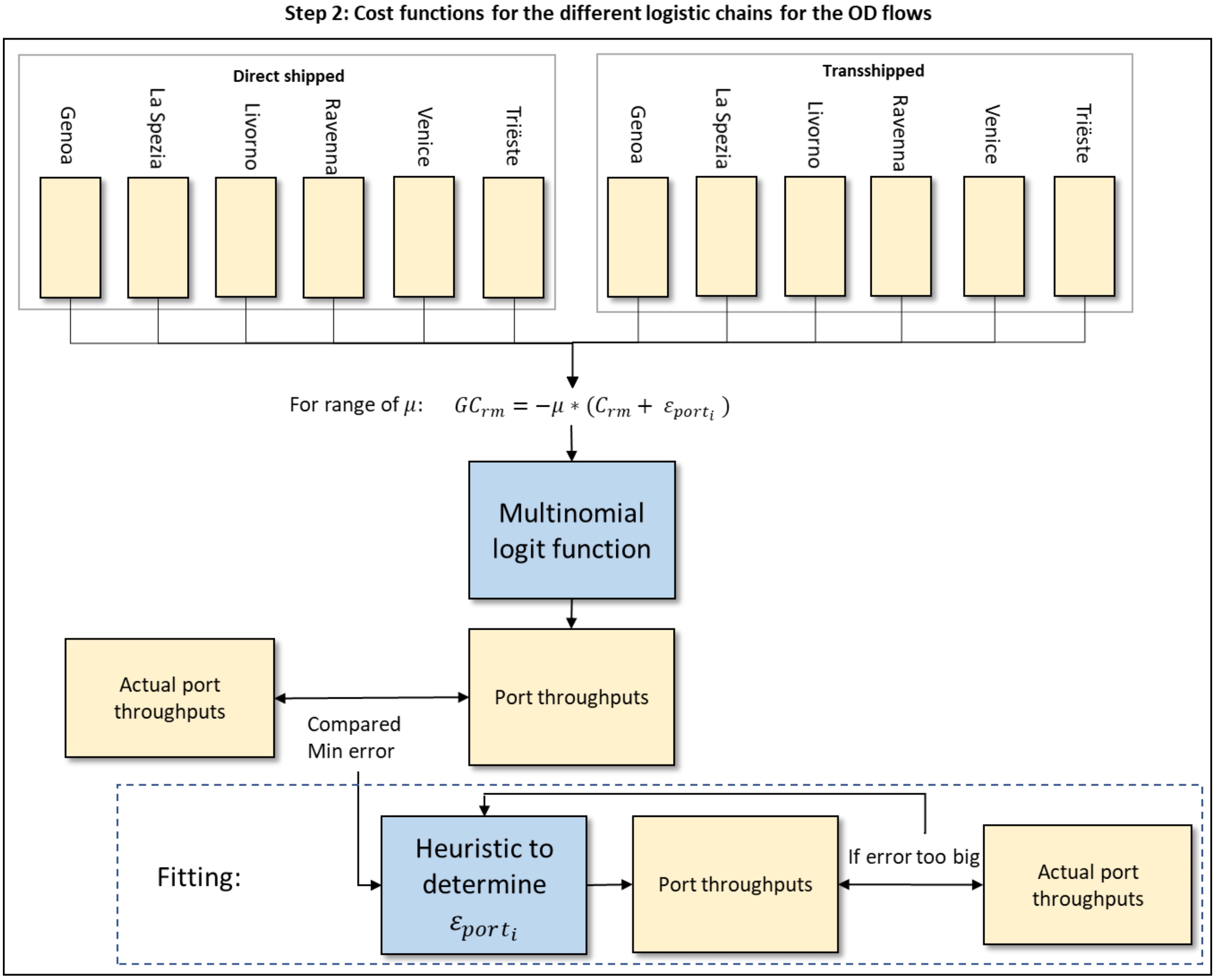


Figure 26: Flow of calibration step 2

Using the cost scale value (μ) that is determined, the next step is determining or fitting the port specific error terms (ε_{port_i}). The maritime route choice is calibrated on the available throughputs of only the loaded containers as stated in section 4.1.

To calibrate the port error terms a heuristic was created. This heuristic determines which port has the largest difference between the model value and the true throughput value for that iteration and adds or subtracts €1 depending on the sign of the error. The significant error is set at 1000TEU per port.

Calibration results step 2.

Calibration of cost scale factor proved that the scope of this model is not large enough to be able to result in a valid μ when calibrating on the throughput of the ports. The found cost scale factor using both R^2 and the least squares method resulted in a cost scale factor μ=0.028 as shown in Figure 27 and Figure 28. This is however too price sensitive and the resulting hinterlands were far to local to be reasonable, in other words it simulated an all or nothing situation. For example, the market share of the port of Trieste in the region Trieste was 1.00.

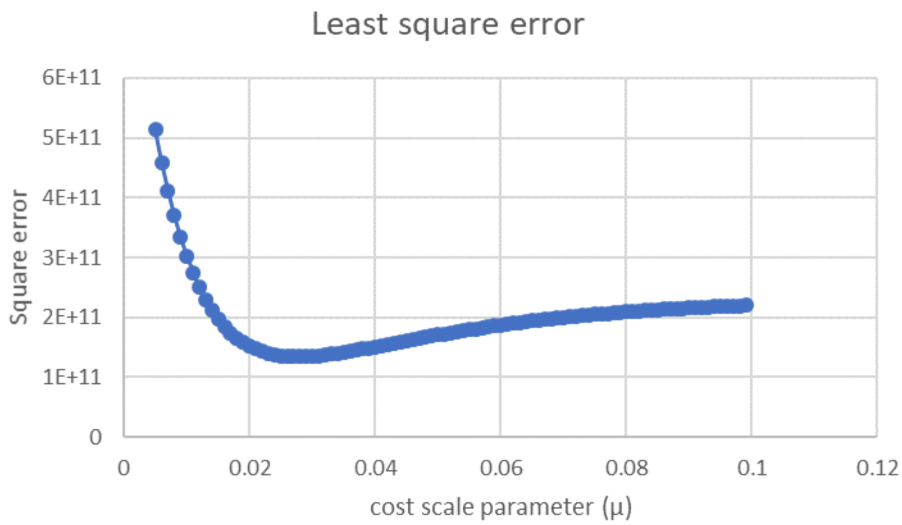


Figure 27: Least square error of the cost scale parameter for the maritime leg

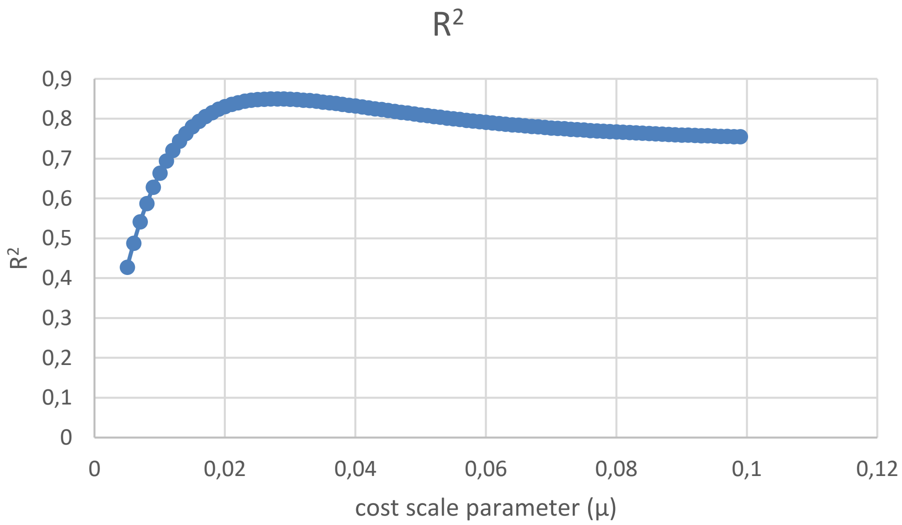


Figure 28: R^2 of the cost scale parameter for the maritime leg

A larger scope with more ports might be required to calibrate this parameter. As described in section 5.2.3 other studies with a larger scope indeed use lower values. For this study the value of 0.01 is used as determined in the previous section, which is in line with literature.

Within the second part of this calibration step, the port error coefficient is set for every (maritime) route that goes through a certain port. As stated above, to calibrate this port error term a heuristic was created. The resulting correction factors are shown in Table 12. Here the correction factors are normalised around the lowest correction factor, which corresponds to the port of Genoa for both import and export. This normalisation is possible as the Multinomial Logit function only 'responds' to price differences.

Table 12: Port error coefficients

	Port error coefficients Import [€]	Port error coefficients Export [€]
Genova	0	0
La Spezia	77	58
Livorno	87	113
Ravenna	195	202
Venezia	166	145
Trieste	78	154

This heuristic was run on both the import and the export simultaneously and required 330 steps to converge. The total amount of misallocated TEU equivalent is shown in Figure 29, this corresponds to a total of around 37% misallocated containers in the base case for both import and export.

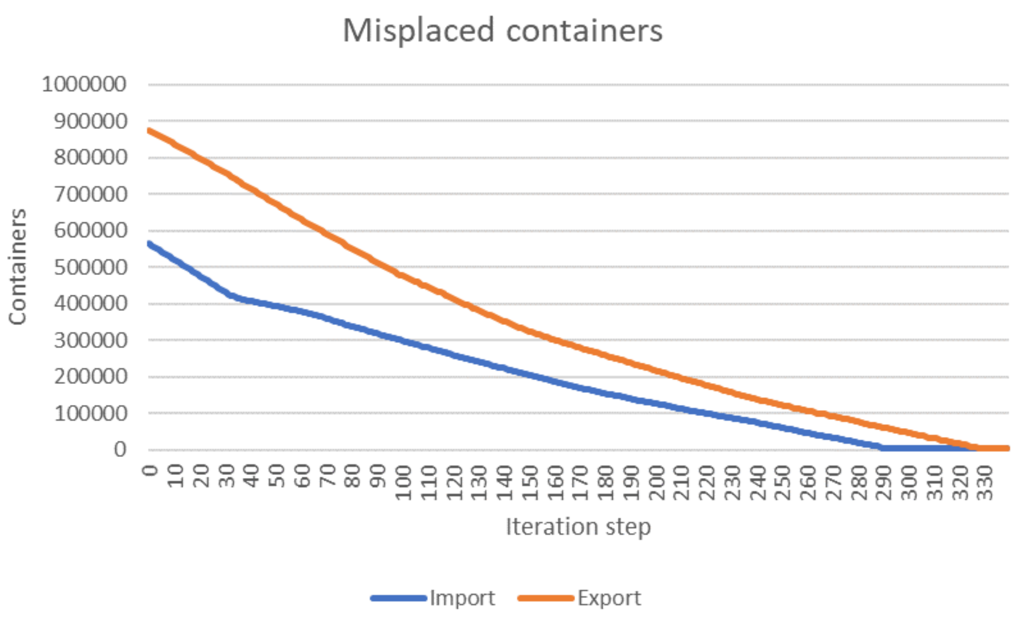


Figure 29: Misplaced containers

As described in section 3.4.1, all factors that cannot be incorporated in monetary value are aggregated into the error terms, as well as any possible mistakes in the established monetary value. From the error terms follow that the port of Ravenna is part of the least attractive logistic chain. This can have a multitude of reasons, from the literature study the following factors were identified as being most important, in order of importance: Port costs, hinterland proximity, hinterland connectivity, port geographical location, port infrastructures, operational efficiency, port service quality, maritime connectivity, nautical accessibility and port site.

Where the model incorporates the first four selection criteria, the ports infrastructure, operational efficiency, port service quality are not modelled explicitly, they are part of the error term. It is highly likely that a small port like Ravenna doesn't have infrastructure, operational efficiency or a service quality that is comparable to larger ports in the scope. This hypothesis is in line with the negative correlation that can be observed between the found error terms and the size or throughput amounts of the ports.

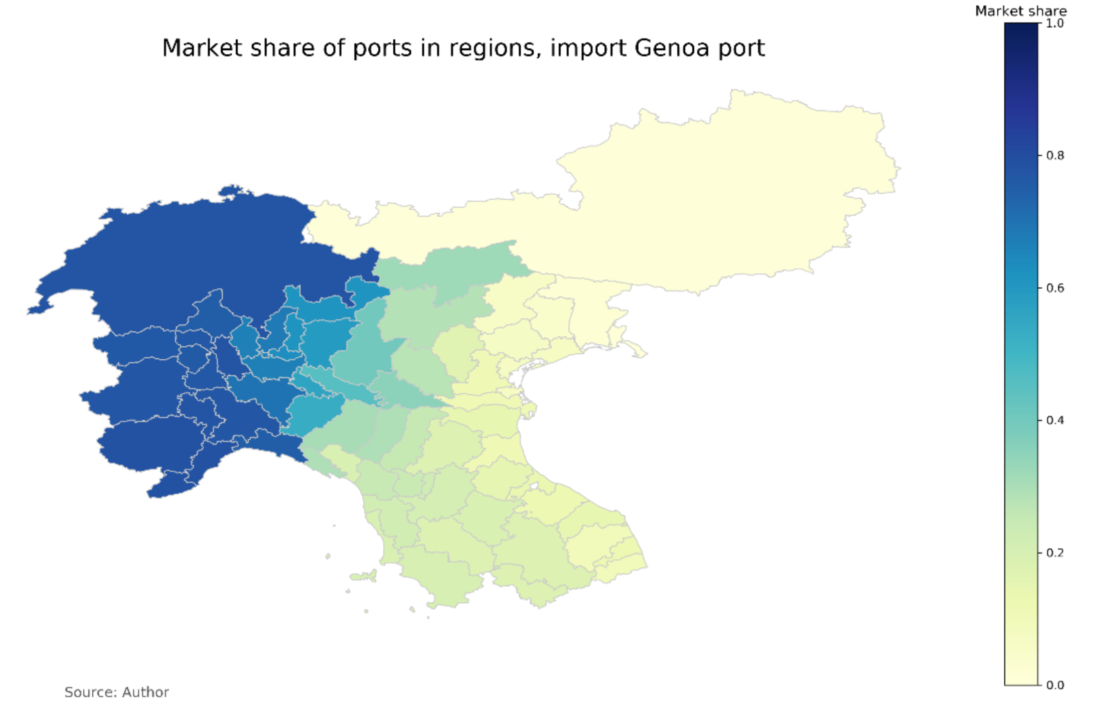
5.4 RESULTS LOGISTIC CHAIN MODEL

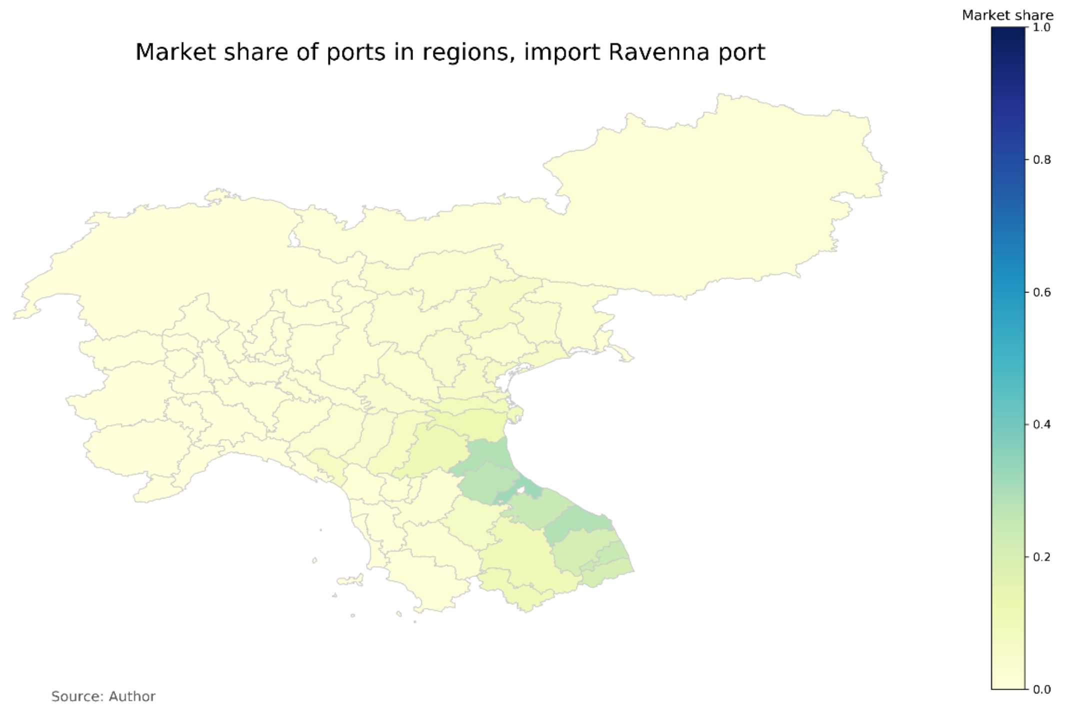
This section will describe the results from the logistic chain model. The calculated results comprise of both the market share for every port in the scope per region as well as the corresponding amount of TEU's. To give an impression, the two extreme cases within the scope are shown in Figure 30 for the import case. These figures were programmed in Python by using the GeoPandas library. The shape files needed were acquired from Eurostat.

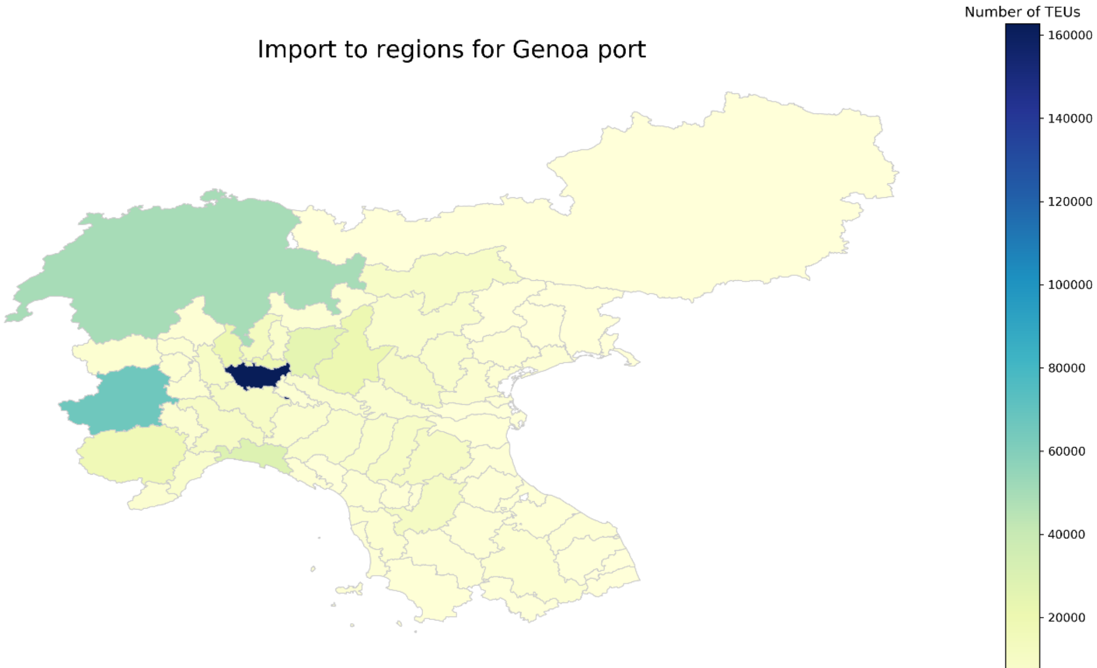
All figures and the complete table with market shares can be found in Appendix F. The role of these ports where already determined in the individual port analysis of section 4.5. The port of Genoa is the largest port in the scope and has a leading market share in a very broad range and serves as a major gateway port to the north Italian region. The port of Ravenna on the other hand is a regional port and only has a substantial market share in regions very close to the port. The highest market share that the port of Ravenna holds is 36% in the neighbouring region of Rimini.

The resulting hinterland shares from the model are in line with expert expectations from Royal HaskoningDHV, and show comparable results to previous studies (Ferrari, Parola en Gattorna, 2011; Zondag, et al., 2010; Moura, Garcia-Alonso and del Rosal, 2018) and internal studies performed by Royal HaskoningDHV. The market share of the ports gradually decrease as the regions is situated further away from the port as shown in Figure 30. Because the difference in throughput in TEU for regions between the ports is very large, the figures all have different scales. This is done as otherwise the throughput of Ravenna wouldn't be visible at all. One could view the figure of the market share as the distribution of the shipments to the ports from the regions perspective. The figure of the import and export could be viewed as the distribution of the shipments to the regions from the ports perspective.

It should be noted that for Austria and Switzerland, the market share only applies to the part of trade that is estimated to go through the Italian ports. As described in section 4.3.3 this is 2.79% for the import and 5.06 for the export of Austria and 15.11% for the import and 27.41% for the export of Switzerland.







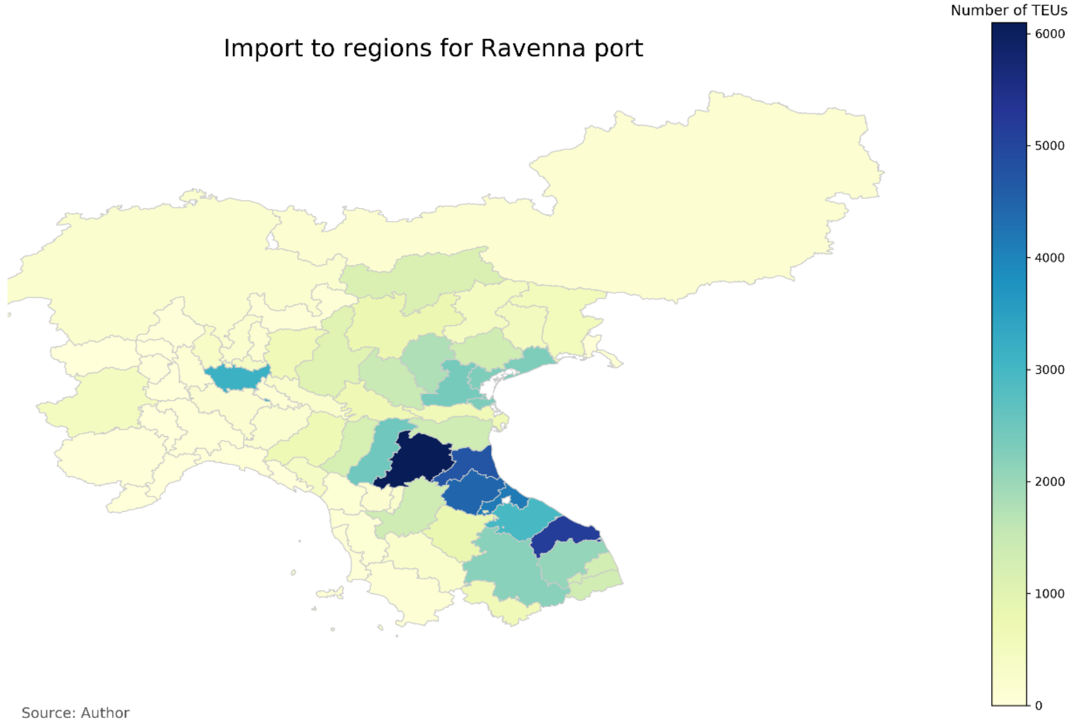


Figure 30: Figures of both Genoa and Ravenna, market shares and flow size

5.5 SENSITIVITY ANALYSIS AND SCENARIO

This section describes the sensitivity of the model to changes in the generalised cost function. As described previously this function incorporated the monetary chain costs as well as the error term which should account for all non-monetary port competition drivers as this is calibrated on the actual throughput. A sensitivity analyses is performed were the generalised cost function is altered for one port at a time which results in a throughput change for that port. This allows to determine which port to quantify a ports susceptibility to changes in generalised cost and subsequently monetary cost. After this a scenario is performed in which the port of Livorno is taken as the subject port and its generalised cost is reduced by 25€. The result this has on the ports in the scope is assessed.

5.5.1 Sensitivity analyses

For every port in the scope individually the generalised cost function was altered in order to determine the sensitivity of that port's throughput to price changes. The range in which this is done is from -50€ to 50€ with 1€ steps. The results are shown in Figure 31 for import and Figure 32 for export.

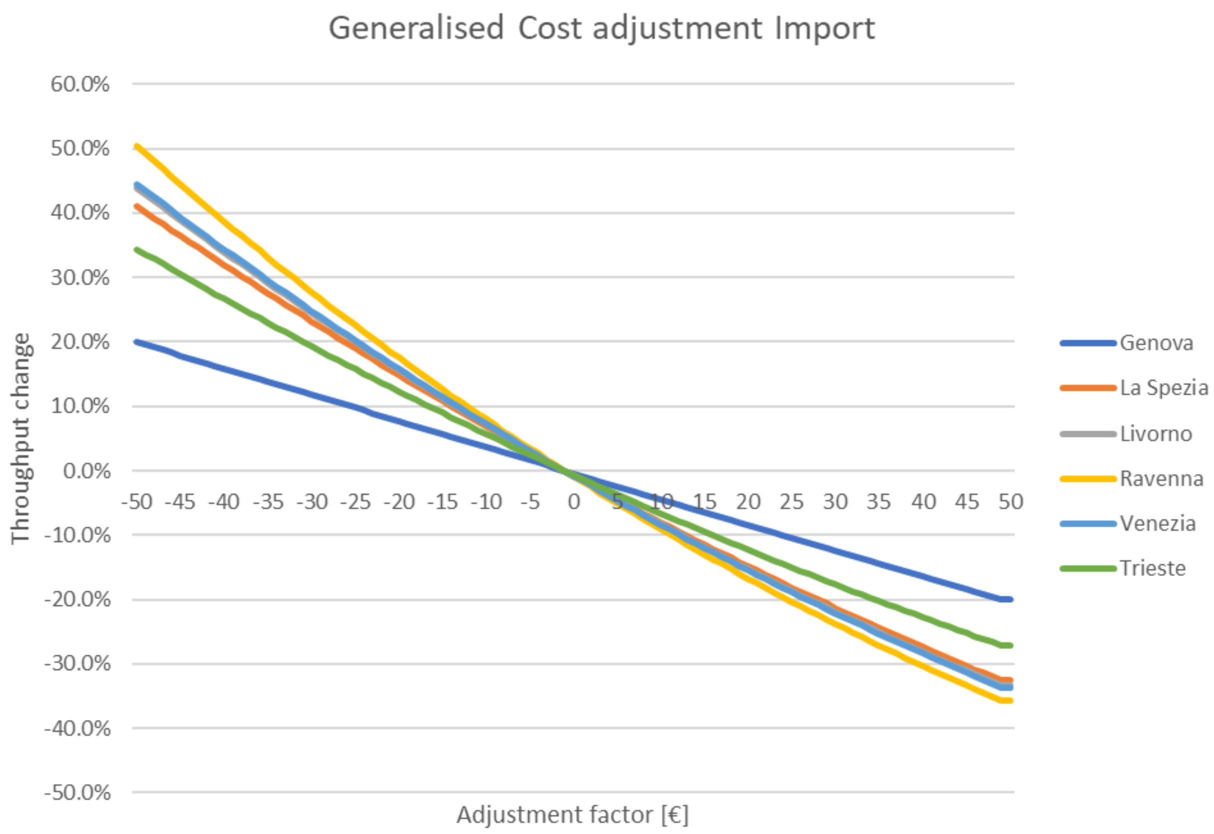


Figure 31: Sensitivity of Throughput to GC adjustment Import

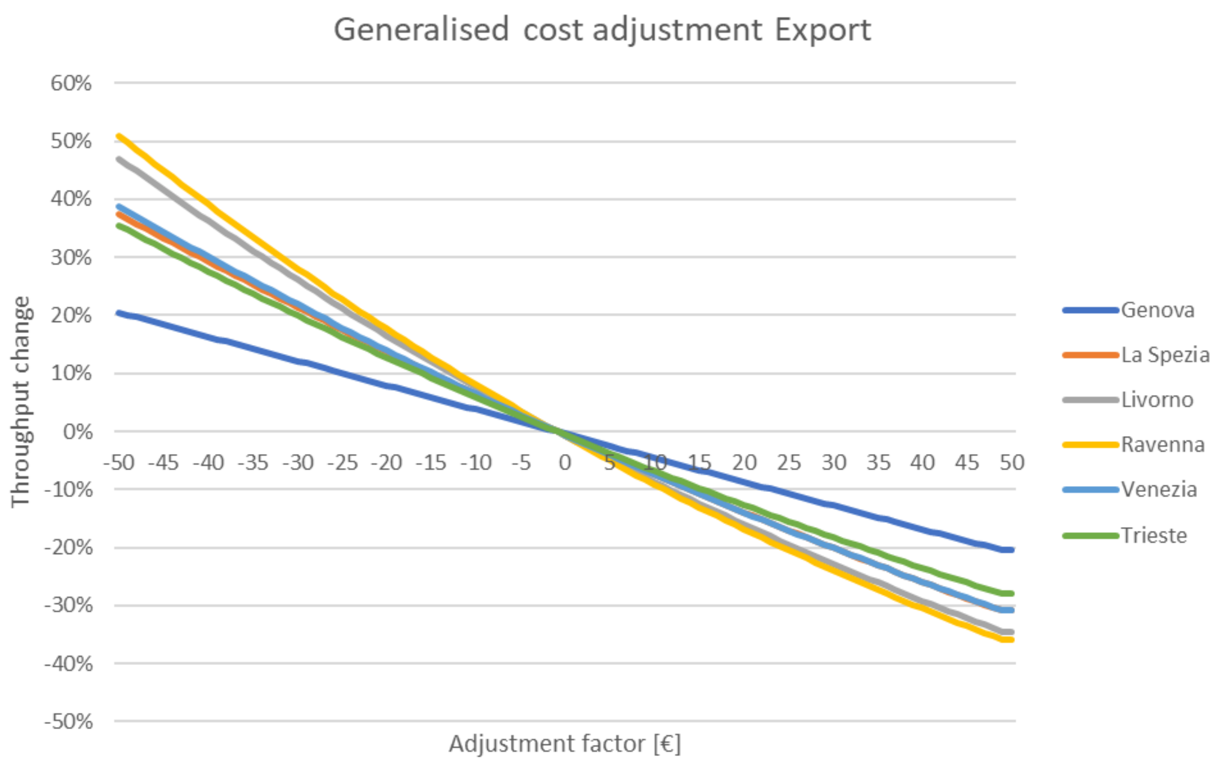


Figure 32: Sensitivity of Throughput to GC adjustment Import

The reaction of the throughput for all the ports is relatively higher for a negative adjustment than to a positive correction. Every port has a different interaction with neighbouring ports that result in different sensitivities to price changes.

The port of Ravenna is most sensitive to price changes regardless of the direction of containers going through the port. This can be explained by the fact that the port has a low market share in most of its key regions and a lot of competitors are active in those regions, with comparable price ranges. The difference of the reaction between a price increase and a decrease can be traced back to the market share size and the logit function. Due to the shape of the logit function price reductions have a greater effect on market shares smaller than 0.5 or 50% as the logit function slope increases up to 50% market share as described in section 3.4.1 and shown in Figure 15.

The figures shown above also show that the port of Genoa has a very strong position throughout as its throughput is the least sensitive to changes. The port has a very strong position in its key regions. There is no difference between a positive or a negative cost change in terms of the magnitude of the throughput change. This means that the weighted average market shares of the regions of Genoa is around 50%.

5.5.2 Scenario: Reduction of port costs Livorno

This section describes the scenario in which the generalised cost per container is reduced by 25€. This can be achieved by lowering the port dues by the port authority or the terminal handling costs by the terminals. It is also possible that he port improves on one of its non-monetary port competition factors such as productivity, however the extent of such improvement is not quantifiable using this model. In the model, this 25€ price change is included by reducing the cost of all transport chains going through the port of Livorno. From the performed sensitivity analyses the resulting throughput change is already clear, as this will result in increase in throughput close to 20% for both import and export. The regions in which this change origins are however unclear. Which ports are most affected by this new cost policy are identified. This implies that the ports most affected are also the main competitors of the port of Livorno.

The change of the throughput after the price reduction is shown in Table 13. This shows that the ports in the Ligurian sea, Genova and La Spezia are the competitors of Livorno. This is shown by the fact that 76% of the throughput increase of Livorno is captured from these two ports.

Table 13: Throughput changes after a price reduction for the port of Livorno

	Import change [TEU]	Import change [%]	Export change [TEU]	Export change
Genova	-16375	-2%	-20346	-2%
La Spezia	-13241	-4%	-20473	-3%
Livorno	39811	21%	53236	22%
Ravenna	-3307	-5%	-3966	-4%
Venezia	-3841	-3%	-6261	-2%
Trieste	-3047	-2%	-2190	-2%

The change of more than 20% seems to be large, however the cost sensitivity of the model is validated by comparing it to other studies as described in section 5.4. Therefor this reaction to a 25€ might seem large but with the fierce port competition that is present in the north of Italy, where 6 ports compete, it is not unrealistic.

In the previous section a relation between the starting market share and the change due to a cost difference was mentioned. It was stated that regions which a market share of around 0.5 react more sensitive to price changes due to the shape of the logit function, this holds for the case of Livorno as shown in Figure 33. However, the spread is significant due to the existence of a multitude of routes/logistic chains, which lead to differences in interactions between the chains.

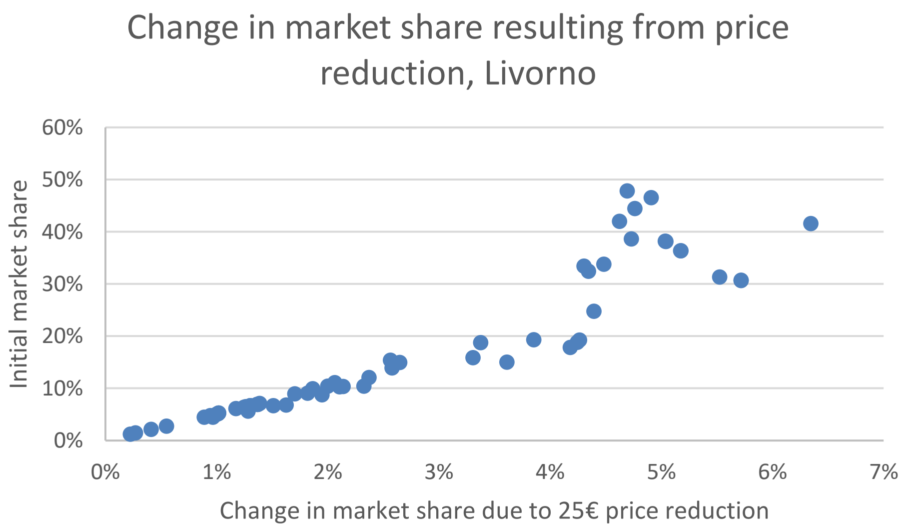


Figure 33: Change of market share vs initial market share, scenario of Livorno price reduction

5.6 CONCLUSION

This chapter described how a logistic chain model was developed in order to quantify the containers shipment destined for, or originated from the hinterland within the scope of this research. The model 'choses' a certain logistic chain based on its corresponding cost. The input for the model was determined in Chapter 4 and consists of the following:

- Trade data between the hinterland regions and all trade partners
- Average vessel size, average feeder size
- Modal split

It was determined to only include the road modality for the hinterland transport.

The first step of the model was to generate all the logistic chains. To include that part of the containers is transhipped from ship to ship a fixed transshipment port was set at the container port of Malta. For every trade partner, a total of 12 routes were determined using Searoutes (SeaRoutes 2019). This comes down to two options per port, a directly-shipped and a transhipped option at Malta. The routes from the ports to all the hinterland regions were also determined by implementing the Google maps API. For some trade-partners the road-direct route is also viable and these distances were also included.

Determining the logistic chain choice consists of two parts. First the fraction of shipments that use a maritime leg was determined. This is done by comparing the weighted average cost of all chains incorporating a maritime leg with the cost of a land direct transport. The cost scale factor and the maritime error coefficient were determined by calibrating on data from Eurostat with the 'least square' method.

For the maritime part of the logistic chains, the calibration of the cost scale factor proved to be give unsatisfactory results and instead the cost scale factor from the previous step was used which is in line with other studies. The port throughputs were calibrated by using a heuristic to alter the error term of the port specific cost function. The data was calibrated against were the actual throughput values for the ports for both import and export separately.

The output of the model are the market shares for the different ports regions within the scope as well as the amount of TEU equivalent units associated with those market shares. These are shown both in table form and in figures, which were programmed in Python. The regions are divided on NUTS-3 level for of the north of Italy and on a NUTS-0 level for Switzerland and Austria. The resulting hinterland shares from the model are in line with expert expectations from Royal HaskoningDHV and show comparable results to previous studies such as (Ferrari, Parola en Gattorna 2011) and internal studies performed by Royal HaskoningDHV.

A sensitivity analyses was performed. This quantified the competitiveness of the ports in the scope. The port of Genoa proved to be the most resilient to changes in price, it has a strong competitive position in its key regions due to a generalised cost advantage in those regions. The port of Ravenna is on the other end of the spectrum. It has a below average market share in its key regions and no obvious generalised cost advantage towards the competition. Chain using different ports have a comparable generalised cost and therefore the throughput proves very price sensitive.

A scenario was presented in which the port of Livorno implements a price reduction of 25€. The analysis of the results from the logistic chain model showed that the throughput increases with more than 20%. The output of the model also shows that the two other ports in the Ligurian sea, Genova and La Spezia are the main competitors of Livorno. This is shown by the fact that 76% of the throughput increase of Livorno is captured from these two ports.

6 CONCLUSION

6.1 GENERAL CONCLUSION

This study was conducted to assess the port competition within a bounded scope for the container shipping market. For this purpose, a logistic chain choice model was created that allows to assess the port competition based on the port hinterlands. In order to calibrate and prove the effectiveness of the model, a subject scope was chosen in the form of the North-Italian ports. The 6 largest ports are used and the port competitiveness of these ports is assessed.

From the literature study, it became clear that the competitive position of a port cannot be solely accounted for by the identifications of its competitive characteristics, the so-called port choice factors. To identify the competitive situation of the port, its position in the total logistic chain must be determined. This was done by creating a logistic chain choice model. For every trade partner of the hinterland of the ports, different logistic chains or routes can be chosen to import or export containers. This discrete choice is simulated by using a Multinomial Logit function that assigns the containers to the chains based on generalised cost. This model allows to identify the hinterland of the port for loaded containers. The market share of ports in key regions is an indicator of the competitiveness of the port. This market share is the result of the interaction between logistic chains and a large market share implies a lower generalised cost for that region.

From the literature study, it also became clear that the influence of the liner services in the shipping market is extensive. Only a limited number of large shipping companies exist and throughput numbers of ports are highly dependent on these companies. Therefor a dashboard was created that can be used to give an overview of the presence of the shipping companies in ports based on the deployed ship capacities. The dependency of a port on a single shipping line is an indicator for the competitiveness of the port. From the type of services in combination with throughput numbers and the ship size it can be identified what the port is used for and by which shipping company. In this research, this dashboard is used to determine the shape of the shipping network implemented in the Logistic chain model. Costs for the maritime part of the logistic chain are dependent on the average ship sizes of the ports, which also follows from the dashboard.

The Logistic chain choice model was created to assess the hinterlands of the ports. The hinterland is limited to the most important hinterland regions of the ports in the scope. This was identified as being the North of Italy, Switzerland and Austria. All bilateral trade of the countries is incorporated in the model. This trade is distributed over the 66 hinterland regions by using social-economic indicators for those regions. The north of Italy is divided into NUTS-3 regions, while Austria and Switzerland are kept on a country or NUTS-0 level. The hinterland transport was reduced to road only. For the maritime part of the logistic chain two options are incorporated, a direct-shipped approach as well as a transhipped approach which uses a fixed transshipment location.

Within the model the logistic chains are modelled based on their monetary cost. The model is calibrated on the actual throughputs using a port specific error term. Therefor all port competition factors are aggregated into the generalised cost function. This means that also non-monetary port competition factors are included implicitly in the model.

A sensitivity analysis was performed using the model. A port proved sensitive to price changes if the port doesn’t have a clear generalised cost advantage and/or multiple ports have a comparable generalised cost in its key hinterland regions. From this analysis resulted that the port of Genoa has the best competitive situation of the ports in the scope. It has a leading position in all its key regions, most importantly Milan. The port of Ravenna, the smallest port in terms of throughput, proved to be most sensitive to price adjustments and overall has the weakest competitive situation as it lacks market share in its key regions.

It can be concluded that the model allows to assess port competition. Using the model on the subject ports gives a clear image of the hinterland of those ports and the key regions for every port within that hinterland. The resulting hinterland shares from the model are in line with expectations from experts of Royal HaskoningDHV and show comparable results to previous academic studies and internal studies performed by Royal HaskoningDHV.
The dashboard allows for the identification of the largest actor responsible for port throughput and the logistic chain model determines the drivers behind the shipments by identifying the hinterland.

The model developed in this study is a stand-alone solution that doesn't rely on extensive black-box models as often found in related literature. The model can be adapted to other scopes with relative ease and outputs are presented in an accessible manner. This could make it worthwhile for Royal HaskoningDHV to implement it in their business process to use on future studies related to port competition.

6.2 DISCUSSION AND RECOMMENDATIONS

As the whole logistic chain model was built from the ground up, the lead time of this research became a factor. A concession was made in the form of creating a static model based on data only from 2017. If developed further the model can be also used to analyse time series.

The logistic chain model can be used to analyse the port competition statically by analysing its hinterland as well as its sensitivity as described above. Due to its generic nature, the logistic chain choice model could also serve as a base model for different scenario analyses. Scenarios could include the change of ship-size, (oil) price or cost scenario's and future throughput forecasts.

6.2.1 Limitations

It should be noted that every model is an approximation of the real world that is made under several assumptions. To keep the model workable some simplifications were incorporated. The following limitations should be kept in mind while using the model developed in this research:

- The calibration of the maritime part of the logistic chains proved to be problematic, therefor a cost scale factor was used from literature on the subject. The results from the model proved to be in line with expectations.
- For the hinterland transport only road is taken into account and it is assumed that the shipments using the rail-modality are destined beyond the hinterland scope of the research.
- The bounded hinterland is used as an estimation for the hinterland of the ports. This inevitable introduces errors into the model.
- Using a bounded hinterland only allows to assess the competitive situation of the ports regarding the other ports in the scope.
- To establish the amount of trade of Austria and Switzerland going through Italian ports, a creative solution was used that combines two incomplete sources. The bill of lading of the import for the US was analysed as well as the data on the Austrian import and export via Italian ports.

6.2.2 Further research logistic chain model

In this research, the origin destination matrix is created by combining data from UNComtrade on the bilateral trades in tonnes with Eurostat data that allows to calculate the stowage factors and containerisation rate. This results in the amount of TEU that the countries can trade. Next the fraction of flows that use the maritime option versus the land direct route is estimated based on Eurostat data. This requires several steps. However, there is also data available from Eurostat that states the number of TEU from port to port on a country level. From this data, it cannot be deducted where the trade originated and therefor it wasn't used in this research. Future research could try to establish if this can be used as valid input for this model as it would bypass some steps. Because of characteristic of the logit function, only the absolute differences between options is of effect. If the amount of TEU that is transported by sea is known, all costs that are the similar for each chain can be omitted. For the scope of the north of Italy this means that the logistic chains can start at the entrances to the Mediterranean Sea, as the routes and the corresponding costs only start differentiating there.

The calibration of the cost scale factor proved to be problematic. To validate cost scale factors for this model it can be calibrated onto a scope of which OD-data is available. It should be however kept in mind that the cost scale factor is expected to vary to some extent between scopes. Spain might be a valid candidate as Spanish customs agency provides OD-data and Spain is located close to Italy.

The model now only incorporates the road-only hinterland transport. For future situations where the share of rail or barge is higher it is advised to implement these modalities into the model. Also, capacity constrains could be implemented to model congestion, for both the hinterland and the maritime part.

To incorporate the value of time in the model more research into this area is required. The way it can be implemented is also debatable. Every type of goods has a different value of time, which means that every trade flow should be analysed on the good-types it contains. Very elaborate nomenclature should be established that can be used for this purpose. Also, average values can be used, but as shown in the literature study, no consensus exists on how the value of time is defined and proposed values differ greatly.

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APPENDIX A

NUTS-3 Regions code nomenclature, source: Eurostat, altered to include ports

Appendix B

Bilateral trade of Countries within scope.

The following table lists the bilateral trade of Italy, Austria and Switzerland.

Table 14: Italian bilateral trade top 10 partners for import and export by weight, 2017. Source: UNComtrade

Italy import			Italy export		
Partner country	**Bilateral trade in kiloton**	**% of total**	**Partner country**	**Bilateral trade in kiloton**	**% of total**
Russia	41036	12.93%	Germany	18433.56855	12.27%
Germany	22774	7.18%	France	17974.64189	11.97%
Algeria	17258	5.44%	Spain	10781.8308	7.18%
France	16471	5.19%	USA	7089.255688	4.72%
Azerbaijan	12286	3.87%	UK	5774.895464	3.84%
Austria	10858	3.42%	Switzerland	4919.012237	3.27%
Iran	10236	3.23%	Austria	4864.00288	3.24%
Spain	9730	3.07%	Turkey	4434.685062	2.95%
USA	9151	2.88%	Netherlands	4392.017855	2.92%
Libya	9060	2.85%	Poland	3618.294896	2.41%

Table 15: Austrian bilateral trade top 10 partners for import and export by weight, 2017. Source: UNComtrade

Austria import			Austria export		
Partner country	**Bilateral trade in kiloton**	**% of total**	**Partner country**	**Bilateral trade in kiloton**	**% of total**
Germany	25455	32.53%	Germany	17394	31.68%
Czechia	8412	10.75%	Italy	9294	16.93%
Hungary	5235	6.69%	Slovenia	2975	5.42%
Italy	4751	6.07%	Switzerland	2908	5.30%
Slovakia	4745	6.06%	Hungary	2804	5.11%
Poland	3323	4.25%	Czechia	2683	4.89%
Slovenia	3152	4.03%	Slovakia	1772	3.23%
Kazakhstan	2398	3.06%	Poland	1722	3.14%
Netherlands	1597	2.04%	France	1276	2.32%
Russia	1569	2.01%	USA	1148	2.09%

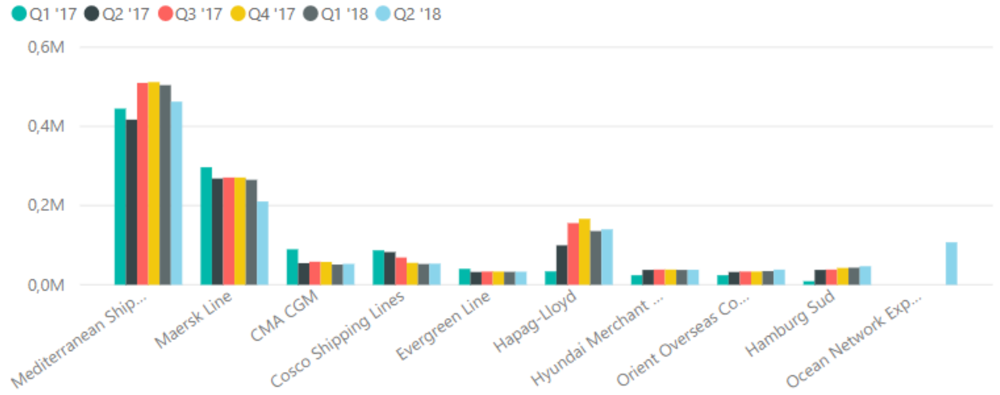
Table 16: Swiss bilateral trade top 10 partners for import and export by weight, 2017. Source: UNComtrade

Switzerland import			Switzerland export		
Partner country	**Bilateral trade in kiloton**	**% of total**	**Partner country**	**Bilateral trade in kiloton**	**% of total**
Germany	20641	40.07%	Germany	5645	29.66%
France	8693	16.88%	France	4774	25.09%
Italy	6125	11.89%	Italy	2501	13.14%
Austria	2842	5.52%	Austria	1165	6.12%
Netherlands	1703	3.31%	USA	626	3.29%
Belgium	1675	3.25%	Netherlands	467	2.45%
Nigeria	1286	2.50%	UK	343	1.80%
Kazakhstan	995	1.93%	Belgium	272	1.43%
China	833	1.62%	Poland	259	1.36%
Spain	684	1.33%	China	249	1.31%

APPENDIX C

Dashboards liner services analysis

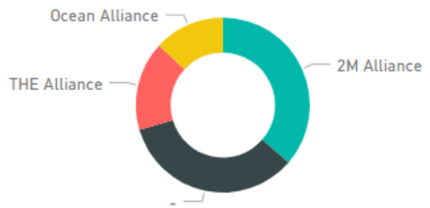
2M Alliance	539.614,29	556.346,57	562.540,57	562.540,57	550.311,43	459.146,46
-	459.922,57	395.427,81	457.011,43	445.798,36	404.231,70	429.240,24
THE Alliance	0,00	225.455,29	195.961,14	180.449,14	179.832,86	208.380,11
Ocean Alliance	0,00	161.522,29	166.966,86	166.966,86	163.337,14	165.152,00
CKYHE Alliance	125.083,14	0,00	0,00	0,00	0,00	0,00
G6 Alliance	160.632,29	0,00	0,00	0,00	0,00	0,00
Ocean Three Alliance	180.542,86	0,00	0,00	0,00	0,00	0,00
Totaal	**1.465.795,14**	**1.338.751,95**	**1.382.480,00**	**1.355.754,93**	**1.297.713,13**	**1.261.918,81**



Container liner capacity deployed, filtered for > 100,000 TEU

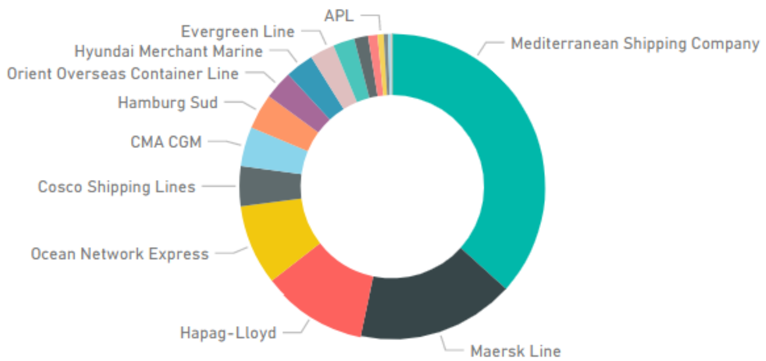
VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
Mediterranean Shipping Company	444.953,57	417.141,84	509.938,91	511.919,34	504.208,57	462.560,29
Maersk Line	296.787,86	268.403,50	270.978,11	270.978,11	265.087,29	210.417,37
Hapag-Lloyd	33.752,97	99.608,28	155.743,92	166.557,09	135.663,30	140.081,74
Ocean Network Express	0,00	0,00	0,00	0,00	0,00	107.213,27
Totaal	**775.494,40**	**785.153,62**	**936.660,95**	**949.454,54**	**904.959,16**	**920.272,67**

Share of Alliance, for 2nd Quarter 2018



La Spezia

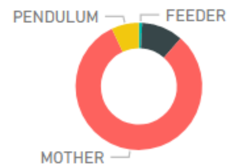
Share of Companies, for 2nd Quarter 2018



Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
MOTHER	1.029.112,36	81,55%
INTRA_REGIONAL	133.718,29	10,60%
PENDULUM	88.491,00	7,01%
FEEDER	10.597,17	0,84%
Totaal	**1.261.918,81**	**100,00%**

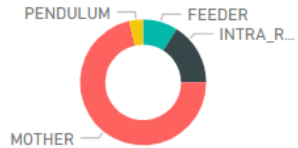
Capacity per service type



Amount of lines per service type

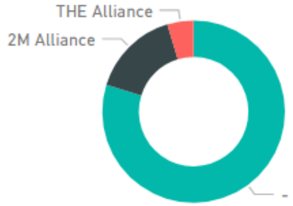
Service type	Totaal van Service type	% van eindtotaal voor Totaal van Service type
MOTHER	40	71,43%
INTRA_REGIONAL	9	16,07%
FEEDER	5	8,93%
PENDULUM	2	3,57%
Totaal	**56**	**100,00%**

Amount of lines per service type



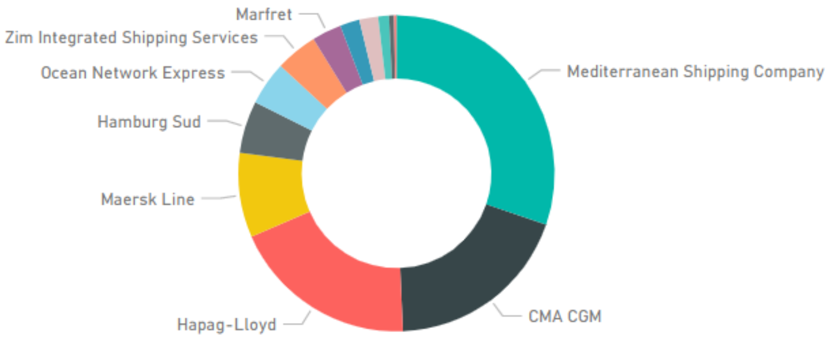
Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
-	589.248,30	437.204,75	494.653,31	481.458,84	513.084,14	451.724,29
2M Alliance	87.094,29	88.062,00	89.029,71	89.029,71	87.094,29	88.062,00
THE Alliance	0,00	55.605,14	16.810,86	0,00	0,00	26.380,11
Ocean Alliance	2.092,71	63.479,00	64.176,57	2.092,71	0,00	0,00
Totaal	**678.435,30**	**644.350,89**	**664.670,45**	**572.581,27**	**600.178,43**	**566.166,40**

Share of Alliance, for 2nd Quarter 2018

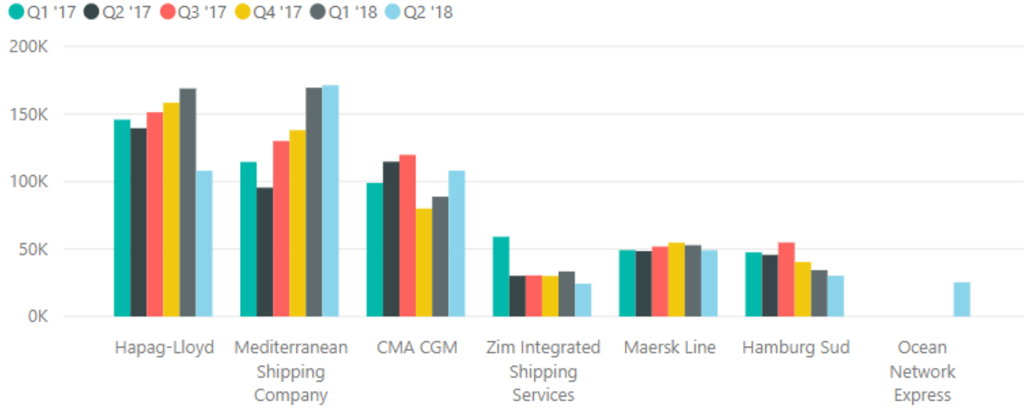


Livorno

Share of Companies, for 2nd Quarter 2018



Container liner capacity deployed, filtered for > 20,000 TEU



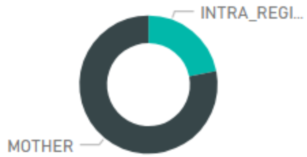
Container liner capacity deployed, filtered for > 20,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
Mediterranean Shipping Company	114.498,31	95.462,90	129.964,09	138.019,51	169.461,00	140.664,29
CMA CGM	78.410,57	99.404,09	96.913,69	63.960,47	73.878,43	96.795,33
Hapag-Lloyd	121.458,89	111.276,74	140.403,26	150.397,97	168.897,86	84.434,81
Maersk Line	47.901,86	48.434,10	48.966,34	48.966,34	47.901,86	31.934,57
Hamburg Sud	26.828,36	27.414,71	27.773,49	27.773,49	27.169,71	25.358,40
Ocean Network Express	0,00	0,00	0,00	0,00	0,00	24.440,40
Totaal	**389.097,99**	**381.992,53**	**444.020,86**	**429.117,79**	**487.308,86**	**403.627,80**

Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
MOTHER	442.286,83	78,12%
INTRA_REGIONAL	123.879,57	21,88%
Totaal	**566.166,40**	**100,00%**

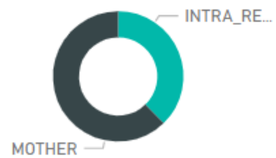
Capacity per service type



Amount of lines per service type

Service type	Totaal van Service type	% van eindtotaal voor Totaal van Service type
MOTHER	33	62,26%
INTRA_REGIONAL	20	37,74%
Totaal	**53**	**100,00%**

Amount of lines per service type

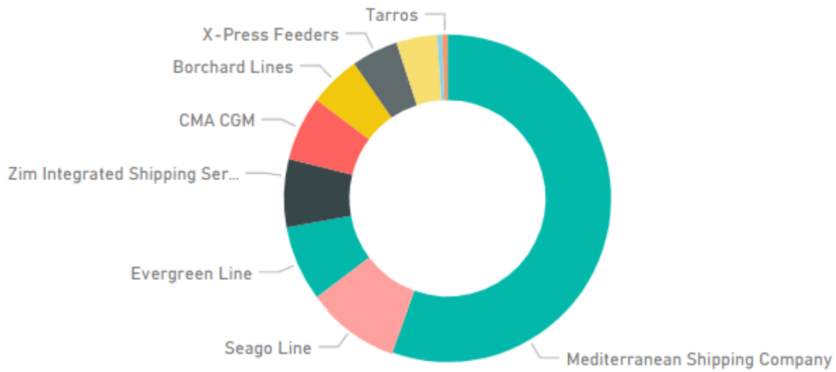


Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
-	151.760,29	197.165,00	202.550,57	202.807,43	191.240,00	196.331,57
Totaal	**151.760,29**	**197.165,00**	**202.550,57**	**202.807,43**	**191.240,00**	**196.331,57**

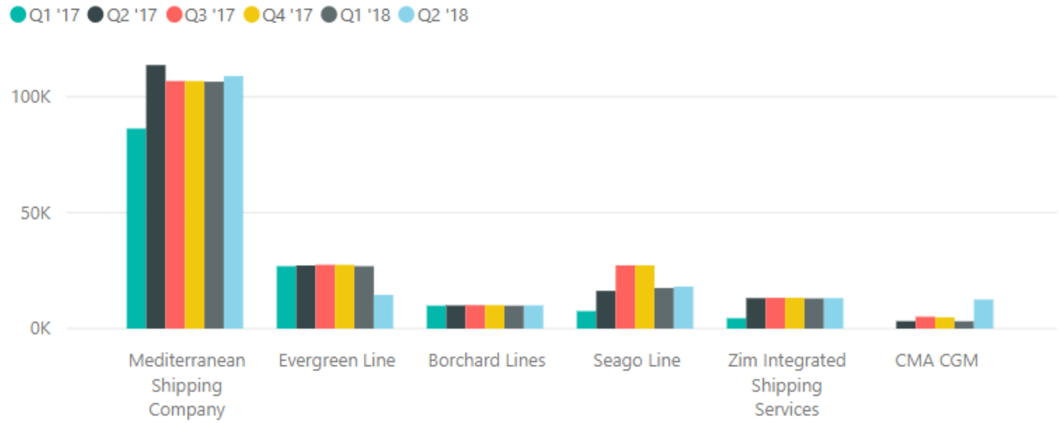
Q2 '18 per Alliance name

Ravenna

Share of Companies, for 2nd Quarter 2018



Container liner capacity deployed, filtered for > 10,000 TEU



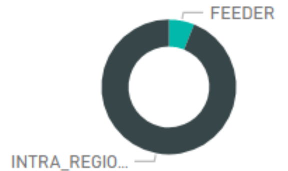
Container liner capacity deployed, filtered for > 30,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
Mediterranean Shipping Company	86.310,00	113.709,89	106.827,77	106.827,77	106.535,14	108.964,70
Seago Line	7.547,14	16.284,11	27.308,23	27.308,23	17.526,29	18.136,30
Evergreen Line	26.935,71	27.235,00	27.534,29	27.534,29	26.935,71	14.579,00
Zim Integrated Shipping Services	4.481,71	13.156,00	13.300,57	13.300,57	13.011,43	13.156,00
CMA CGM	0,00	3.224,00	5.149,77	4.868,11	3.174,86	12.531,50
Borchard Lines	9.900,00	10.010,00	10.120,00	10.120,00	9.900,00	10.010,00
Totaal	**135.174,57**	**183.619,00**	**190.240,63**	**189.958,97**	**177.083,43**	**177.377,50**

Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
INTRA_REGIONAL	184.293,57	93,87%
FEEDER	12.038,00	6,13%
Totaal	**196.331,57**	**100,00%**

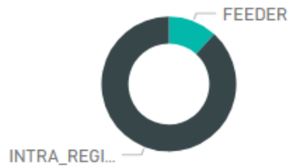
Capacity per service type



Amount of lines per service type

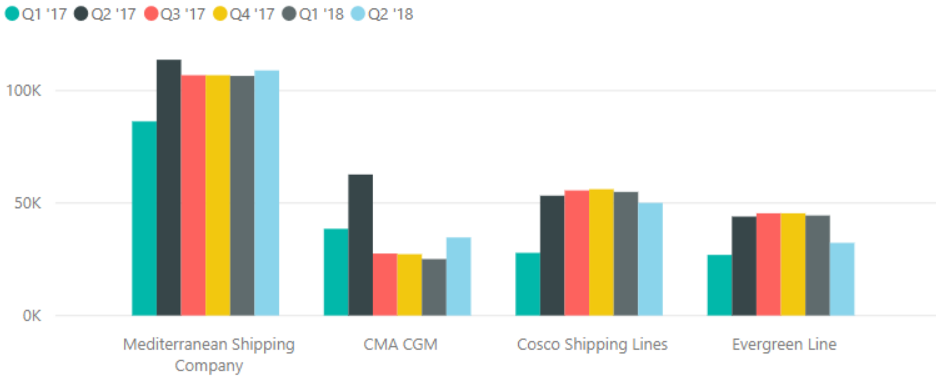
Service type	Alliance name	% van eindtotaal voor Totaal van Service type
INTRA_REGIONAL	-	88,24%
FEEDER	-	11,76%
Totaal		**100,00%**

Amount of lines per service type

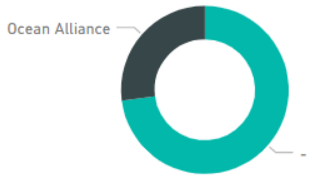


Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
-	250.696,00	296.771,86	256.442,76	246.156,51	233.646,71	239.364,76
Ocean Alliance	0,00	83.751,71	89.594,86	89.594,86	87.647,14	88.621,00
Totaal	**250.696,00**	**380.523,57**	**346.037,61**	**335.751,37**	**321.293,86**	**327.985,76**

Container liner capacity deployed, filtered for > 20,000 TEU



Share of Alliance, for 2nd Quarter 2018

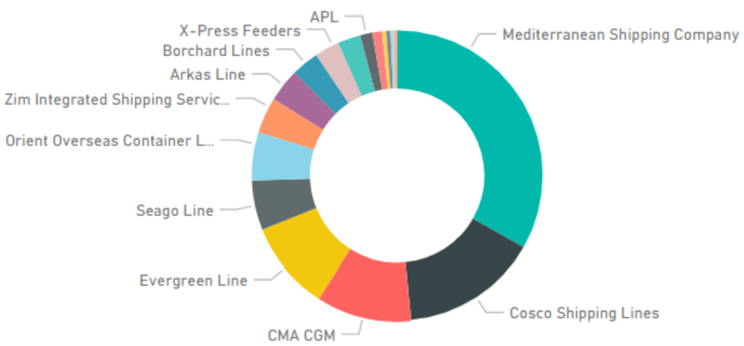


Venice

Container liner capacity deployed, filtered for > 20,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
CMA CGM	38.532,86	62.694,79	27.548,49	27.266,83	25.086,64	34.686,75
Cosco Shipping Lines	27.848,57	53.283,51	55.611,60	56.160,74	54.939,86	50.064,30
Evergreen Line	26.935,71	43.985,34	45.453,26	45.453,26	44.465,14	32.303,20
Mediterranean Shipping Company	86.310,00	113.709,89	106.827,77	106.827,77	106.535,14	108.964,70
Totaal	**179.627,14**	**273.673,53**	**235.441,11**	**235.708,60**	**231.026,79**	**226.018,95**

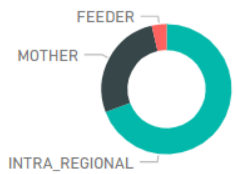
Share of Companies, for 2nd Quarter 2018



Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
FEEDER	12.038,00	3,67%
MOTHER	88.621,00	27,02%
INTRA_REGIONAL	227.326,76	69,31%
Totaal	**327.985,76**	**100,00%**

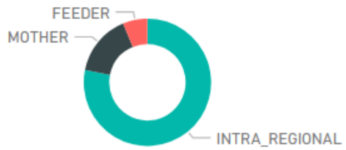
Capacity per service type



Amount of lines per service type

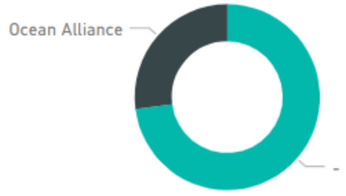
Service type	Service type	% van eindtotaal voor Totaal van Service type
INTRA_REGIONAL	INTRA_REGIONAL	78,13%
MOTHER	MOTHER	15,63%
FEEDER	FEEDER	6,25%
Totaal		**100,00%**

Amount of lines per service type



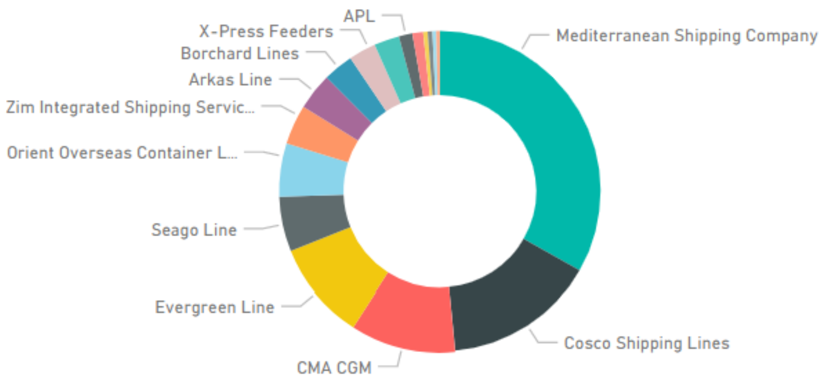
Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
-	250.696,00	296.771,86	256.442,76	246.156,51	233.646,71	239.364,76
Ocean Alliance	0,00	83.751,71	89.594,86	89.594,86	87.647,14	88.621,00
Totaal	**250.696,00**	**380.523,57**	**346.037,61**	**335.751,37**	**321.293,86**	**327.985,76**

Share of Alliance, for 2nd Quarter 2018

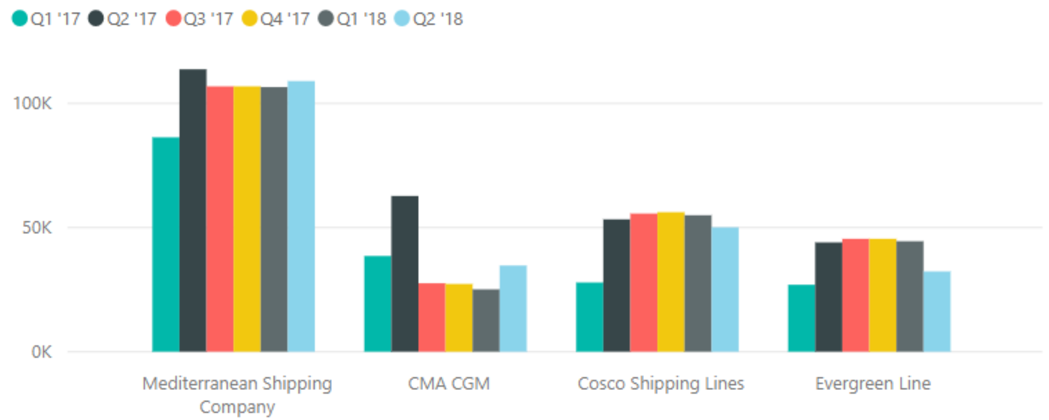


Venice

Share of Companies, for 2nd Quarter 2018



Container liner capacity deployed, filtered for > 20,000 TEU



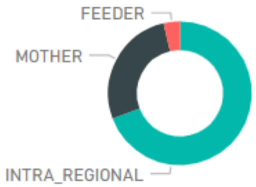
Container liner capacity deployed, filtered for > 20,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
CMA CGM	38.532,86	62.694,79	27.548,49	27.266,83	25.086,64	34.686,75
Cosco Shipping Lines	27.848,57	53.283,51	55.611,60	56.160,74	54.939,86	50.064,30
Evergreen Line	26.935,71	43.985,34	45.453,26	45.453,26	44.465,14	32.303,20
Mediterranean Shipping Company	86.310,00	113.709,89	106.827,77	106.827,77	106.535,14	108.964,70
Totaal	**179.627,14**	**273.673,53**	**235.441,11**	**235.708,60**	**231.026,79**	**226.018,95**

Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
FEEDER	12.038,00	3,67%
MOTHER	88.621,00	27,02%
INTRA_REGIONAL	227.326,76	69,31%
Totaal	**327.985,76**	**100,00%**

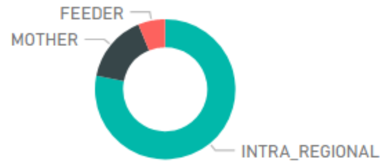
Capacity per service type



Amount of lines per service type

Service type	Service type	% van eindtotaal voor Totaal van Service type
INTRA_REGIONAL	INTRA_REGIONAL	78,13%
MOTHER	MOTHER	15,63%
FEEDER	FEEDER	6,25%
Totaal		**100,00%**

Amount of lines per service type



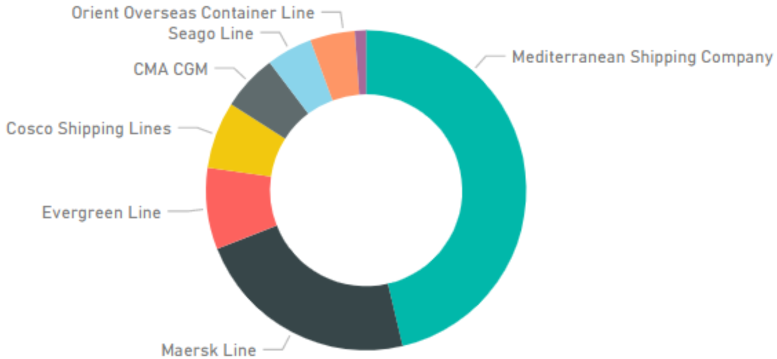
V

Alliance name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
2M Alliance	128.725,71	146.107,00	159.746,86	163.089,71	159.544,29	161.317,00
-	126.205,71	137.731,29	121.978,86	121.978,86	145.571,43	141.680,00
Ocean Alliance	0,00	83.751,71	89.594,86	89.594,86	87.647,14	88.621,00
Ocean Three Alliance	123.428,57	0,00	0,00	0,00	0,00	0,00
Totaal	**378.360,00**	**367.590,00**	**371.320,57**	**374.663,43**	**392.762,86**	**391.618,00**

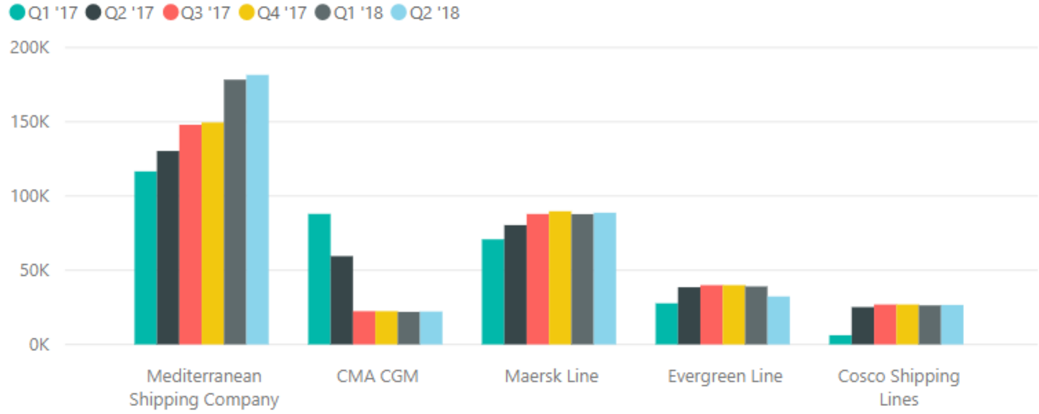
Share of Alliance, for 2nd Quarter 2018

Trieste

Share of Companies, for 2nd Quarter 2018



Container liner capacity deployed, filtered for > 20,000 TEU



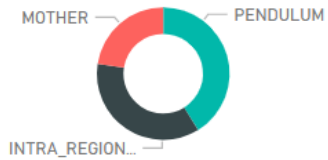
Container liner capacity deployed, filtered for > 20,000 TEU

VSA - company name	Q1 '17	Q2 '17	Q3 '17	Q4 '17	Q1 '18	Q2 '18
Mediterranean Shipping Company	116.542,29	130.290,86	147.983,23	149.487,51	178.330,07	181.557,35
Maersk Line	70.799,14	80.358,85	87.860,77	89.699,34	87.749,36	88.724,35
Evergreen Line	27.681,43	38.499,34	39.906,97	39.906,97	39.039,43	32.303,20
Cosco Shipping Lines	6.171,43	25.125,51	26.878,46	26.878,46	26.294,14	26.586,30
CMA CGM	87.904,29	59.470,79	22.398,71	22.398,71	21.911,79	22.155,25
Totaal	**309.098,57**	**333.745,36**	**325.028,14**	**328.371,00**	**353.324,79**	**351.326,45**

Capacity per service type

Service type	Q2 '18	% van eindtotaal voor Q2 '18
PENDULUM	161.317,00	41,19%
INTRA_REGIONAL	141.680,00	36,18%
MOTHER	88.621,00	22,63%
Totaal	**391.618,00**	**100,00%**

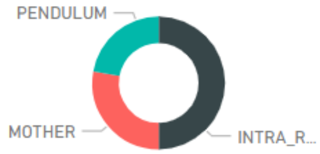
Capacity per service type



Amount of lines per service type

Service type	Totaal van Service type	% van eindtotaal voor Totaal van Service type
INTRA_REGIONAL	9	50,00%
MOTHER	5	27,78%
PENDULUM	4	22,22%
Totaal	**18**	**100,00%**

Amount of lines per service type



APPENDIX D

Specific Fuel Consumption table; Maritime costs

Speed [kn]	1000 TEU	2000 TEU	2500 TEU	3000 TEU	3500 TEU	4500 TEU	4800 TEU	6800 TEU	8500 TEU	10800 TEU	12500 TEU	13000 TEU	14500 TEU	18000 TEU	20000 TEU	22000 TEU
12.00	6	7	8	9	10	12	14	17	21	24	28	27	33	40	43	47
13.00	7	9	10	11	12	15	17	20	25	29	33	32	39	48	51	56
14.00	8	11	12	13	15	18	20	24	30	34	40	38	46	57	61	67
15.00	9	13	14	16	17	21	23	28	35	40	47	45	54	68	72	78
16.00	13	18	20	22	25	29	33	40	49	56	66	63	77	96	101	111
17.00	16	21	24	27	30	35	40	48	59	68	79	76	92	115	122	133
18.00	19	25	29	32	35	42	47	57	70	80	94	90	110	136	144	158
19.00	22	30	34	37	41	49	55	67	82	95	110	106	129	160	170	186
20.00	26	35	39	44	48	57	64	78	96	110	129	124	151	187	198	216
21.00	31	41	47	52	57	68	75	91	114	131	151	147	174	216	231	252
22.00	36	48	54	60	66	78	86	104	131	153	175	173	200	249	267	291
23.00	41	55	62	69	76	90	98	119	150	177	201	204	229	284	307	335
24.00	47	63	71	79	87	103	111	136	170	205	230	239	260	323	352	384
25.00	54	72	81	90	99	117	126	153	192	235	262	277	294	365	400	437
26.00	61	81	92	102	112	133	142	172	216	268	297	317	331	411	452	494

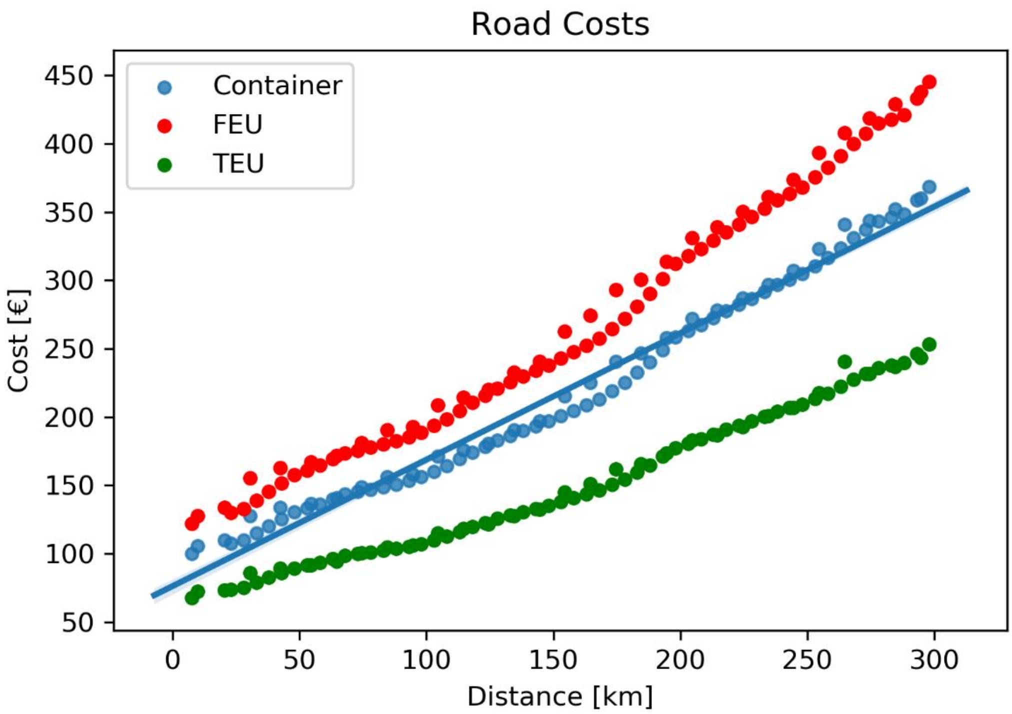
Source: Royal HaskoningDHV

Ship size	1000TEU	2000TEU	2500TEU	3000TEU	3500TEU	4500TEU	6800TEU	8500TEU	10800TEU	12500TEU	14500TEU	18000TEU	20000TEU	22000TEU
Slots	800	1600	2000	2400	2800	3600	5440	6800	8640	10000	11600	14400	16000	17600
Capital Costs														
Newbuild Price - mUS$	16	22	26	29	33	43	60	83	94	109	120	145	158	133
Daily Capital Charge - $	6720	8987	10527	12066	13605	17728	24736	34218	38753	44937	49472	59779	65139	54832
Operating Costs														
Manning - US$/day	3100	3200	3350	3500	3650	3650	3650	3650	3650	3650	3800	4100	4097	4179
Repair & Maintenance - US$/day	1000	1096	1253	1411	1568	1734	2456	2903	3238	3573	3948	4353	5082	5508
Insurance - US$/day	600	655	748	842	936	1035	1466	1733	1933	2133	2350	3100	3274	3559
Admin/Other Charges - US$/day	900	1000	1033	1067	1100	1100	1200	1200	1200	1300	1475	1650	1646	1719
Total operating costs - US$	5600	5951	6385	6819	7253	7519	8773	9486	10021	10656	11573	13203	14100	14965
Fuel cost														
IFO - US$/tonne	350	350	350	350	350	350	350	350	350	350	350	350	350	350
MDO - US$/tonne	532	532	532	532	532	532	532	532	532	532	532	532	532	532
Consumption at sea														
Speed (knots)	13	13	13	13	13	13	14	14	14	14	14	14	14	14
IFO - tonnes/day	6.6	9.0	10.1	11.3	12.5	14.9	24.1	29.6	33.9	39.6	46.3	57.5	61.0	66.5
MDO - tonnes/day	2.0	2.0	2.2	2.3	2.5	2.5	2.8	2.8	3.0	3.2	3.2	3.2	3.2	3.2
Fuel costs at sea - US$/day	3378	4203	4703	5204	5705	6529	9933	11834	13470	15568	17911	21818	23037	24994
Consumption In port														
IFO - tonnes/day	0.7	0.9	1.0	1.1	1.2	1.5	2.4	3.0	3.4	4.0	4.6	5.7	6.1	6.7
MDO - tonnes/day	2.0	2.0	2.2	2.3	2.5	2.5	2.8	2.8	3.0	3.2	3.2	3.2	3.2	3.2
Fuel costs in port - US$/day	1295	1378	1508	1638	1767	1850	2334	2524	2783	3089	3323	3714	3836	4032
Total														
Total cost at sea - US$/day	15698	19141	21615	24089	26563	31775	43442	55538	62244	71161	78956	94801	102275	94791
Total cost at port - US$/day	13615	16316	18419	20523	22626	27096	35843	46228	51557	58682	64369	76696	83074	73829
Total per slot														
Total cost at sea - US$/slot]	**19.62**	**11.96**	**10.81**	**10.04**	**9.49**	**8.83**	**7.99**	**8.17**	**7.20**	**7.12**	**6.81**	**6.58**	**6.39**	**5.39**
Total cost at port - US$/slot]	**17.02**	**10.20**	**9.21**	**8.55**	**8.08**	**7.53**	**6.59**	**6.80**	**5.97**	**5.87**	**5.55**	**5.33**	**5.19**	**4.19**

Source: Royal HaskoningDHV

APPENDIX E

Road costs



OLS Regression Results

Dep. Variable:	Cost	R-squared:	0.983
Model:	OLS	Adj. R-squared:	0.983
Method:	Least Squares	F-statistic:	4814.
Date:	Thu, 4 Apr 2019	Prob (F-statistic):	6.04e-76
Time:	15:46:41	Log-Likelihood:	-321.59
No. Observations:	86	AIC:	647.2
Df Residuals:	84	BIC:	652.1
Df Model:	1		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	76.2211	2.366	32.214	0.000	71.516	80.926
Distance	0.9260	0.013	69.383	0.000	0.899	0.953

Omnibus:	3.627	Jarque-Bera (JB):	1.968
Prob(Omnibus):	0.163	Prob(JB):	0.374
Skew:	-0.008		
Kurtosis:	2.259		

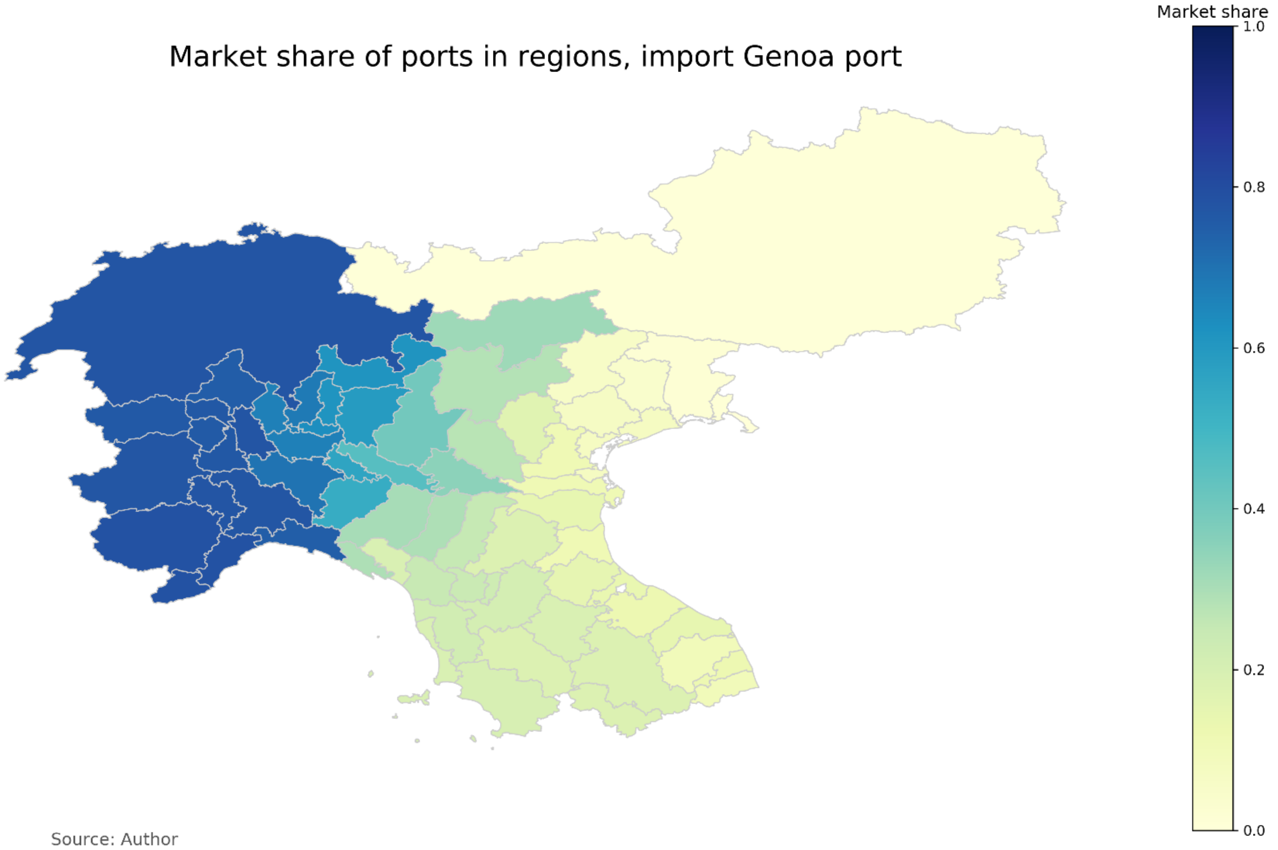
APPENDIX F

Results model: Market shares of ports in scope

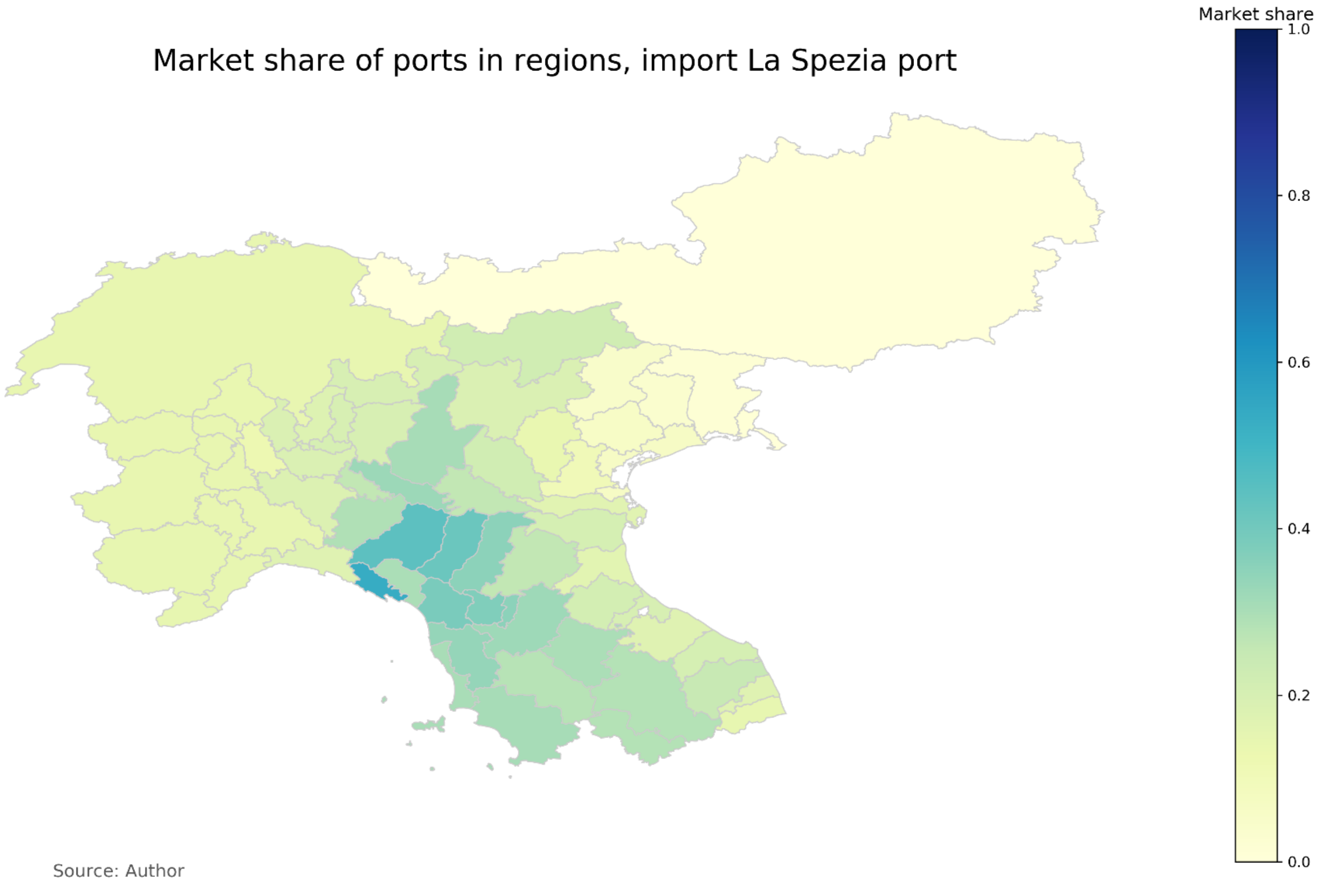
Import		Port							
Code	Region	Genoa	La Spezia	Livorno	Ravenna	Venice	Trieste	Total TEU region	
AT00	Austria	2%	2%	1%	2%	10%	84%	11323	0.75%
CH00	Switzerland	78%	15%	5%	0%	1%	1%	63723	4.21%
ITC11	Torino	77%	15%	5%	1%	1%	1%	85865	5.68%
ITC12	Vercelli	77%	15%	5%	1%	1%	1%	5418	0.36%
ITC13	Biella	76%	15%	5%	1%	2%	1%	5310	0.35%
ITC14	Verbano-Cusio-Ossola	75%	15%	5%	1%	2%	2%	4187	0.28%
ITC15	Novara	78%	13%	4%	1%	2%	1%	12641	0.84%
ITC16	Cuneo	78%	15%	5%	0%	0%	0%	22717	1.50%
ITC17	Asti	77%	15%	5%	1%	1%	1%	6315	0.42%
ITC18	Alessandria	77%	15%	5%	1%	1%	1%	13981	0.92%
ITC20	Valle d'Aosta/Vallée d'Aoste	76%	15%	5%	1%	2%	1%	5284	0.35%
ITC31	Imperia	79%	16%	5%	0%	0%	0%	6101	0.40%
ITC32	Savona	79%	15%	5%	0%	0%	0%	9529	0.63%
ITC33	Genova	75%	18%	6%	0%	0%	0%	38912	2.57%
ITC34	La Spezia	30%	53%	15%	1%	0%	0%	8909	0.59%
ITC41	Varese	66%	20%	7%	2%	4%	2%	29686	1.96%
ITC42	Como	68%	19%	6%	1%	3%	2%	18984	1.26%
ITC43	Lecco	62%	20%	7%	2%	6%	4%	11848	0.78%
ITC44	Sondrio	62%	20%	7%	2%	6%	4%	6065	0.40%
ITC46	Bergamo	59%	20%	7%	2%	7%	4%	41761	2.76%
ITC47	Brescia	40%	31%	10%	2%	10%	6%	49449	3.27%
ITC48	Pavia	70%	19%	6%	1%	2%	1%	14691	0.97%
ITC49	Lodi	56%	26%	9%	2%	4%	2%	6899	0.46%
ITC4A	Cremona	46%	33%	11%	3%	5%	3%	12897	0.85%
ITC4B	Mantova	36%	26%	12%	5%	13%	8%	15288	1.01%
ITC4C	Milano	67%	20%	7%	2%	3%	2%	241983	16.00%
ITC4D	Monza e della Brianza	63%	21%	7%	2%	5%	3%	30312	2.00%
ITH10	Bolzano-Bozen	33%	22%	10%	5%	19%	11%	28713	1.90%
ITH20	Trento	29%	20%	9%	4%	17%	22%	23390	1.55%
ITH31	Verona	28%	22%	10%	5%	22%	13%	37547	2.48%
ITH32	Vicenza	18%	14%	9%	6%	33%	20%	35400	2.34%
ITH33	Belluno	7%	6%	6%	7%	35%	40%	8693	0.57%
ITH34	Treviso	8%	7%	7%	4%	39%	35%	36102	2.39%
ITH35	Venezia	8%	7%	7%	8%	43%	27%	34199	2.26%
ITH36	Padova	12%	11%	10%	7%	37%	22%	39870	2.64%
ITH37	Rovigo	12%	17%	16%	11%	28%	17%	7225	0.48%
ITH41	Pordenone	5%	5%	4%	5%	28%	52%	12117	0.80%
ITH42	Udine	3%	3%	3%	3%	18%	70%	20788	1.37%
ITH43	Gorizia	3%	2%	2%	2%	14%	77%	5061	0.33%
ITH44	Trieste	1%	1%	1%	1%	8%	87%	11677	0.77%
ITH51	Piacenza	53%	29%	10%	2%	3%	2%	10948	0.72%
ITH52	Parma	31%	44%	15%	4%	4%	2%	20847	1.38%
ITH53	Reggio nell'Emilia	30%	41%	14%	6%	6%	3%	23577	1.56%
ITH54	Modena	26%	35%	19%	8%	8%	5%	34759	2.30%
ITH55	Bologna	19%	26%	25%	13%	11%	7%	53831	3.56%
ITH56	Ferrara	15%	21%	19%	14%	19%	12%	11204	0.74%
ITH57	Ravenna	12%	16%	15%	32%	16%	10%	16533	1.09%
ITH58	Forlì-Cesena	15%	21%	19%	30%	9%	6%	16262	1.08%
ITH59	Rimini	14%	19%	18%	36%	8%	5%	12860	0.85%
ITI11	Massa-Carrara	20%	29%	38%	8%	3%	2%	5824	0.39%
ITI12	Lucca	26%	38%	33%	1%	1%	1%	14116	0.93%
ITI13	Pistoia	25%	37%	32%	2%	2%	1%	9622	0.64%
ITI14	Firenze	22%	32%	39%	3%	3%	2%	52070	3.44%
ITI15	Prato	24%	35%	34%	3%	3%	2%	10261	0.68%
ITI16	Livorno	20%	30%	48%	1%	1%	1%	11910	0.79%
ITI17	Pisa	22%	33%	42%	1%	1%	1%	17461	1.15%
ITI18	Arezzo	20%	29%	38%	8%	3%	2%	11885	0.79%
ITI19	Siena	19%	28%	46%	3%	3%	2%	11443	0.76%
ITI1A	Grosseto	21%	31%	44%	2%	2%	1%	6919	0.46%
ITI21	Perugia	19%	28%	36%	12%	3%	2%	20999	1.39%
ITI22	Terni	19%	28%	36%	12%	3%	2%	6272	0.41%
ITI31	Pesaro e Urbino	13%	17%	31%	27%	8%	5%	12029	0.80%
ITI32	Ancona	15%	20%	19%	32%	9%	5%	17851	1.18%
ITI33	Macerata	11%	24%	31%	23%	6%	4%	9913	0.66%
ITI34	Ascoli Piceno	11%	15%	42%	23%	6%	4%	6465	0.43%
ITI35	Fermo	13%	17%	31%	27%	8%	5%	5298	0.35%

Export		Port							
Label	Region	Genoa	La Spezia	Livorno	Ravenna	Venice	Trieste	Total TEU region	
AT00	Austria	3%	3%	2%	2%	19%	72%	39572	1.63%
CH00	Switzerland	76%	18%	3%	0%	1%	0%	151864	6.27%
ITC11	Torino	76%	18%	4%	1%	1%	0%	128903	5.32%
ITC12	Vercelli	76%	18%	4%	1%	2%	0%	8095	0.33%
ITC13	Biella	75%	18%	4%	1%	2%	1%	7843	0.32%
ITC14	Verbano-Cusio-Ossola	74%	18%	3%	1%	3%	1%	6195	0.26%
ITC15	Novara	77%	16%	3%	1%	3%	1%	18907	0.78%
ITC16	Cuneo	77%	18%	4%	0%	0%	0%	34699	1.43%
ITC17	Asti	76%	18%	4%	1%	1%	0%	9569	0.40%
ITC18	Alessandria	76%	18%	4%	1%	1%	0%	21507	0.89%
ITC20	Valle d'Aosta/Vallée d'Aoste	75%	18%	4%	1%	2%	1%	7810	0.32%
ITC31	Imperia	77%	18%	4%	0%	0%	0%	9412	0.39%
ITC32	Savona	77%	18%	4%	0%	0%	0%	14772	0.61%
ITC33	Genova	74%	21%	4%	0%	0%	0%	61486	2.54%
ITC34	La Spezia	28%	60%	10%	0%	1%	0%	14352	0.59%
ITC41	Varese	65%	23%	5%	1%	4%	1%	43935	1.81%
ITC42	Como	67%	22%	4%	1%	4%	1%	28119	1.16%
ITC43	Lecco	61%	24%	5%	1%	7%	2%	17587	0.73%
ITC44	Sondrio	61%	24%	5%	1%	7%	2%	8905	0.37%
ITC46	Bergamo	58%	24%	5%	2%	9%	2%	62547	2.58%
ITC47	Brescia	39%	36%	7%	2%	12%	3%	74719	3.08%
ITC48	Pavia	69%	23%	4%	1%	2%	1%	22337	0.92%
ITC49	Lodi	55%	31%	6%	2%	5%	1%	10442	0.43%
ITC4A	Cremona	45%	38%	8%	2%	6%	2%	19774	0.82%
ITC4B	Mantova	36%	32%	8%	5%	16%	4%	23493	0.97%
ITC4C	Milano	66%	23%	5%	1%	4%	1%	368635	15.22%
ITC4D	Monza e della Brianza	62%	25%	5%	1%	5%	1%	45357	1.87%
ITH10	Bolzano-Bozen	33%	27%	7%	4%	23%	6%	41867	1.73%
ITH20	Trento	31%	25%	7%	4%	21%	13%	35013	1.45%
ITH31	Verona	28%	27%	7%	4%	26%	7%	57132	2.36%
ITH32	Vicenza	18%	18%	6%	5%	41%	11%	54686	2.26%
ITH33	Belluno	8%	8%	5%	6%	48%	25%	13982	0.58%
ITH34	Treviso	9%	10%	5%	4%	51%	21%	57415	2.37%
ITH35	Venezia	9%	9%	5%	7%	54%	15%	54494	2.25%
ITH36	Padova	13%	14%	8%	6%	46%	13%	62398	2.58%
ITH37	Rovigo	13%	22%	12%	9%	35%	10%	11259	0.46%
ITH41	Pordenone	7%	7%	4%	5%	41%	35%	19494	0.80%
ITH42	Udine	5%	5%	3%	4%	30%	54%	34705	1.43%
ITH43	Gorizia	4%	4%	2%	3%	24%	62%	8518	0.35%
ITH44	Trieste	2%	3%	1%	2%	15%	77%	20296	0.84%
ITH51	Piacenza	52%	35%	7%	2%	4%	1%	16797	0.69%
ITH52	Parma	30%	51%	10%	3%	4%	1%	32532	1.34%
ITH53	Reggio nell'Emilia	29%	48%	9%	5%	6%	2%	36675	1.51%
ITH54	Modena	26%	43%	13%	7%	9%	2%	54221	2.24%
ITH55	Bologna	20%	33%	18%	11%	14%	4%	84704	3.50%
ITH56	Ferrara	16%	26%	14%	12%	24%	7%	17556	0.72%
ITH57	Ravenna	13%	21%	12%	28%	20%	6%	26764	1.10%
ITH58	Forlì-Cesena	16%	27%	15%	27%	12%	3%	26145	1.08%
ITH59	Rimini	15%	25%	14%	32%	11%	3%	20819	0.86%
ITI11	Massa-Carrara	21%	38%	29%	7%	4%	1%	9496	0.39%
ITI12	Lucca	26%	47%	24%	1%	1%	0%	22689	0.94%
ITI13	Pistoia	25%	46%	23%	2%	3%	1%	15390	0.64%
ITI14	Firenze	23%	41%	29%	3%	4%	1%	85194	3.52%
ITI15	Prato	24%	44%	25%	3%	3%	1%	16509	0.68%
ITI16	Livorno	22%	39%	37%	1%	1%	0%	19394	0.80%
ITI17	Pisa	24%	43%	31%	1%	1%	0%	28330	1.17%
ITI18	Arezzo	21%	38%	29%	7%	4%	1%	19356	0.80%
ITI19	Siena	20%	37%	36%	3%	3%	1%	18755	0.77%
ITI1A	Grosseto	22%	40%	34%	2%	2%	1%	11154	0.46%
ITI21	Perugia	20%	37%	28%	10%	4%	1%	34306	1.42%
ITI22	Terni	20%	37%	28%	10%	4%	1%	10237	0.42%
ITI31	Pesaro e Urbino	14%	23%	24%	25%	10%	3%	19355	0.80%
ITI32	Ancona	16%	27%	14%	29%	11%	3%	28733	1.19%
ITI33	Macerata	12%	32%	24%	21%	8%	2%	15983	0.66%
ITI34	Ascoli Piceno	12%	20%	34%	22%	9%	2%	10460	0.43%
ITI35	Fermo	14%	23%	24%	25%	10%	3%	8530	0.35%

Figures market share import



Source: Author



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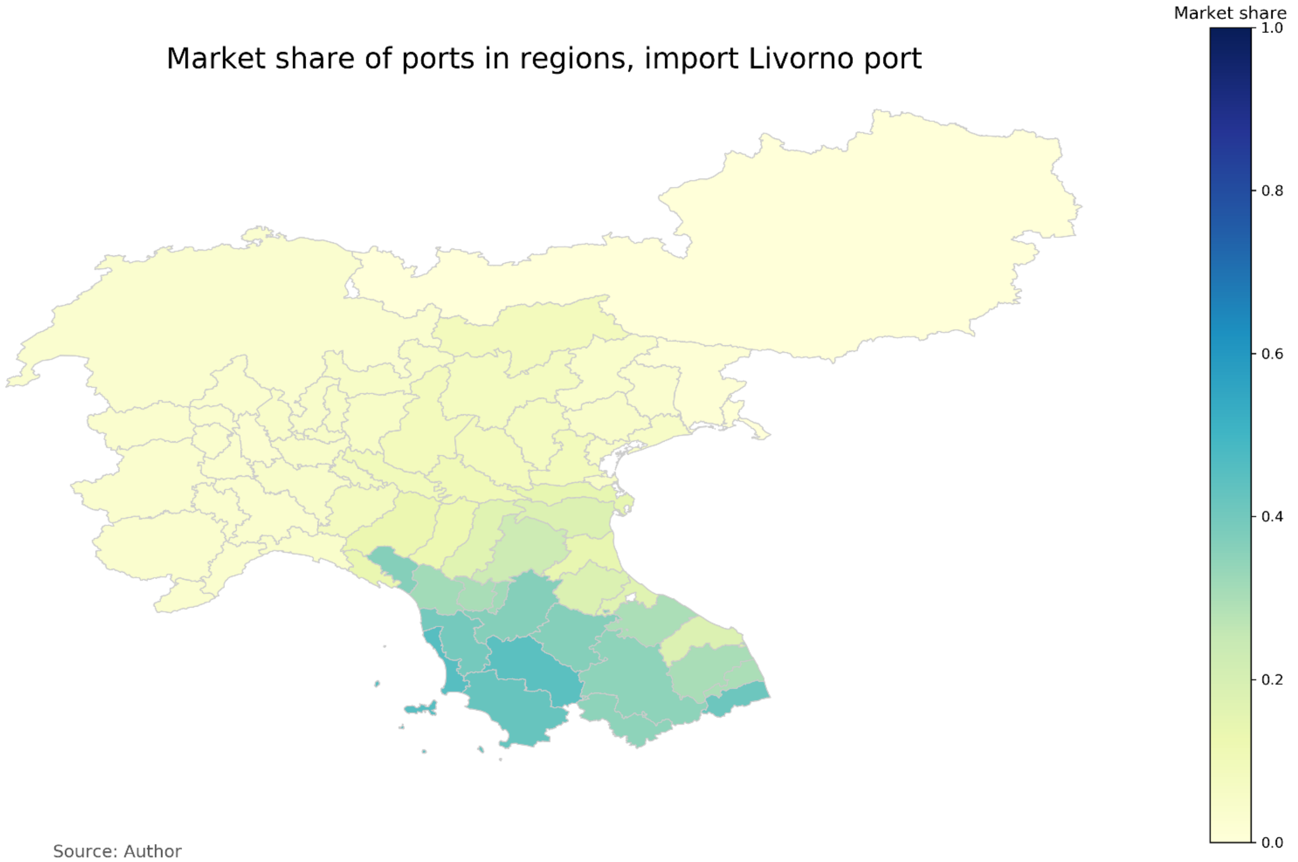

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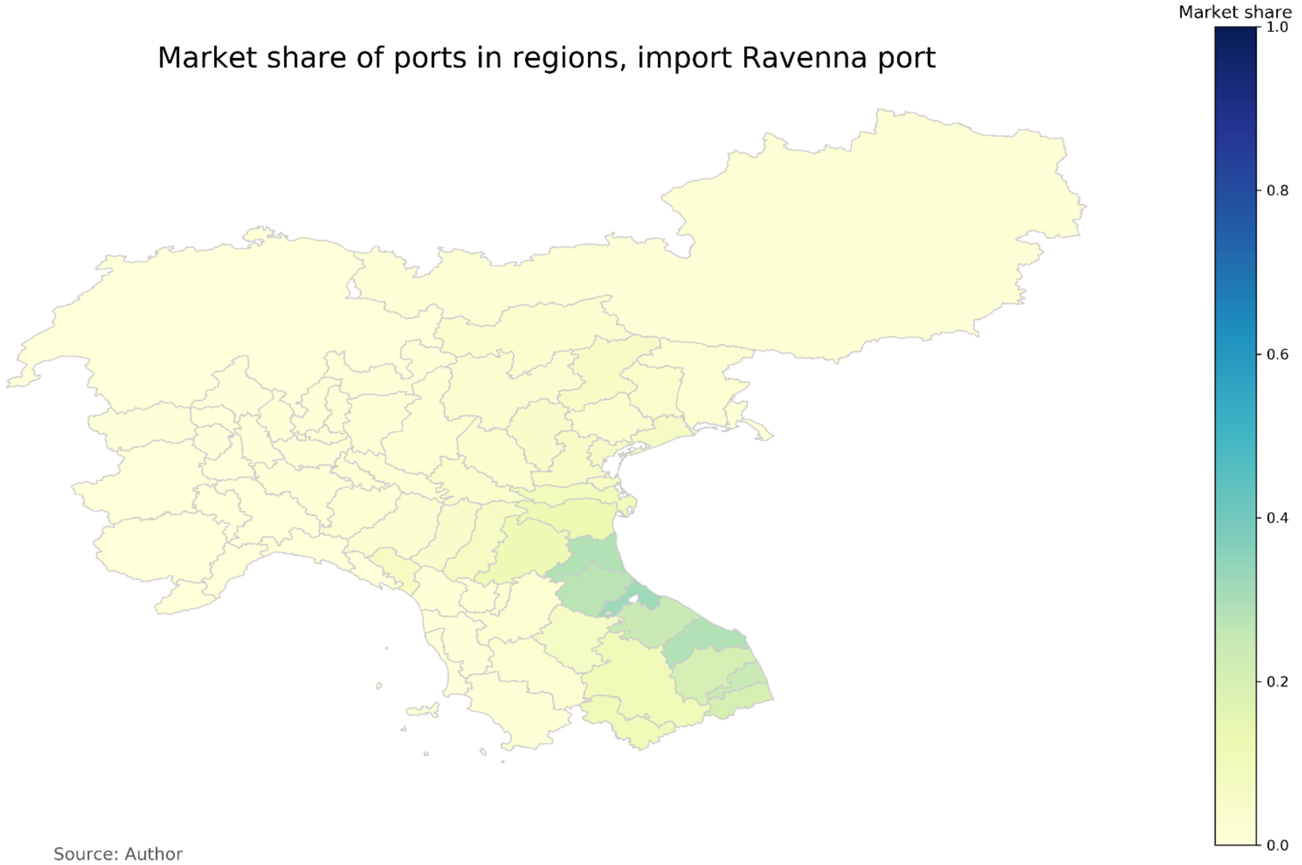

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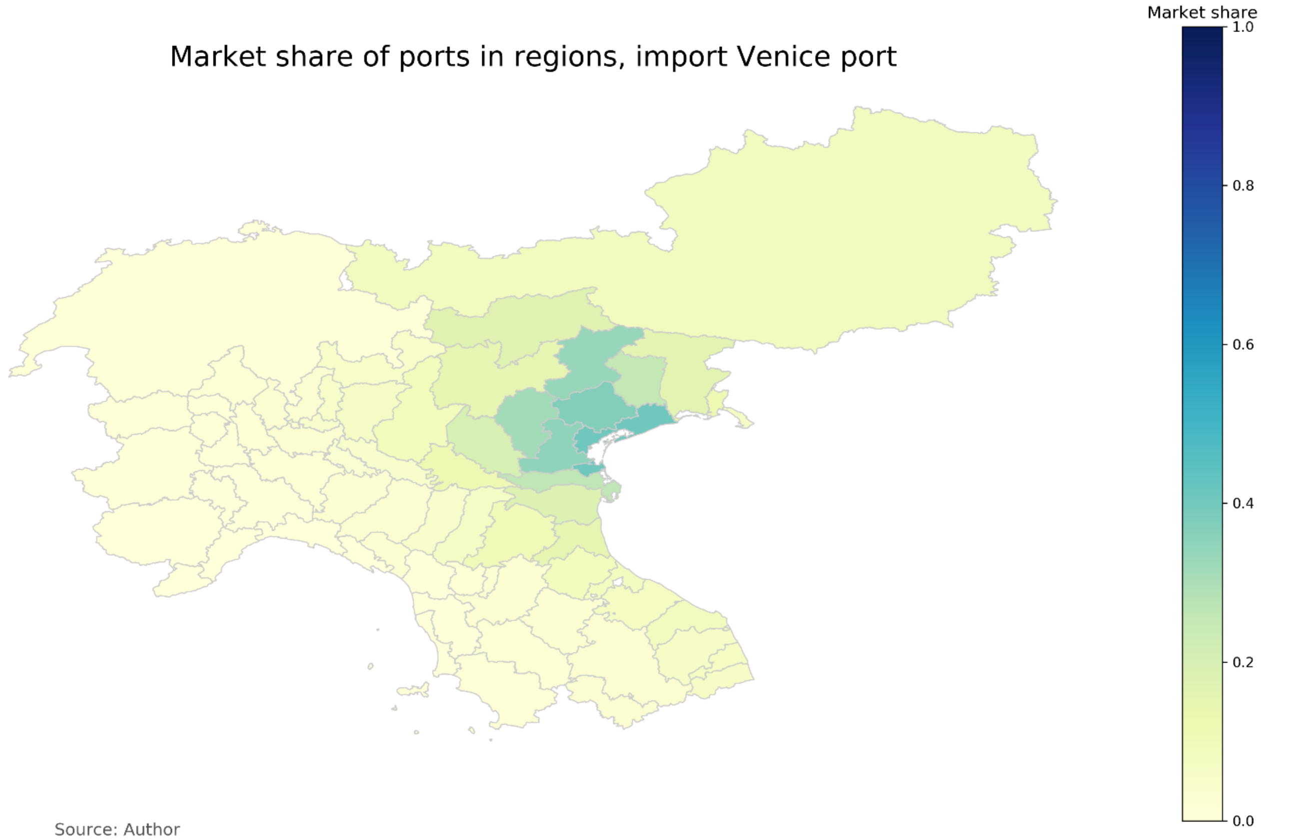

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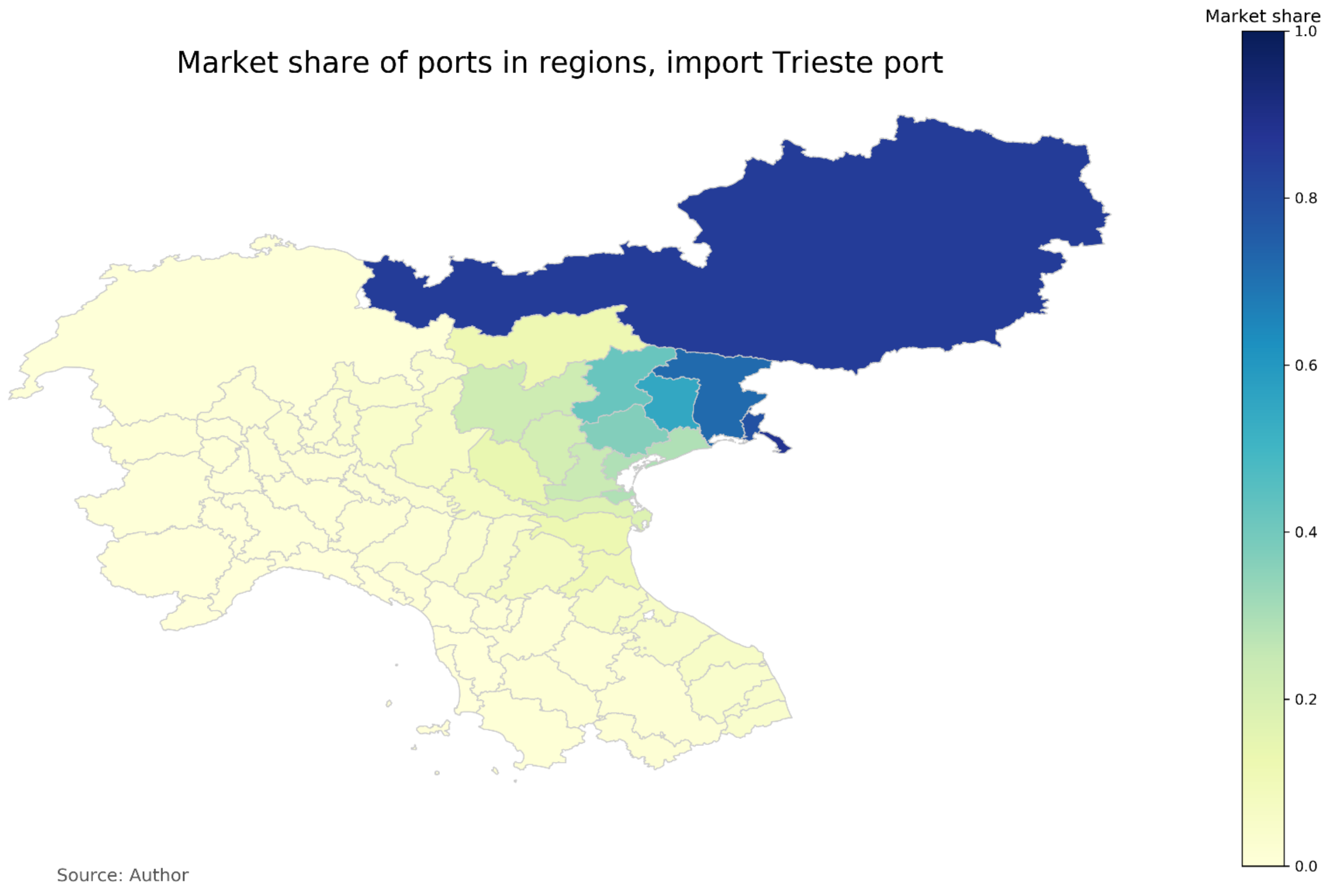

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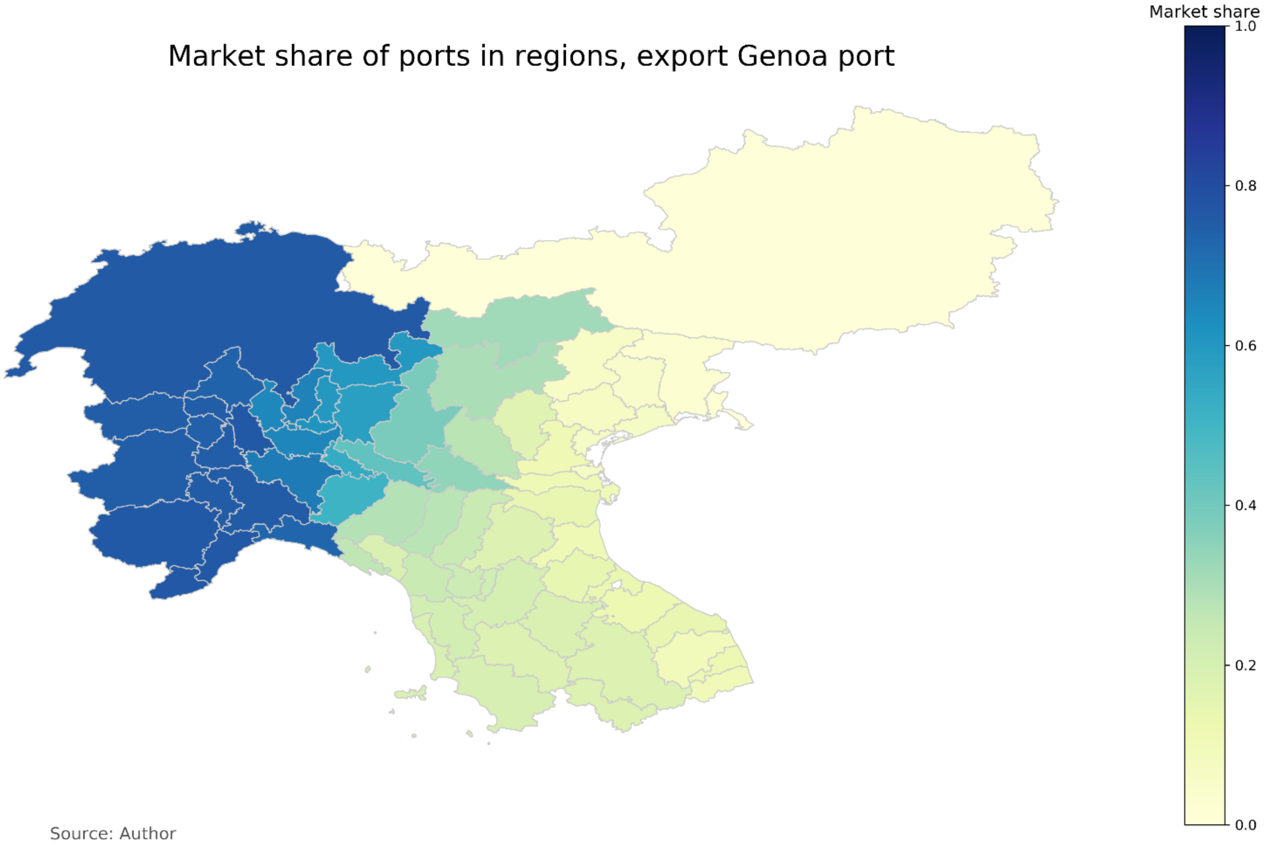
Figures market share export



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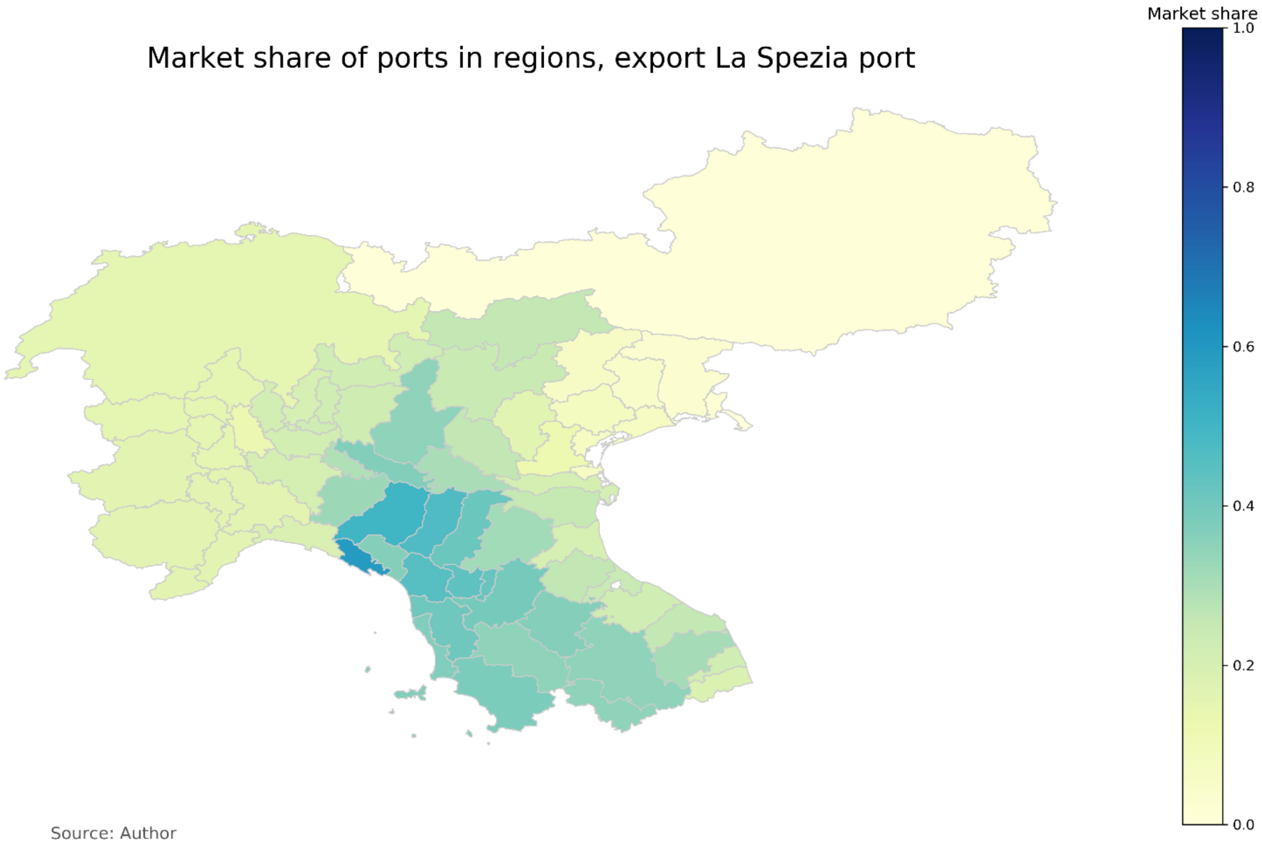

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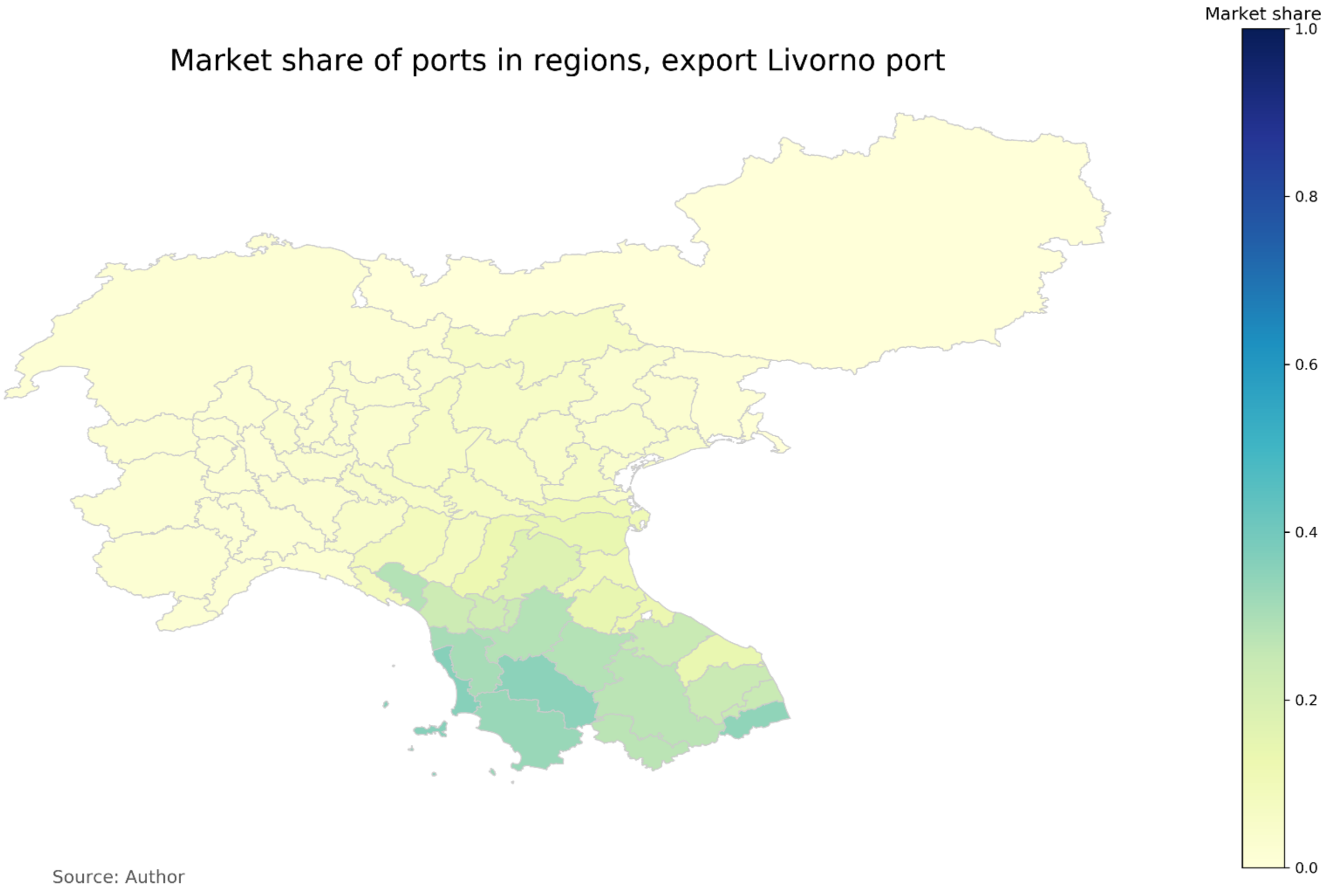
Market share of ports in regions, export Livorno port



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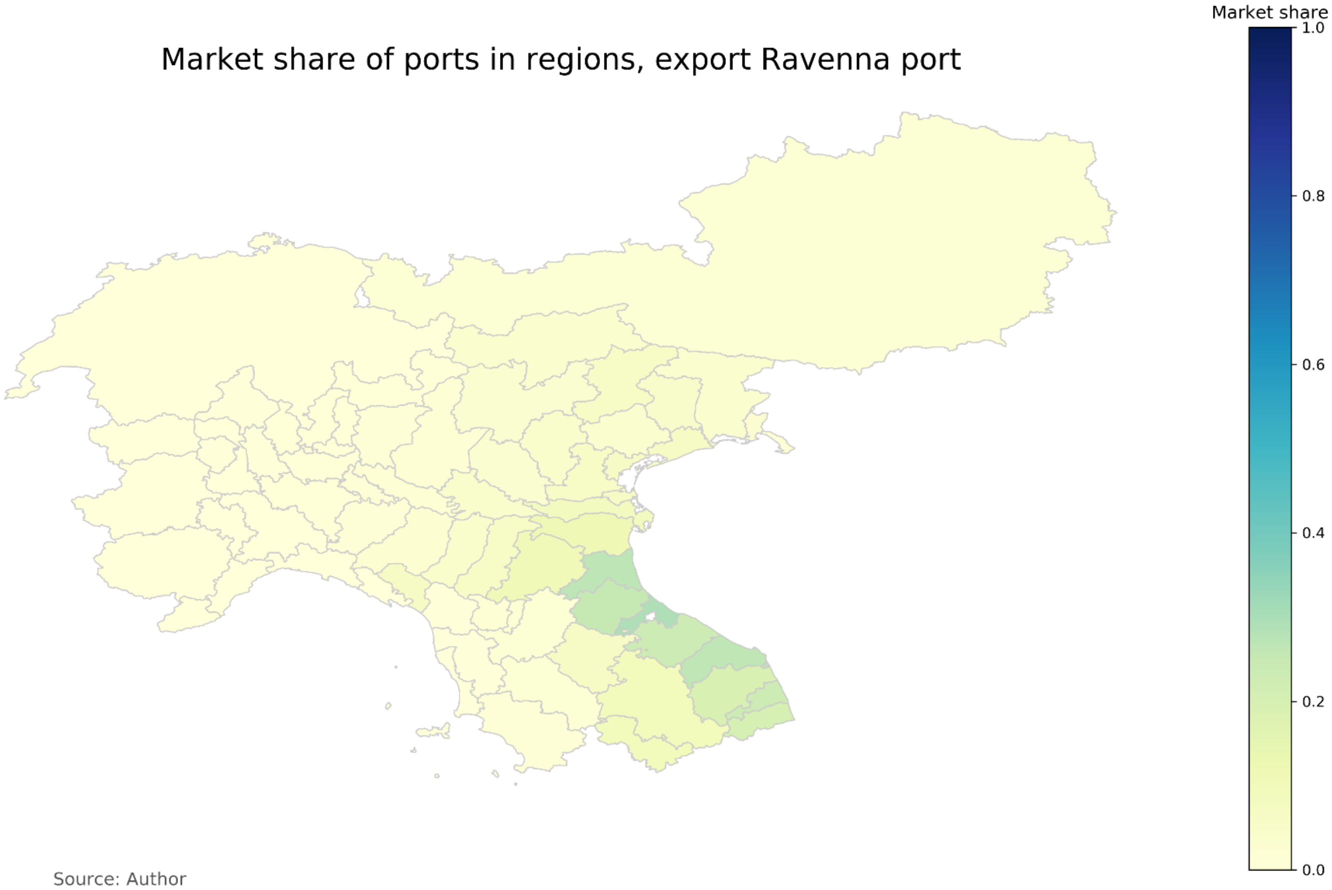
Market share of ports in regions, export Ravenna port



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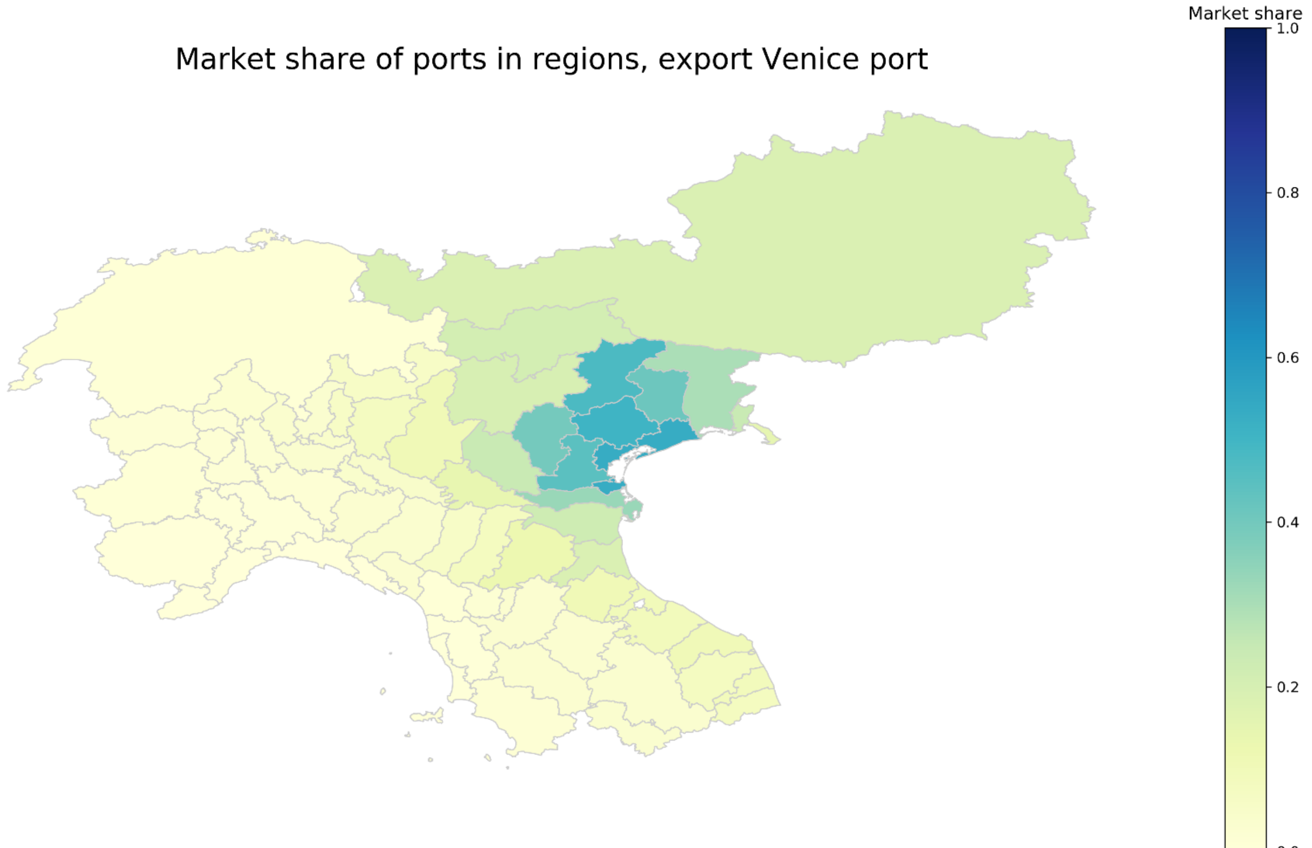

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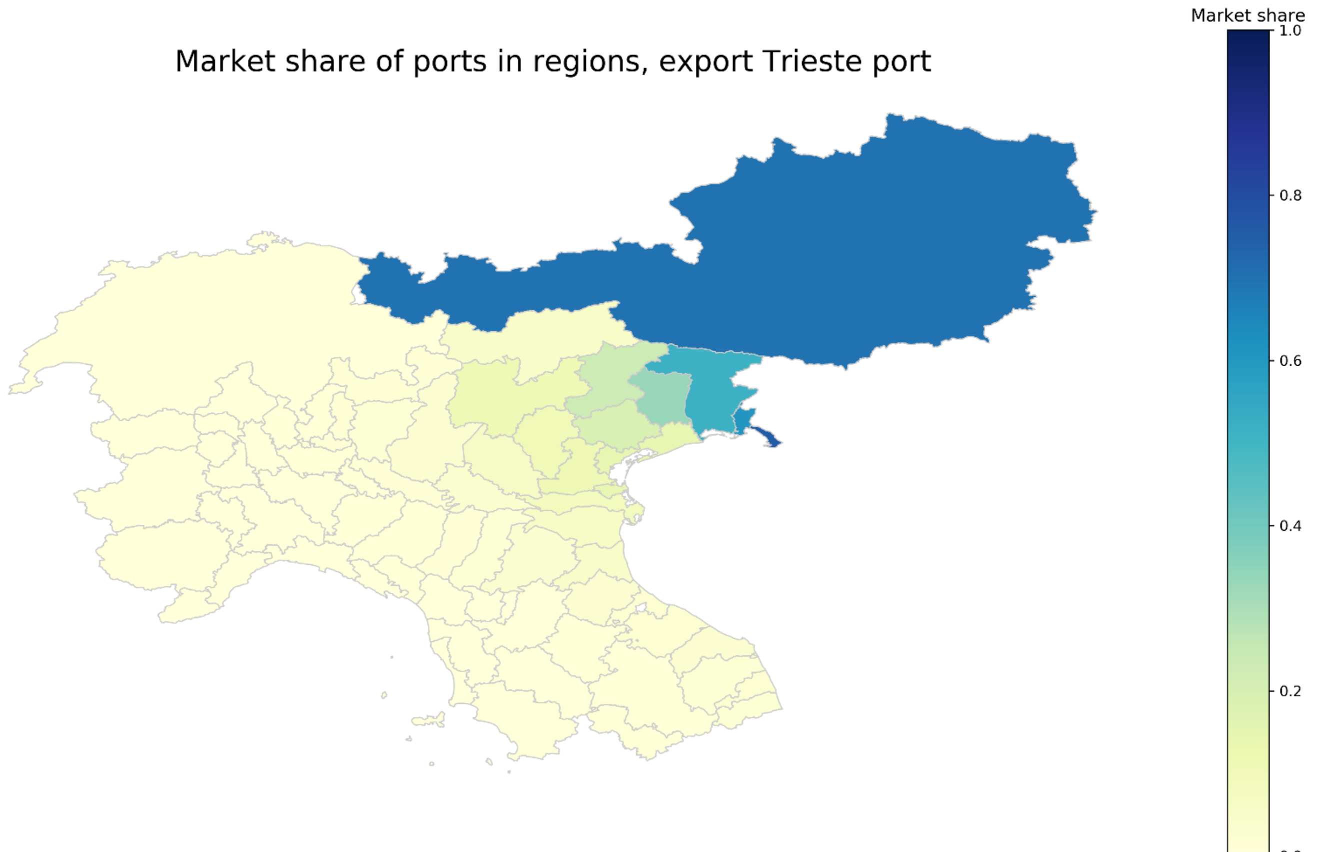
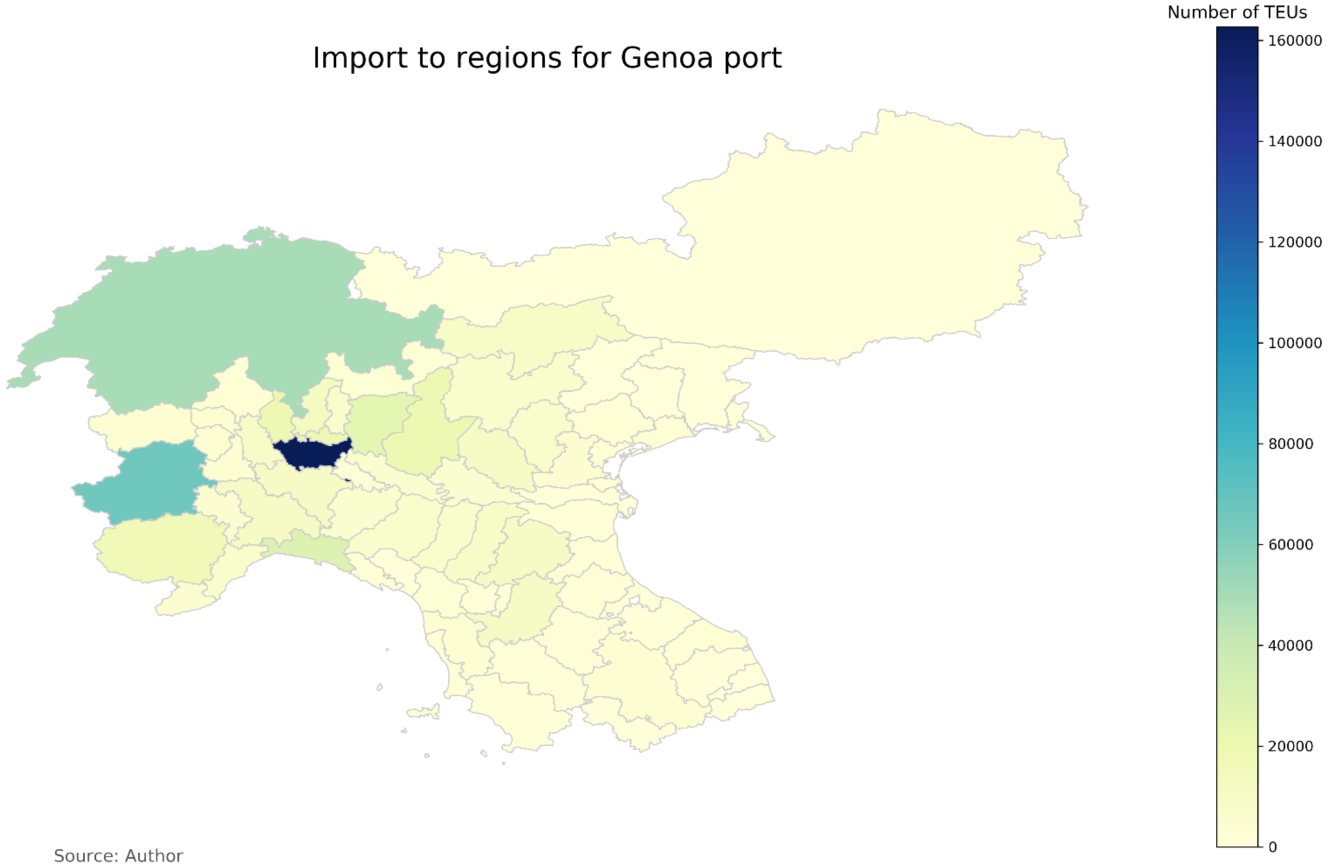


Source: Author

Import in TEU equivalent units



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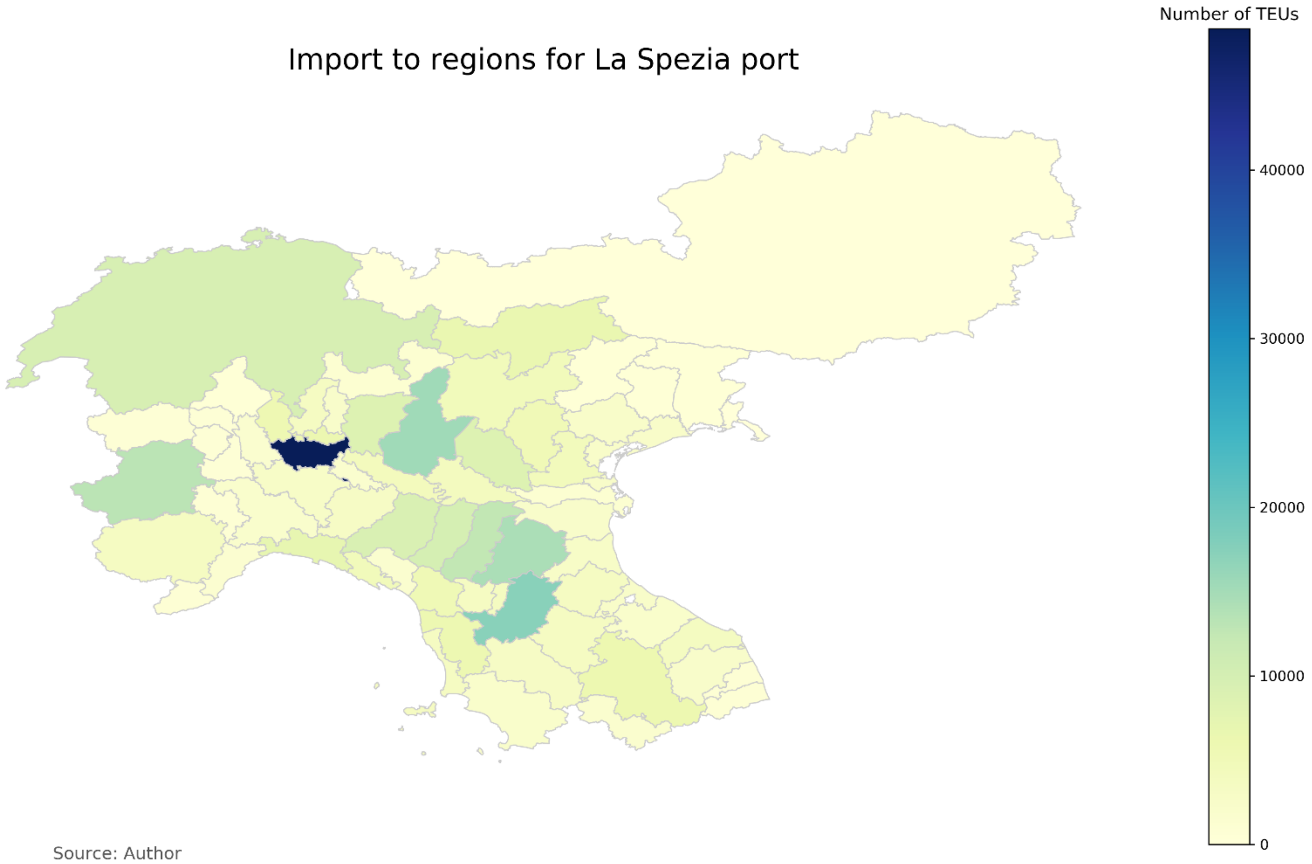

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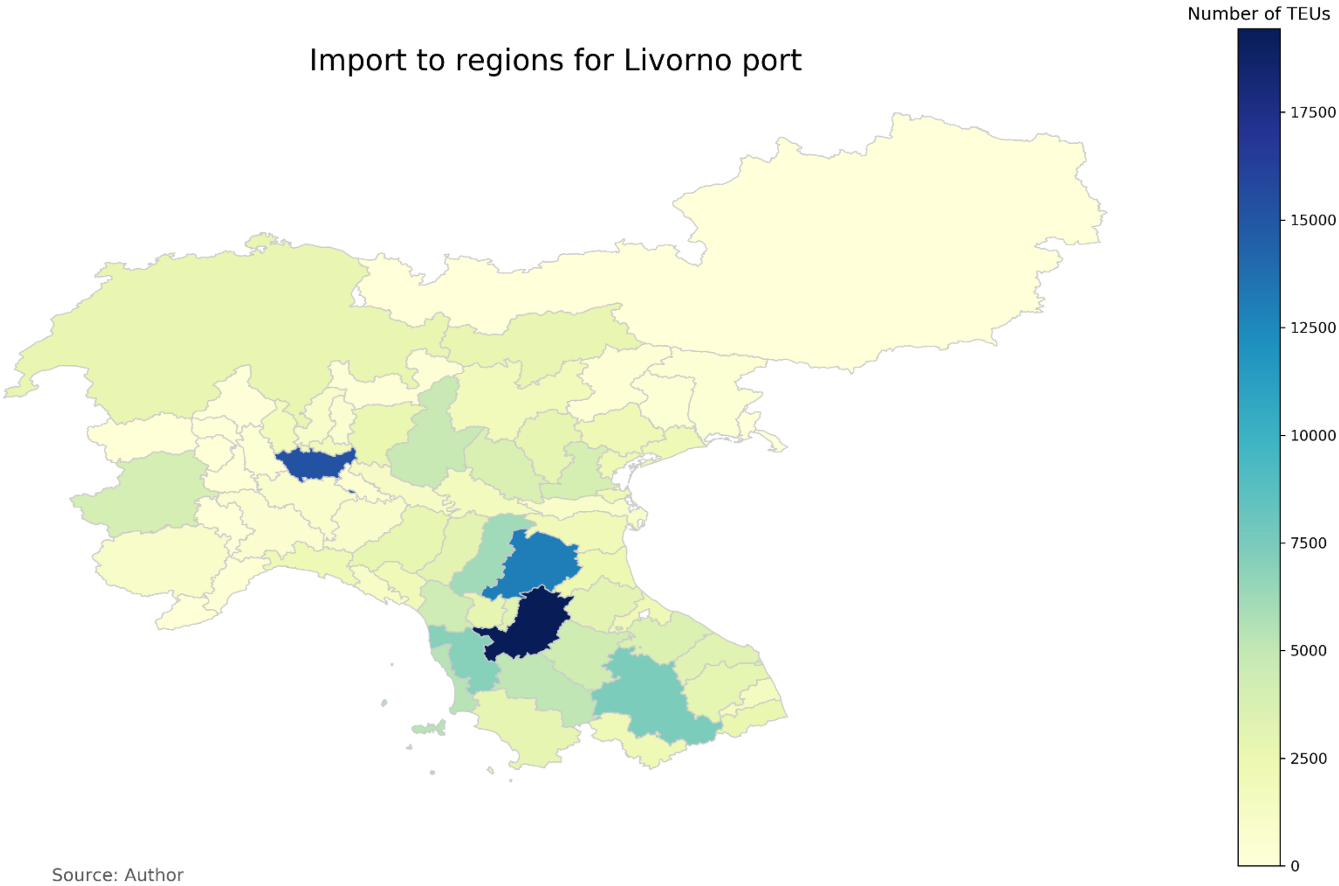
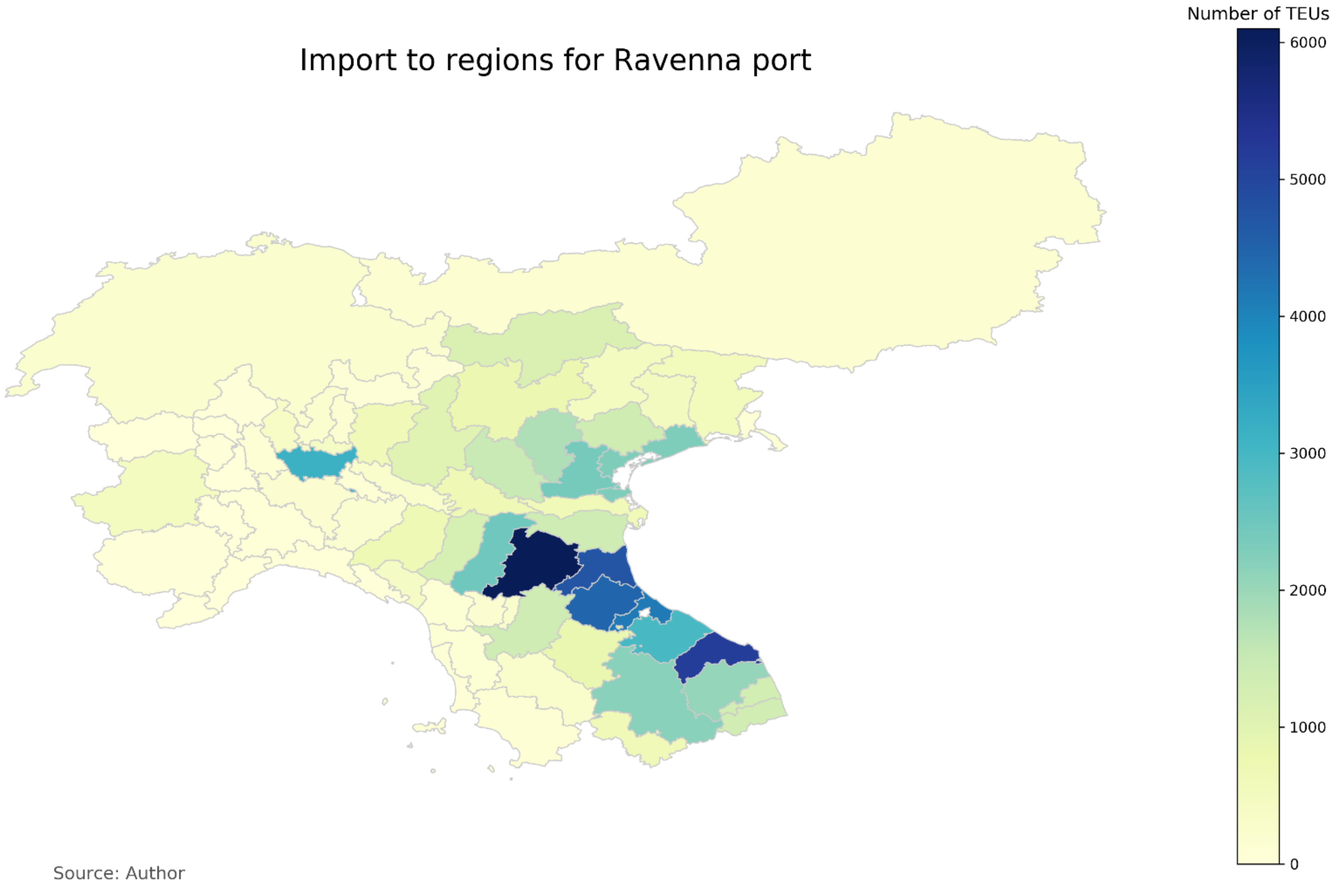
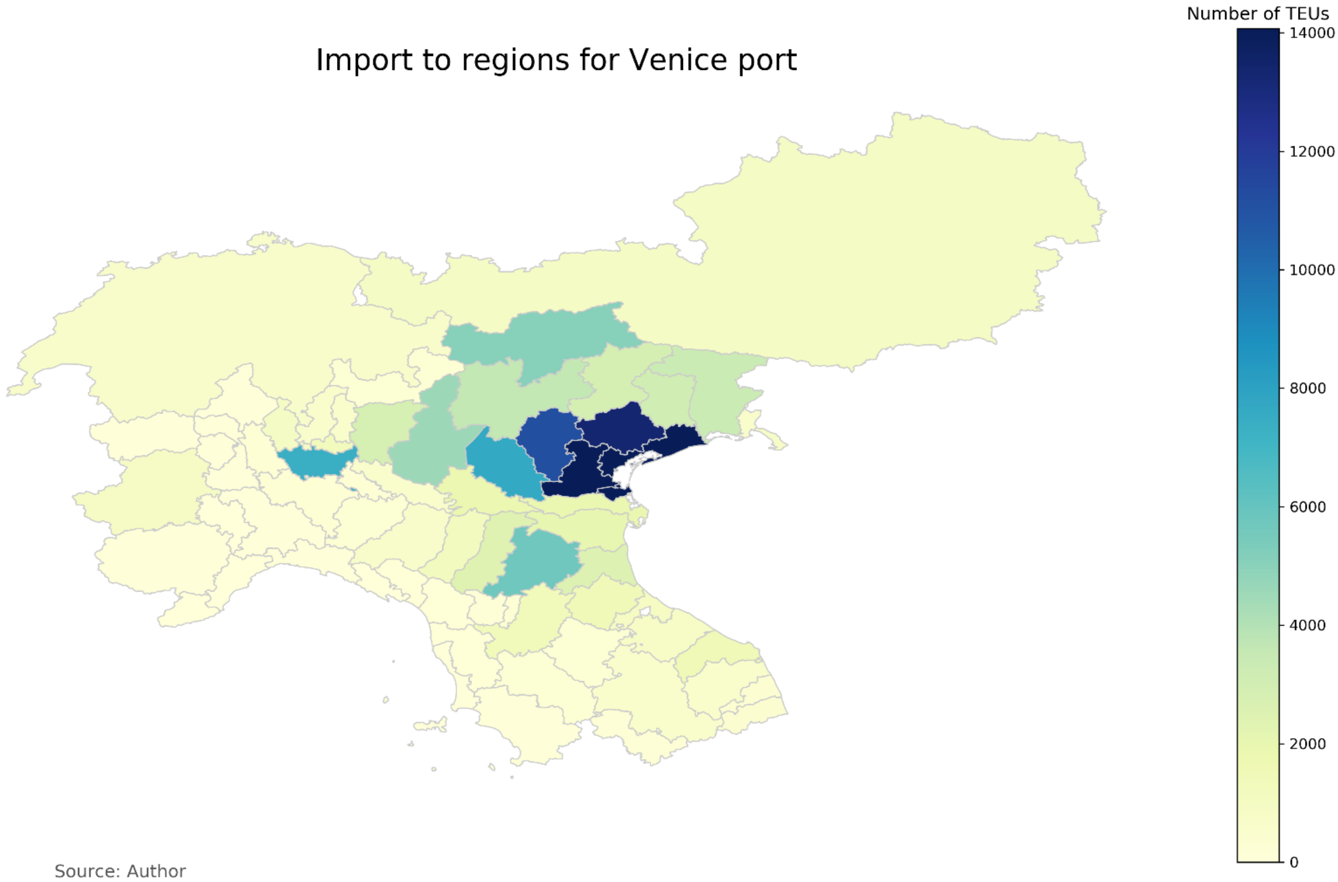

Import to regions for Livorno port
Number of TEUs
17500
15000
12500
10000
7500
5000
2500
0
Source: Author

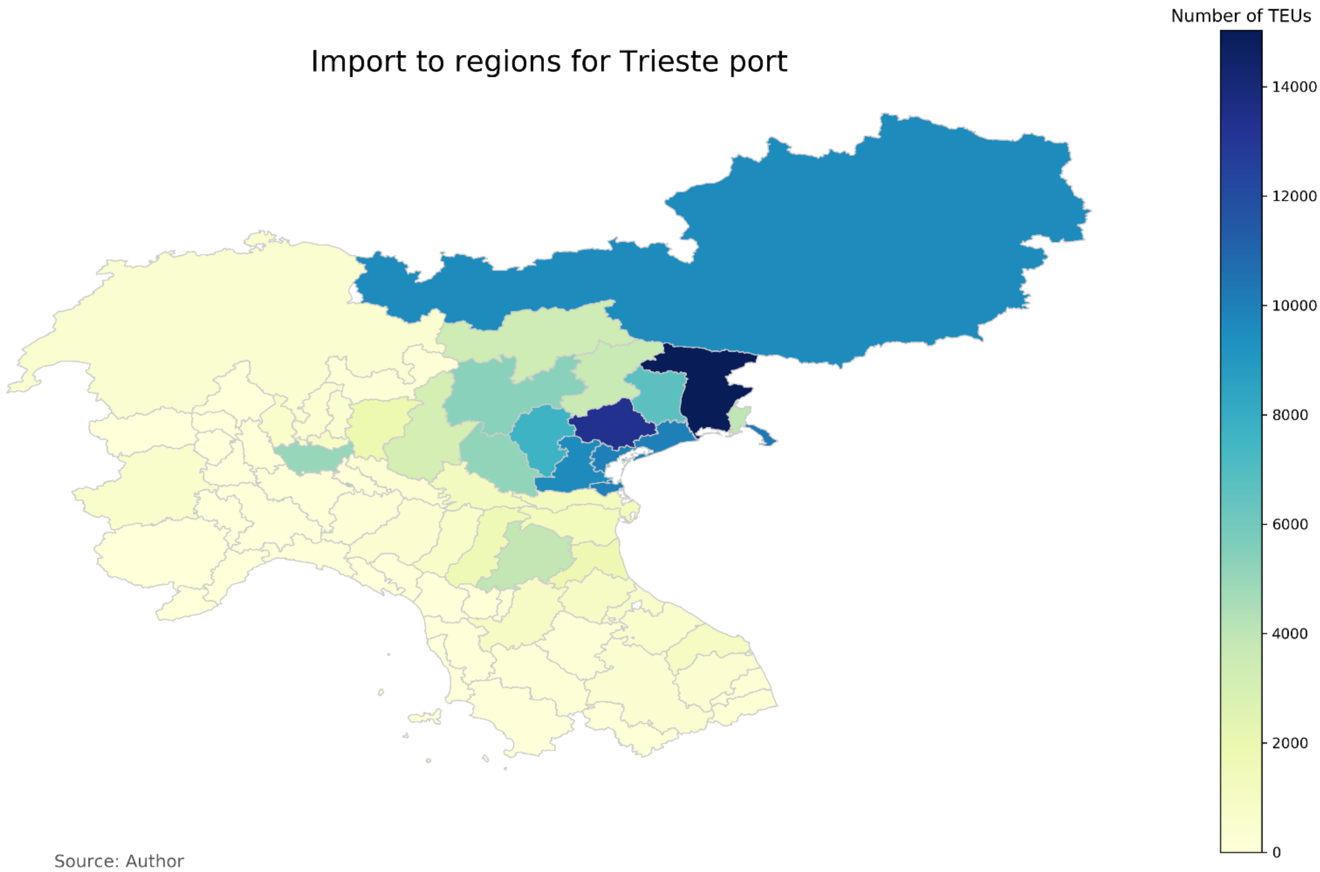

Import to regions for Ravenna port
Number of TEUs
6000
5000
4000
3000
2000
1000
0
Source: Author

Import to regions for Venice port



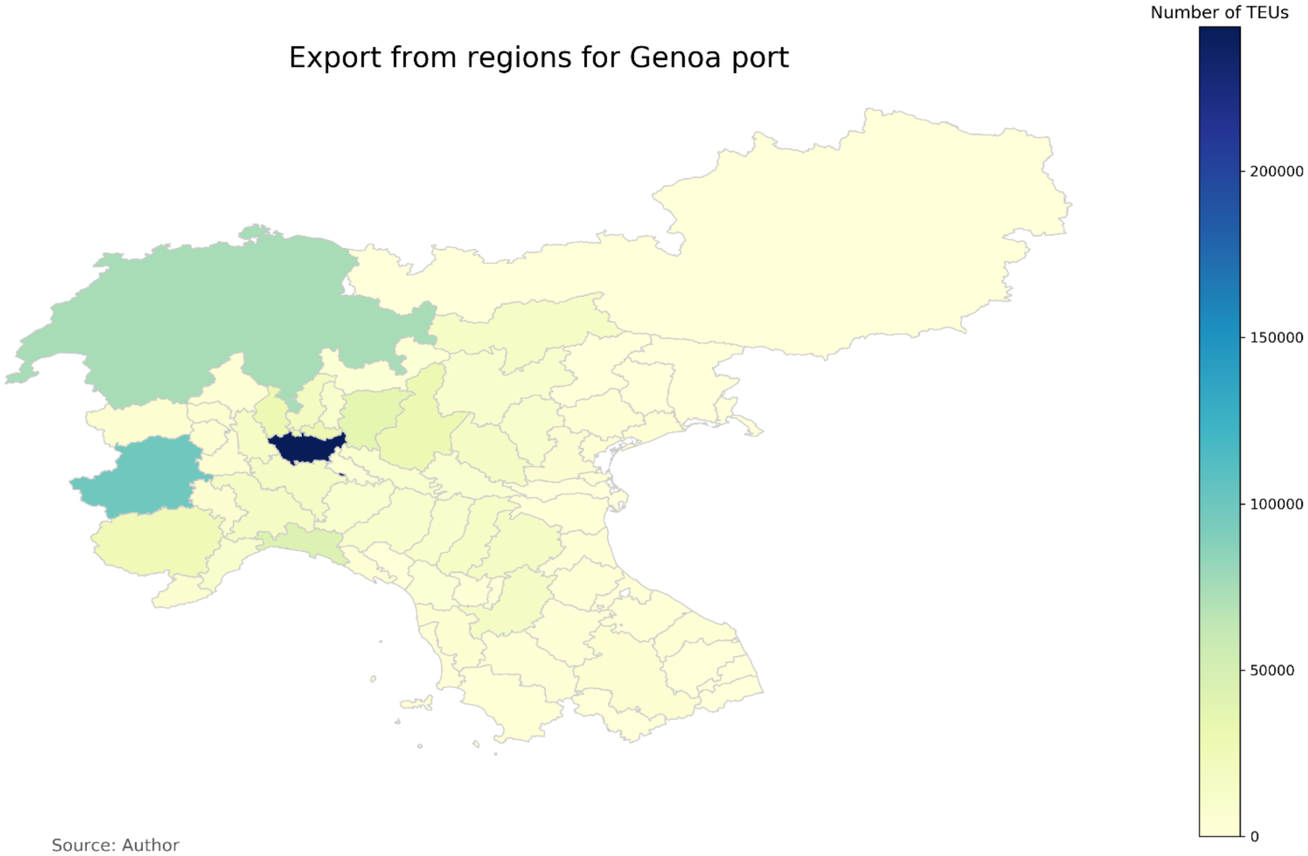
Source: Author

Import to regions for Trieste port

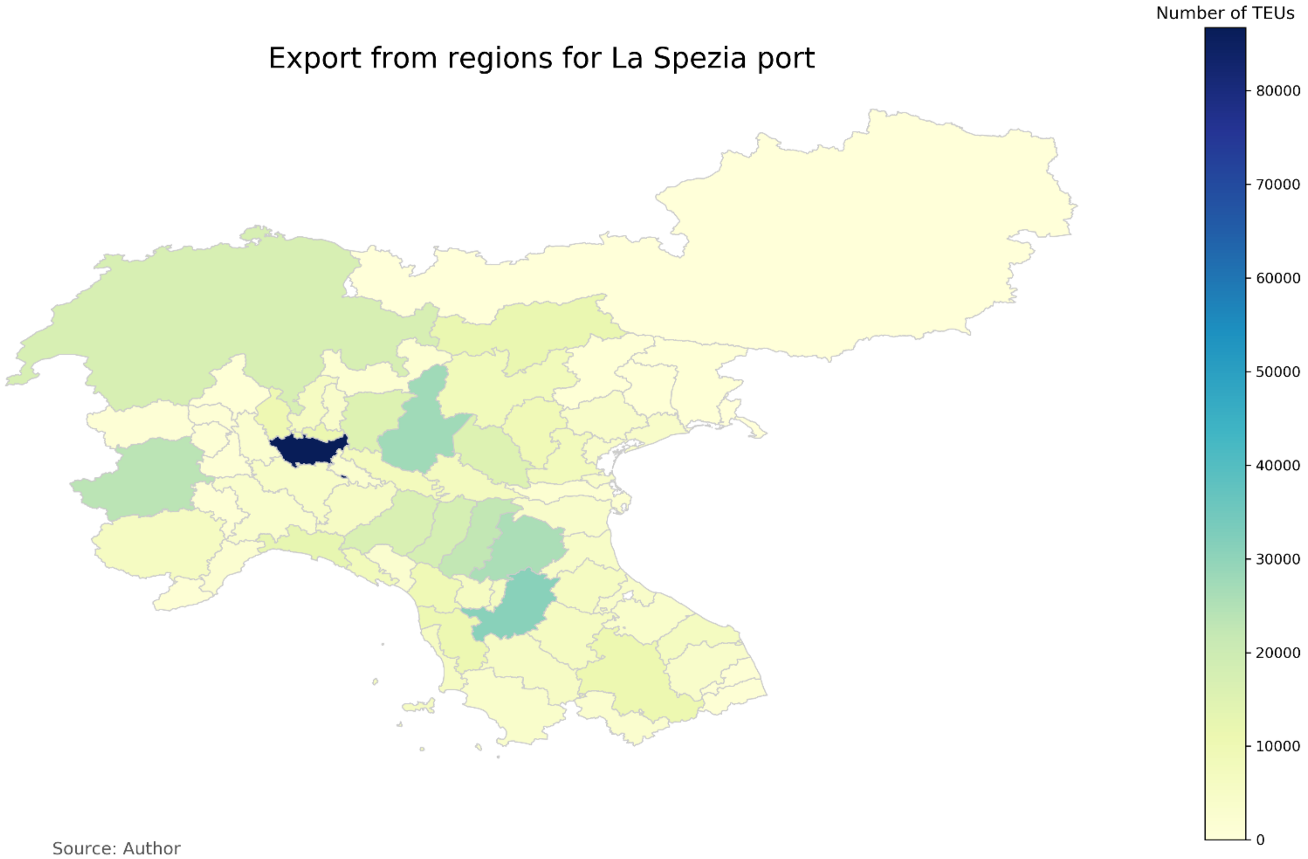


Source: Author

Export in TEU equivalent units

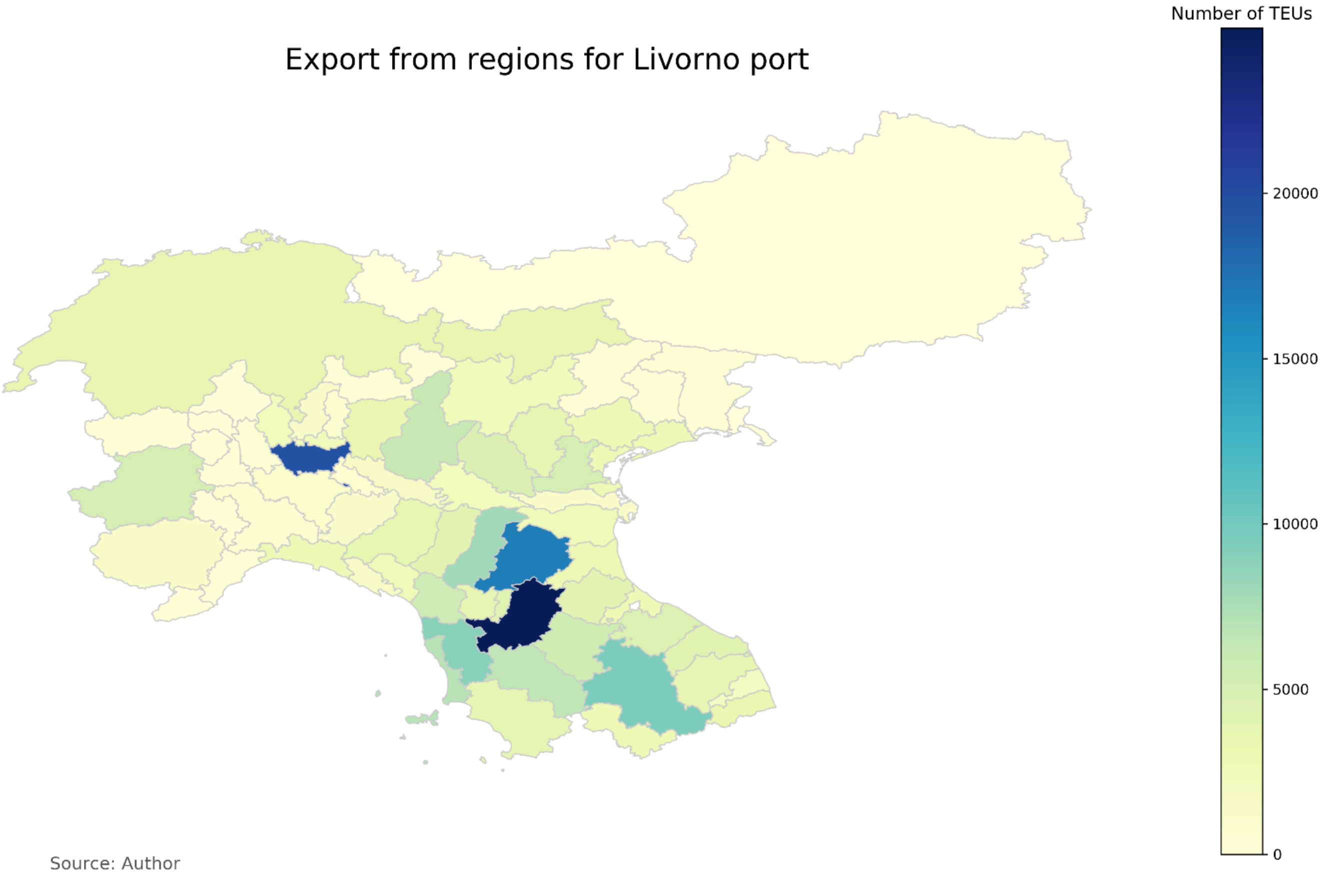


Source: Author



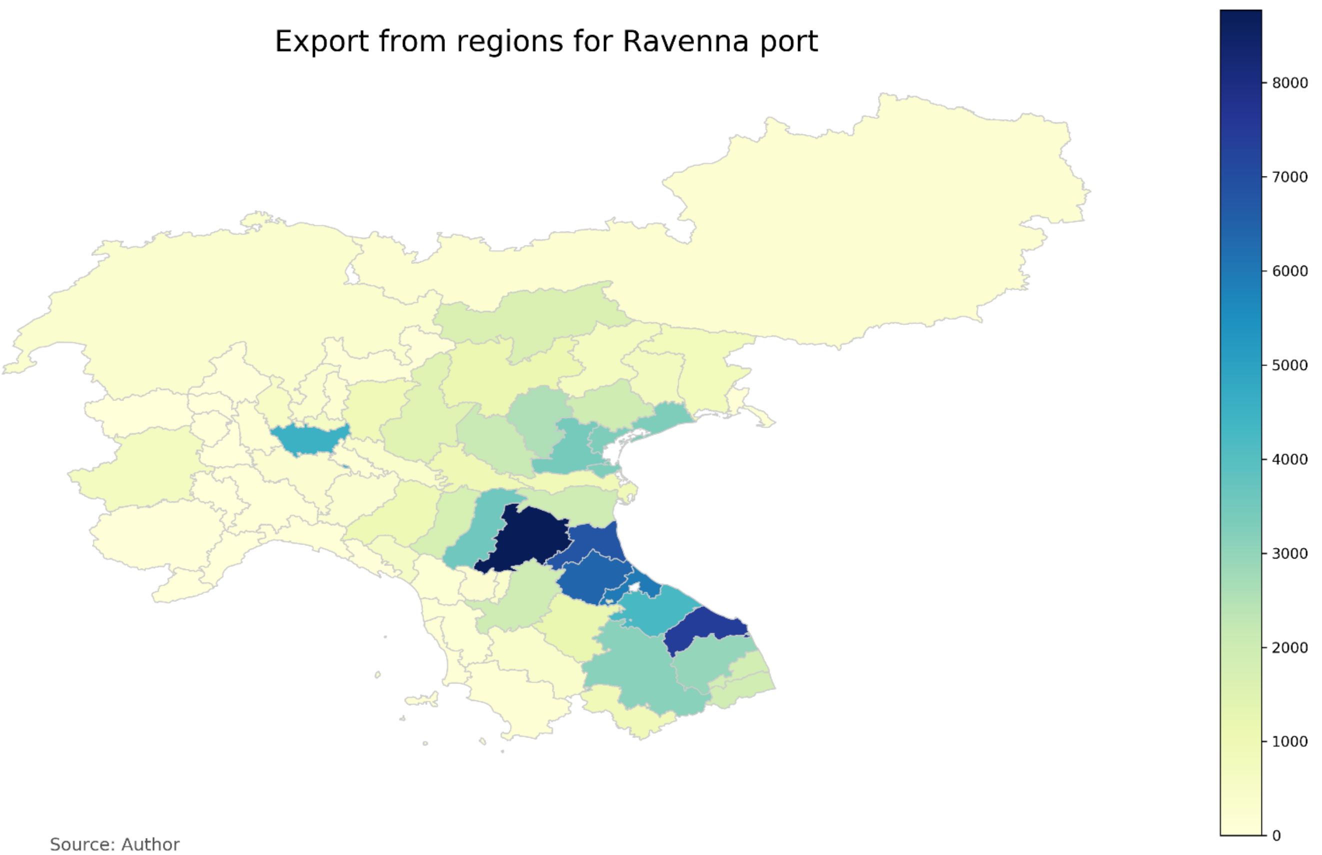
Source: Author

Export from regions for Livorno port



Source: Author

Export from regions for Ravenna port



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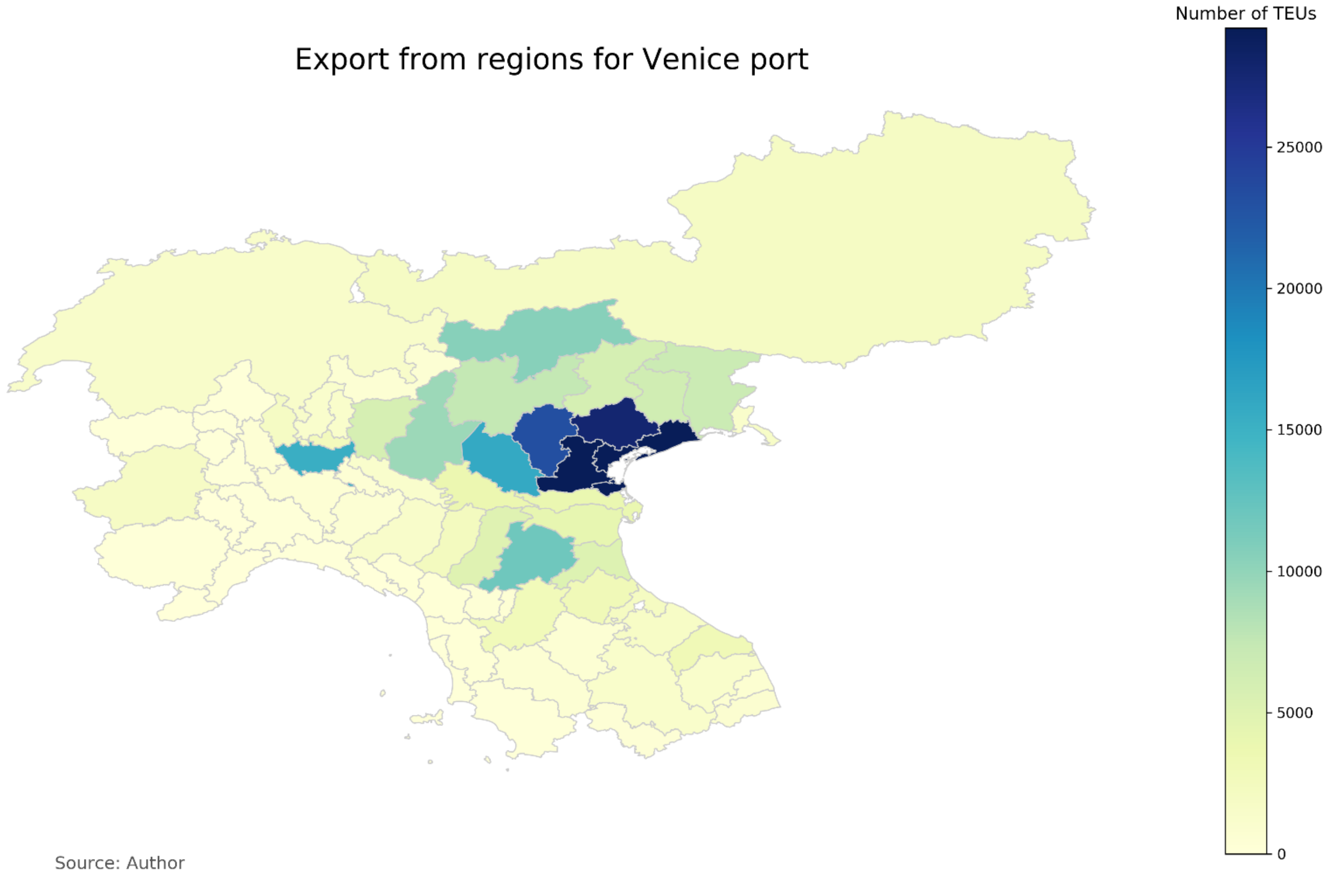
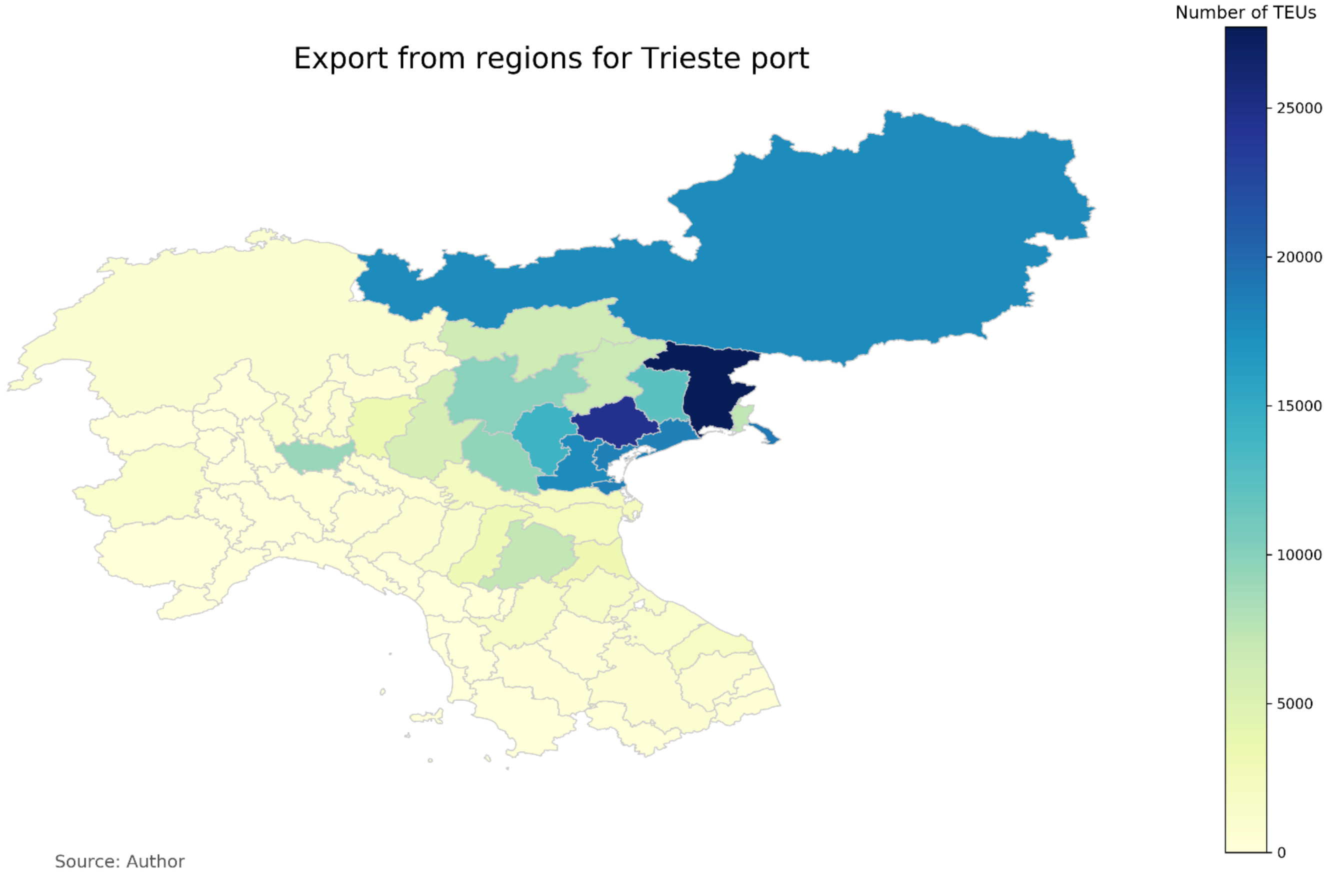


Export from regions for Venice port
Number of TEUs
25000
20000
15000
10000
5000
0
Source: Author



Export from regions for Trieste port
Number of TEUs
25000
20000
15000
10000
5000
0
Source: Author