POLITECNICO DI TORINO

Master of science in Civil Engineering

Master thesis

PORT-HINTERLAND CONNECTIVITY: THE ROLE OF INTERMODAL TRANSPORT AND FREIGHT DISTRIBUTION NETWORKS IN PIEDMONT REGION.

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ABSTRACT

The strategic position of the Piedmont region and its proximity to the western Ligurian ports offer concrete opportunities for the development of freight traffic. The recent opening of the new semi-automated deep-sea container terminal at the port of Vado Ligure (Savona) - which intends to handle 40% of container traffic by rail when fully operational - and the future opening of the Turin-Lyon railway line (scheduled for 2030) could create the conditions for increasing intermodal transport in this area, which is currently dominated by road haulage. However, infrastructures are not enough: in this Master's Thesis the criticalities of the intermodal transport in relation to the connections between Piedmont and the Ligurian ports have been identified and analysed, and a comparative model of the costs and times related to the alternatives of road and intermodal transport (road-rail combined transport) has been developed, considering three destinations in Piedmont chosen on the base of the ability to generate traffic of industrial origin. With the aim of relaunching the competitiveness of intermodal transport, in line with the objectives of the Transport White Paper (2011) and the European Green Deal (2020), some scenarios have been evaluated, which foresee both interventions on the demand side and on the supply side: for example, plant upgrades in the Turin-Orbassano logistics platform as well as improvements on the Turin-Savona railway line and on the rolling stock, through the use of new generation high performance trains finally also for freight. Finally, a mixed model of intermodal traffic management is proposed.

PART I

SUMMARY OF DISCUSSION

1 INTRODUCTION

Maritime freight transport experienced substantial growth and profound change over recent decades. Since the end of World War II, different levels of liberalization and global economic integration significantly impacted our world, making efficient transport a key trade driver. Nowadays, the shifts in global production and international trade affect the activity level and functioning of ports since the demand for port activities is for a large part determined by global economic interests and world trade. In this summary, the three most significant changes in the maritime sector are described.

1.1 CONTAINERIZATION

On April 26th, 1956, the Ideal-X, a converted World War II tanker, left Newark - New Jersey - to the port of Houston – Texas – with 58 containers, along with a regular load of 15000 tons of bulk petroleum. This journey was so special because a ship had its cargo packed into containers for the first time in history, rather than just loosely placed throughout. The idea of transporting freight by placing it in large containers was developed by the American transport entrepreneur Malcolm McLean that revolutionized transport and international trade in few decades. Before the Ideal-X, the cargo was brought to port in trucks and loaded onto ships piece by piece, and the whole loading process might take more than a week. Unbearably simple, the container was designed as a corrugated steel box capable of creating an integrated transport system between sea and inland transportation. At that time, the US's standard truck size was 35 feet; therefore, the first 35-feet unit containers were realized. Nowadays, the ISO containers have four standard dimensions, but the most popular ones are the TEU – Twenty feet Equivalent Unit 20' x 8' x 8'6" - and the FEU – Forty feet Equivalent Unit 40' x 8' x 8'6" - that together cover the 90% of the entire container demand [1]. Containerization seems to be a simple, uninfluential concept, but its affects are more evident than almost any other invention of the XX century; without that box, we would not have our phones from China, our clothes from India and all the finished goods moving around the world. Shipping is thereby, the "behind the scenes" process that makes our world what it is today, and containerization is the driver of developing a global economy and trade network.

The gradual shift from conventional break-bulk terminals to container terminals brought a fundamental change in terminals' layout and the rising of specialized container ports. According to the literature, the ratio between a containership and an equivalent break-bulk cargo ship in terms of dwell time is about 1:10, and the usual time spent in port by a containership is $\simeq$ 24 hours [2].

Nowadays, commercial shipping varies in capacity and functionality, and different ships have distinct roles:

- **Deep-sea international shipping** - connect large ports (hub ports) usually between continents with containerships up to 23000 TEU of capacity;
- **Coastal or short-sea shipping** - collect a critical mass and concentrate it in few hub ports or connect the main ports with smaller regional ports utilizing feeder ships with reduced load capacity (800-2800 TEU);
- **Inland shipping** - transport containers in the hinterland[1] on rivers or canals with ships (or barges) with limited capacity (100-1000 TEU).

Since the start of containerization, the size of containership increased and today, 90% of the world's international trade is transported by sea [3]. The causes of this growth in containerships must be sought in the higher capability of handling container operations and the achievement of economies of scale. The advent of mega-ships has decreased the ships' operating costs and therefore the unit costs of transport; however, for many ports it is impossible to provide the accessibility to modern cargo operations.

1.2 THE ADVENT OF GLOBAL SUPPLY CHAIN

During the past years, ports were deeply impacted by global processes, becoming a multidimensional entity covering an essential role within supply chains. A Likert-style questionnaire in 2010 revealed that for the shipping lines, the attractiveness of a port did not depend exclusively on the cost but also on other factors such as service quality, time efficiency, and geographical location [4]. This reflects the players' efforts in various segments to consolidate, vertically integrate or sign long-term contracts to decrease the costs and increase the level of coordination and synchronization [5].

Nowadays, ocean liner shipping companies - as well as the physically transport the cargoes - play a significant role in international trade. Since the first generation of shipping alliances in 1996, they have tried to gain ownership advantages by sharing ships, sailing schedules, and itineraries with the direct competitors. Together with the use of joint terminals and container coordination on a global scale, these sharing policies made the alliances essential for the shipping lines. Indeed, partnerships allow those companies to acquire new bigger ships together and share vessels benefiting economies of scale and achieving broad global service coverage [6]. Since April 2017, all major container carriers are involved in one of the three global alliances: *2M*, *Ocean Alliance* and *THE Alliance* that together reach a global market of almost 80%. In Figure 1 and Figure 2 the changes through the years and the market share of the actual three groups are reported.

[1] *"the interior region served by the port" [17].*

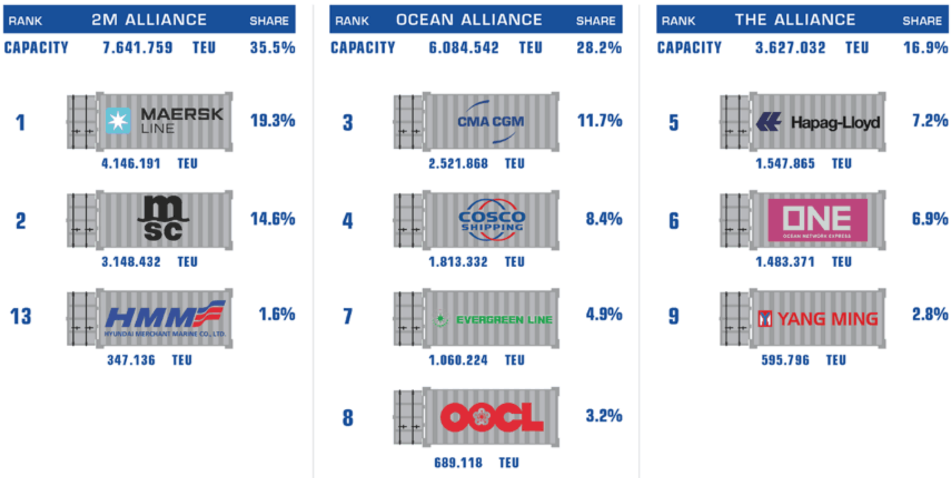

Figure 1 The actual three global shipping alliances [Source: [7]*]*

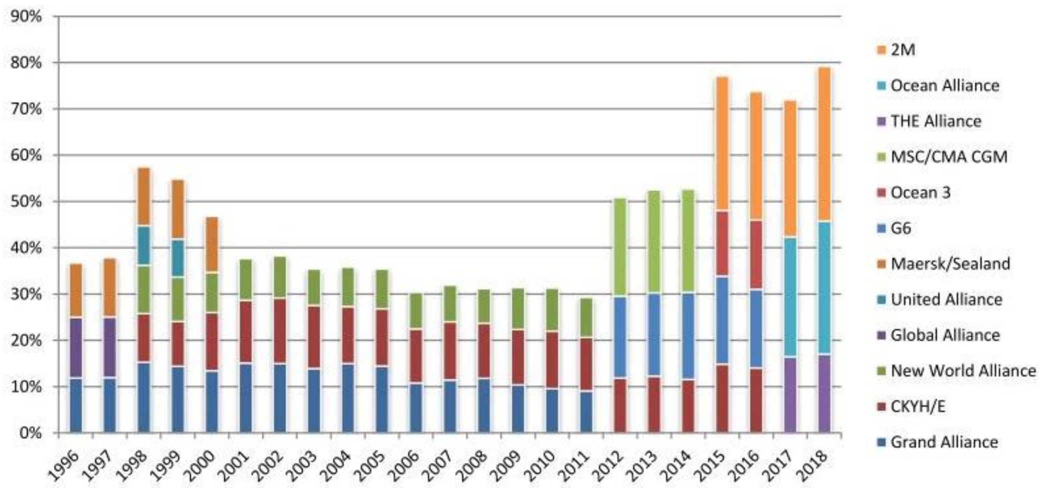

Figure 2 Global market share of alliances [Source: The impact of alliances in container shipping (2018)]

These alliances aim to meet the needs of the modern supply chains, including risk, costs, and investment sharing; they operate in a wider global environment with improvements in port infrastructures and developments of new inland transport corridors [6]. Collaborations between liner shipping thereby often extend also in vertical integration with other actors of the chain - as terminal operations and logistics activities in inland transport - having a significant impact in ports and hinterland connections.

The shipping companies' increased negotiating power making port’s competitiveness dependent on external factors and shifting the port selection criteria to a more global-oriented perspective based on the total logistics costs (TLC). Among the physical attributes that characterize the port selection, the geographical position, the efficiency, the technical infrastructure, and the hinterland connectivity have a significant impact on the internal – handling, parking, port taxes etc. - and the external costs – connections with hinterland – [8]. The success of a port thereby does not depend on its internal weaknesses and strengths but on the port community's ability to cooperate with other transport nodes and other players within the logistics network [8].

1.3 ROLE OF TRANSSHIPMENT HUBS

The third key driver of the maritime freight transport environment regards the extension of the role of transshipment due to the growth of containerization and long-distance shipment. Since it is unfeasible to connect all possible port pairs directly, transshipment hubs can ensure connectivity within the global trading system.

Transshipment emerged in the 1970s, and it was developed to serve smaller ports unable to accommodate larger containerships due to the port infrastructure and their limited draft [8]. As the complexity of maritime networks increased, gateways ports became more oriented in transhipments, and today, more than 20 of the 100 largest ports worldwide are pure transshipment hubs [5]. A transshipment hub is - in according to Rodrigue - *"a port terminal used for ship-to-ship operations within a maritime transport system"* [2]. Transshipment operations need a large staking space where containers can be stored - usually from one to three days - waiting for the connecting ship. From a transport mode perspective, the emergence of transshipment leads to two separate handling operations into a port:

- the sea-sea transshipment cargo, with temporary storing in the gateway;
- the gateway cargo with a contribution of inland transportation.

To assess a port's dependency on transshipment flows, the literature [9] suggests a classification based on the port's transshipment incidence (T/S)[2]. The thresholds of these classes - reported in Table 1 – have been determined by the authors and port experts.

T/S share	Class	Description
< 25%	**Gateway or feeder ports**	port areas that are very much hinterland-focused and only handle small sea-sea transshipment flows. They have a strong focus on import/export cargo, developing commercial relations with the hinterland.
25 - 65%	**Mixed or hub ports**	ports that combine gateway/inland cargo with the transshipment business. Such ports usually become hubs after maritime shipping companies decide to use them as such.
> 65 %	**Pure transhipment hubs**	ports where transshipment activity is the core of the port's operational and commercial base.

Table 1 Levels of transshipment incidence

Analyzing the European port system Figure 3 shows the heterogeneous nature of the ports. It is composed of Gateway or feeder ports, mixed or hub ports (offshore and not), and a relevant number of medium-sized and smaller ports. Each port has its specific characteristics depending on location, hinterland connectivity, and markets served [8]. The Pure transhipment hubs ports are mainly located in the Mediterranean area in proximities of the major maritime shipping route, while the gateway/mixed hubs are mostly positioned in Northern Europe.

[2] T/S: transshipment flows (ship-to-ship) vs total volume handled by a port.

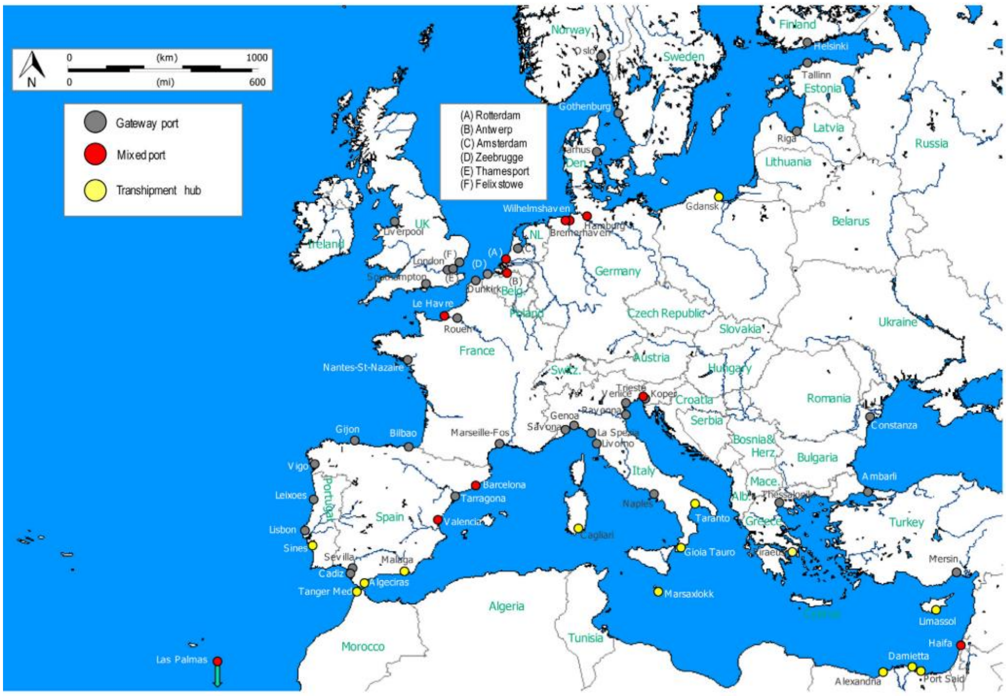

Figure 3 Ports classification in Europe [Source: The relationship between transhipment incidence and throughput volatility in North European and Mediterranean container ports (2019)]

2 THE NAVAL GIGANTISM

After so many years of transportation, maritime transport remains the most economical solution to transport goods between two points located far away. The container's advent in the 60s and the following container's size standardization (ISO) brought to important cooperation between ports and the hinterland. Then, the growth of the containerships determined a further reduction of the costs. This last phenomenon - named *"naval gigantism"* – started as a shipping line strategy to break down their costs. Actually, the most important containerships are seven and, sorted in terms of capacity, they are Small Feeder, Feeder, Feedermax, Panamax, Post Panamax, New Panamax, and Ultra Large Container Vessels (ULCV).

The containerships' size moved from few thousands of containers in the 60s to more than 20000 TEU with a remarkable growth during the decades, especially starting from the 90s (Figure 4).

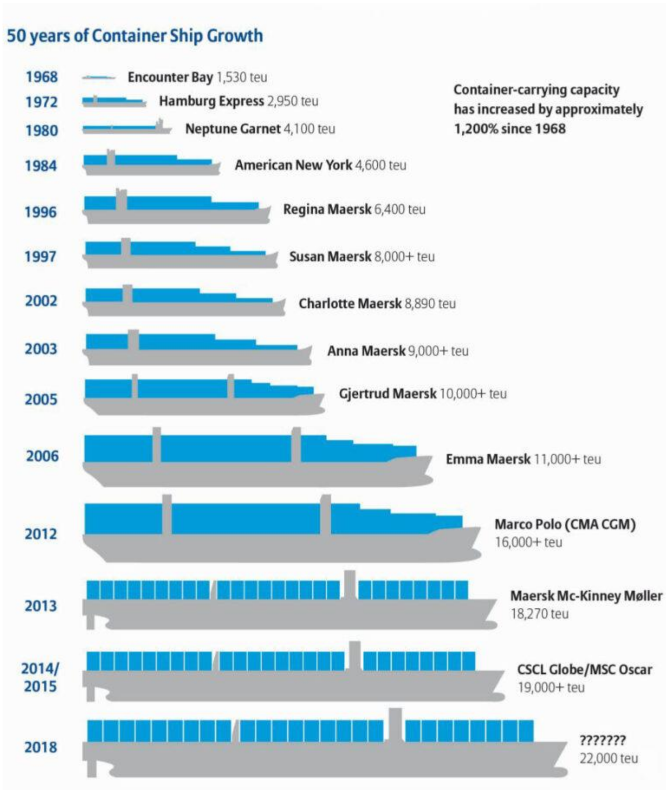

Figure 4 50 years of container ship growth – 2019 [Source: Il gigantismo navale (2019)]

As well as the size of the containerships, the container-carrying fleet's total capacity continued to grow. In Figure 5, we can see this tendency, although the shrinking demand caused by the world financial crisis in 2008.

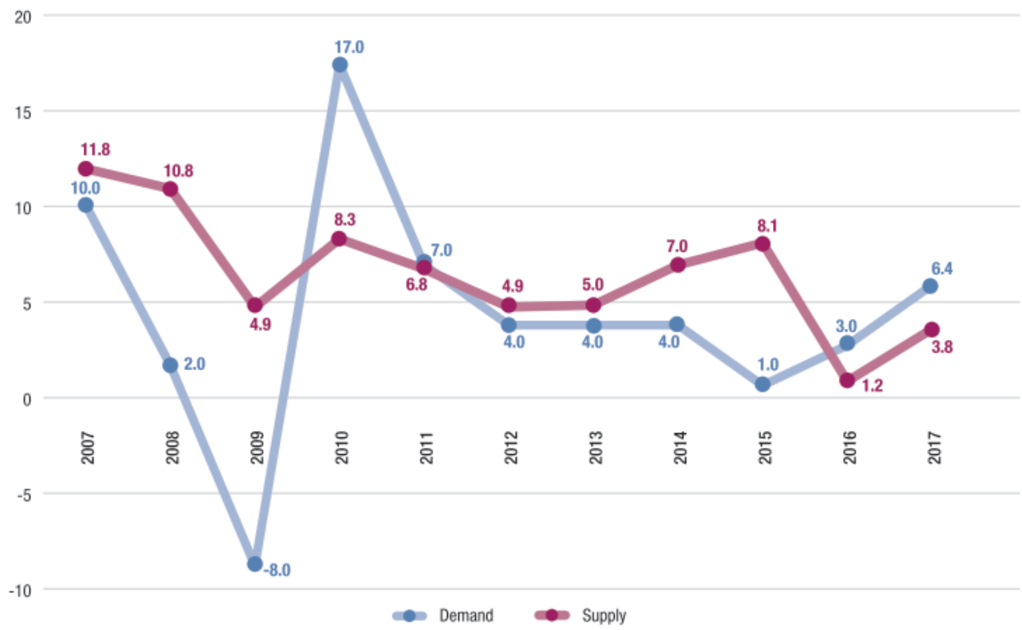

Figure 5 Growth of demand and supply in container shipping 2007-2017 [Source: Review of Maritime Transport (2018)]

Analyzing this last graph, it is possible to affirm that the shipping companies invested year by year on the ships' capacity even during the great recession. Looking at the graph indeed, in 2009 there was about 50% of the actual fleet. The reasons of this increment in the fleet can be explained through two main factors:

- the advantageous interest rates related to the construction of new mega-ships;
- the perspective that the demand would be increased again[3] [10].

The growth and the use of many mega-ships during the economic crisis have determined a reduction of the freight rates (the unit rate applied for the transport of each container) as well as forcing the shipping companies to slow down the vessels (*slow steaming*[4]) to decrease the fuel consumption and thus reduce the costs. These two operations were the most attractive solutions for the shipping companies to try to fill the gap between the demand and the supply without sacrificing the *economies of scale*.

The concept of *economies of scale* is driven by the existing relationship between the growth of the capacity and the decrease of the unit cost for transport, translating in a greater profit for the shipping companies. Although the concept of *economies of scale* might seem barely simple, the achievement of it needs two crucial considerations:

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[3] *This seems to be true looking at the last period (2015-2017). However it is important to consider that the tendency of this positive increment might be correlated also to other aspects such as a general consolidation of the market, a mixing of the strategic alliances, and the recent development of the e-commerce [11].*

[4] *The slow steaming technique permits to bought time in the market instead of having to wait for a new contract empty as well as lowering significantly* ($consumption \ \alpha \ speed^3$) *the fuel consumption and the fuel costs* [52].

1. The containerships must travel with a high filling rate and so, the demand of transport capacity, should grow with the supply;
2. It is necessary to consider the implications generated by the *economies of scale* in terms of infrastructure and transport networks in the hinterland.

These aspects – especially the latter - hide a series of limitations that must be considered in perspective of a further development of the naval gigantism. In the following list the potential infrastructural, energetic, safety and economic constraints are reported [11]:

- **Infrastructural constraints**: these limitations emphasize the induced pressure on the hinterland connections during the peak hour caused by the megaships, the necessity of infrastructural support to efficiently manage massive quantities in the port area as well as the draft required. Indeed, many of the actual ports cannot guarantee an average depth of 16m [5] , and sometimes that depth is physically impossible to achieve. Finally, there is also an economic component related to the massive costs of these infrastructural works;
- **Safety constraints:** the ships are built following a series of nautical quality to ensure the use also under challenging conditions; this means that the potential accident related to the big vessels might cause damage proportionally critical with the transported cargo. It results in a significant risk and thus an economic limit for the insurance companies that may not be able to cover the damage in case of a *total loss*;
- **Economic constraints:** it is necessary to evaluate if there is a real transport demand able to meet the volumes transported to guarantee the naval gigantism's efficiency. Indeed, the service quality might be compromised if there are no infrastructures and a port's organization capable of managing the volumes disembarked. Moreover, as already mentioned at the point before, the risks taken by the insurance companies in case of *total loss* are enormous, and the insurance costs might become too high for the maritime companies;
- **Energetic constraints:** the International Maritime Organization (IMO) has defined a strategy to decarbonize the maritime transport sector. The agreement - signed by the UN's member States in 2016 - wants to halve the total annual emission before 2050. Since the life cycle of a containership is almost 20 years, the actions must be taken in a short period to have satisfying results in 2050. The strategy encourages the utilization of alternative fuel and obliges – starting from 2020 – using low sulphur oil.

The constrained just highlighted caused a sort of consciousness that the naval gigantism might be near to saturation because of a series of cascading effects related to these limitations. First of able, the achievement of the economies of scale depends on the filling rate of the bigger vessels and today, shipping lines have difficulties reaching the utilization rated needed. According to the *International transport forum,* the utilization rate of an 18 000 TEU ship to be cost-saving in relation to a fully loaded 14 000 TEU ship is approximately 91%, and - depending on the alliances - this rate actually fluctuates between 65 and 103%[6] [12]. Secondly, the risks related to the losses in case of an incident have important impacts: considering a total loss and subsequent removal of

[5] Average depth in the last generation of megaships with length >400m [Source: [11]]
[6] These utilization rates are evaluated assuming a ship loaded at 85% of its theoretical capacity (so 65% of 85% and 103% of 85%).

wreck of a 19000 TEU the potential losses estimated are more than 1 billion $[7] to add to the environmental damage and the time needed to remove all the containers (assuming that it was possible at all) which could take more than 2 years [13]. It is then necessary to carefully follow the development of the demand and the supply during the years to be competitive in the market. The years before the economic crisis showed substantial growth of the demand, forcing the maritime companies to order bigger containership to be competitive and satisfy the demand. The following recession period then brought to a collapse of the demand, causing some important company's financial failure (e.g. Hanjin Shipping) partially connected to the time discrepancy between the construction of new mega-ships and the demand variations. Moreover, the use of slow steaming technique is not sufficient to cover this divergence because further reductions of the sailing speeds could be no more beneficial both from an economic and a technological perspective; shipper's losses might become higher than the gains and a lower speed may cause damage to the ship's engine. Finally, many adaptions in the ports might be required to receive the mega-ships. These changes, such as deeper access and new lock system, longer and stronger quays, new cranes, have both economic and physical limitations.

2.1 THE GROWTH OF HUB AND SPOKE STRATEGIES

The expansion of naval gigantism significantly impacted maritime transport, affecting the port choice and port competitivity. The ports' infrastructural limits due to the advent of mega-ships brought to a reassemble of the ship trajectories based on the *hub and spoke strategies* [11]. Together with the development of strategic alliances, this system started a process focused on the cost's minimization through a relocation of the ports (nodes) and the connections (links). It aims to consolidate the big volumes (international deep-sea shipping) in few mega ports located in proximities of the major maritime shipping routes and then redistribute the containers in smaller ports using feeder ships (**coastal or short-sea shipping**). From an operational perspective, the transformation of a port in a hub can be described as replacing the mother ships with feeder ships to ensure the ship-to-ship transfer. This procedure is an evolution from a direct service - a default configuration with a sequence of ports (A,B,C) served by the same shipping route - to a new structure can be described by four models [14] as shown in the following figure.

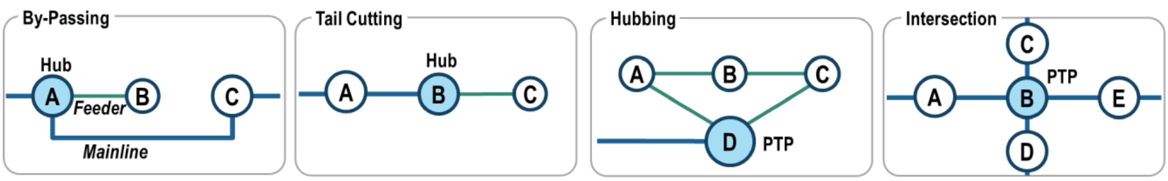

Figure 6 Transshipment patterns [Source: Port Economics, Policy and Management (2020)]

- **By-passing**: mainly because of a loss of importance of the intermediate ports and a crucial decrement of the volume, a port called may be dropped along a port sequence and replaced by a feeder service (B). In this case another port (A) has to handle also the throughput of the feeder port (B);
- **Tail cutting**: similar to by-passing, but in this case the further port along a sequence is replaced by a feeder service, shortening the path;

[7] *Considering $ 35 000 per container and a fill rate equal to 80%*

- **Hubbing:** the most popular, it creates a new node (hub) to accommodate the larger ships. The ports no longer directly serviced are reached by feeder ships (spoke) with smaller shipping routes;
- **Intersection**: some of the principal services are connected by two or more new links, to reach different markets.

Among the different operational models, the hub and spoke scheme aims to improve the overall efficiency and geographical coverage of the maritime container shipping network with smaller ports no longer served by the larger ships but through feeder ships (*spoke*) with short shipping connections. Nevertheless, it is necessary to consider the relevant costs related to the transshipment operations and the feeder services required in a hub and spoke strategy as well as the risks linked with it. It is essential to consider that the infrastructures needed to receive the last generation of mega-ships involve expanding ports, and, in many cases, this is financed by public contributions. It should be considered thereby – from a community point of view - if it is worth investing these limited assets to support the naval gigantism or if it is better to promote a more equilibrated distribution of the volumes between the ports, losing the attractiveness of the mega-ships and the role of hub. On the other hand, it is evident that the role of the hub has important benefits such as including the connection with the international routes due to the possibility to receive the last generation of containerships.

3 IMPACTS IN PORTS, VERTICAL INTEGRATION, AND SOCIAL COSTS

The more efficient cargo movement due to containerization impacted the maritime freight transport with a profound change and a strong growth of the traffic. Among the different consequences of the mega-ships as the impacts on maritime ecosystems and the climate issues, the construction of these containerships determined important infrastructural and organizational effects on the ports, pressing the ports to increase their depth. This determined new challenges in the ports as cooperation between the tiers of the supply chain, the research of more efficient solutions to move the cargo, and the integration of multimodality. The use of transport mode as road freight, rail, and barge became more frequent (especially in the Northern Europe ports), increasing the vertical coordination between the shipping lines and terminal operators. The development of port hinterland, perceived as an opportunity to improve the global freight distribution efficiency, brought to a collaboration between ports and intermodal operators.

3.1 PORT REGIONALIZATION

The advent of global supply chains in gateway ports identifies the port as a replaceable chain element, with relatively weak negotiating power. This global-oriented perspective shifts the focus of the shippers to services not strictly oriented to the gateway but more related to the hinterland connectivity and the port community's ability to cooperate within the logistics network. The reliability and the capability of a port deeply affect the shipper's choices, and the ports can increase their attractiveness by efficiently use their capacity and the connected hinterland. The conventional strategy to address the capacity of a port - and thereby increase efficiency - is moving some port function into the hinterland, reducing the gateway's pressure [5]. The expansion of terminal facilities and the purchase of more efficient intermodal equipment are the last phase of the port development and in the literature is called *"port regionalization"*; a gradual process that provides continuity between the maritime and the inland transport system.

Analyzing the hinterland side, to guarantee connectivity with the inland, a higher level of integration between the shippers and intermodal transport systems as on-dock rail transshipment facilities or the use of fluvial barges is necessary. These intermodal developments enhance the regionalization phase, shifting some of the port's functions (as collection and distribution) to the hinterland, preventing the congestion of the seaport areas. To decrease inland logistics costs, shipping lines can adopt different strategies like management of container terminal operation and inland transport, as well as structural co-ordination with independent inland transport operators or selective investments in key supporting activities. Thus, Port regionalization is more than just simple decentralization since it considers higher levels of integration with the foreland and inland freight distribution system. However, this phase is not easily achievable because generally, the shipping lines generally do not own inland transportation, and there is no integration on the transport chain between the different actors due to commercial constraints.

3.2 HINTERLAND CONNECTIVITY AND SOCIAL IMPACTS

Containerization and port regionalization intensify the port activity and competition, increasing the ports' cargo movement. The tendency to move some port functions to the hinterland is related to the difficulties to increase the in-port capacity due to the infrastructural and economic constraints of the ports [5]. However, the continuous growth of the containerships determines the freight volumes' increment, intensifying the pressure on the hinterland connections (especially road network) with social impacts such as congestion effects and local and global pollution.

While efficient ports are necessary to economic growth, the related ship traffic, the handling of the goods in the ports and the hinterland distribution have several negative environmental impacts. These effects may be direct – taking place in the port area – or indirect - due to ship movement and the use of other kinds of transportation modes in the transport chain - [15]. For these reasons, the environmental impacts of ports can be subdivided into three categories:

1. Impacts caused by port activity itself;
2. Impacts caused at sea by ships calling at the port;
3. Impacts from inter-modal transport chains serving the port hinterland.

The first category regards the emissions of the handling equipment and their noise levels. The second one, includes the shipping, with environmental impacts both in the ports and the ports' proximity. The latter, includes the social costs of hinterland distribution, as congestion and air pollution.

Among these categories, different kinds of issues take place. Direct effects such as exhaust emissions of CO_2, NO_x and SO_2 The combustion of ship's heavy fuel oil or marine distillate oil has environmental problems in the ports area while in proximity of the ports' loud ship engines and machinery used for load-unload activities might have a noise impact. Indirect problems such as hinterland congestion have extended spatial imprint and concerns - especially for large ports – [5]. Road, rail, or barge traffic to and from the port area cause different environmental problems depending on the fuels and vehicle's standard. Generally, transportation by rail, inland waterways and short sea shipping requires less energy per tonne transported than transport by road with fewer emissions of greenhouse gases [15] ; nevertheless, the road haulage still remains the predominant transport mode to move the freight.

4 TRANSPORTATION MODE AND UNITARY COST STRUCTURE

Containerization and the advent of global supply chains increased the pressure on maritime transport, with a concentration of ship calls in a limited number of load centres and maritime transport expansion into the hinterland. These changes became a challenge for many container ports forced to insert *satellite terminal*[8] and transloading activities in port operations to increase throughput and productivity of the port [2] as well as facilitating the rise of gateway ports. Today, most of the European ports act as them (Figure 3) with extended inland networks.

Port regionalization then brings a higher level of integration between maritime and inland transport systems, with the development of intermodal corridors by rail, barge, and inland terminal. However, rail and barge's success are generally limited to a few corridors, making the road haulage the principal transport mode. An extension of Wardrop's first principle of traffic engineering can be used to understand road haulage's success with respect to alternative transport modes. The principle is related to the Nash equilibrium in non-cooperative game theory and describes how "*at equilibrium, the cost of a path with a positive residual capacity is higher, or equal to the cost of any path carrying positive flow"* [16].

$$C_m(x^*) \begin{cases} = C_{OD} & if\ x^* > 0 \\ \geq C_{OD} & if\ x^* = 0 \end{cases}$$

$with:$
$C_m(x^*)$ $generalised\ transport\ cost\ for\ mode\ m$
x^* $decision\ variable\ (flow)$
C_{OD} $minimum\ transport\ cost\ for\ the\ OD\ pair$

According to Wardrop, given a certain OD pair, any generalized[9] transport cost greater than the minimum one should be removed from the network because it is more expensive and thus not utilized. Since transportation modes have different cost functions depending on the distance, the three modalities, *road, rail and maritime,* can be represented with three linear proportional unit cost function C_1, C_2 and C_3. Figure 7 shows the suitability of road haulage for short distance with respect rail transport or maritime transport, that instead, become more competitive for longer distances.

[8] "*An intermodal facility built in proximity to the port in order to handle additional traffic*" [18].
[9] *In transport economics, the **generalised cost** is the sum of the monetary and non-monetary costs of a journey. Monetary (or "out-of-pocket") costs include are expressed in €; non-monetary costs refer to the time spent undertaking the journey. Time is converted to a money value using a value of time figure.*

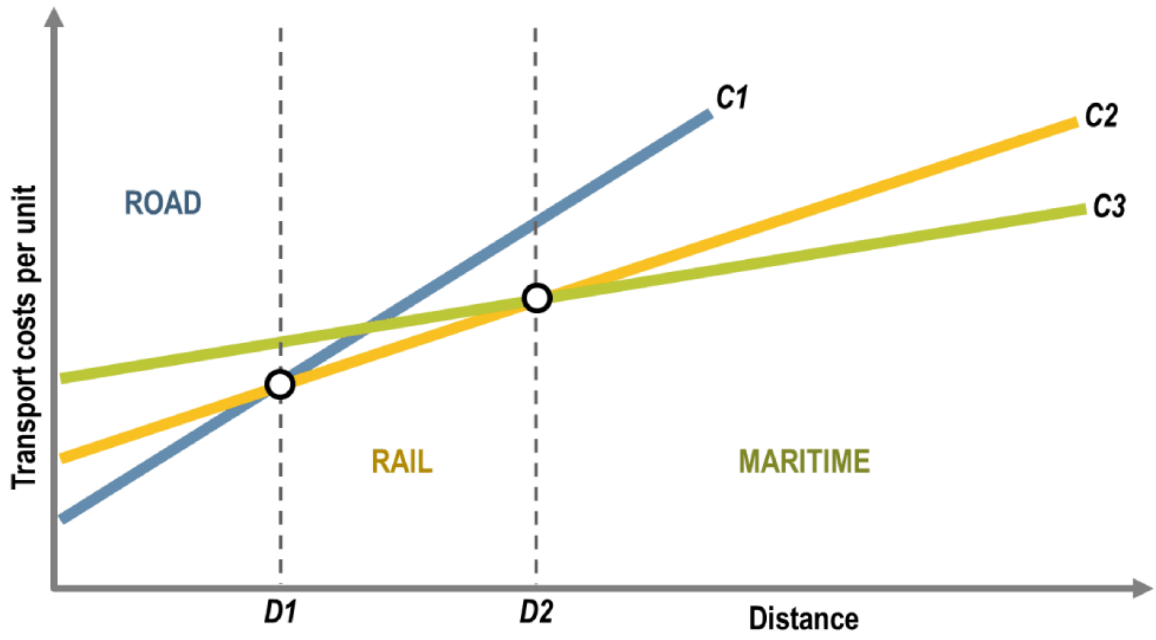

Figure 7 Distance, modal choice and transport cost [Source: (Rodrigue, 2020)]

Although this linear relation is easily understandable, it is not properly correct. The reason is that it assumes the interchangeably of the different transportation modes without considering that transport modality such as rail and maritime cannot be used as a single option because of their accessibility to the network. Indeed, generally they need a road segment at the beginning and at the end (*pre and post-haulage*) to reach the locations, modifying their cost structures. For this reason, the alternative to the door-to-door road haulage is usually called intermodality (or *combined transport*), where more than one transportation mode is involved.

The shift to intermodal transport can be achieved with an overall reduction of the costs, but both political and practical reasons make this implementation complicated. First of all, it is necessary to invest in dedicated infrastructures that are unlikely to earn back in a short time. Secondly, extra transshipment of cargo from one mode to another one cause additional generalized costs such as monetary costs (terminal handling) time costs (delays) and risk costs (damage) [17] Finally, there are important commercial and normative constraints which make the intermodal transport less attractive than the road transport for the market. For these reasons, intermodal transport is usually a valid alternative to road haulage only if large volumes are handled and over long distances. A more detailed analysis of the costs is reported in the successive chapters.

4.1 INLAND TERMINALS AND FAST CORRIDORS

The concentration of cargo on limited set port calls and the massification of the flows in the corridors - at some level of activity - results in congestion, experienced delay, and loss of efficiency, promoting the development of *inland terminals* [18]. In literature, a wide range of terms are used to define these facilities (*dry ports, inland ports, inland hubs*) but fundamentally - regardless of the terminology - they can be considered as the extension of some port activities in the hinterland.

Traffic arriving at a transport terminal is generally bound to another terminal with an integrated intermodal transport system in the maritime/land interface to minimize transportation costs and delays. Inland terminals are crucial for developing intermodal networks in ports with high-volume flows, transferring a part of the hinterland's collection and distribution functions to prevent further congestion and preserve the port's attractiveness. They are generally (but not necessarily) located nearby the ports or within the ports, and they complete the intermodal transfer through apposite infrastructures and equipment. The *dry port* thereby, establishes a direct connection between the port and the hinterland through a dedicated corridor (often less than 100km), offering advantages both on the maritime and on the inland site. The port takes advantage increasing its throughput and efficiency without additional land. At the same time, the inland terminals can consolidate containerized shipments with fewer land constraints and more available space for logistical services.

These dedicated rail/barge corridors between the on-dock rail facilities and their satellite terminals are characterized by trains with high frequency and relevant speed (up to 120 km/h) able to improve the service's efficiency. This permits to accommodate additional traffic relieving seaport areas from potential congestion with a reliable connection provided by those *intermodal shuttles*[10]. The inland terminals have a series of important auxiliary activities as well as the core function related to the loading and unloading operations. The large volumes managed provide the possibility to extend the inland terminals' capabilities with a variety of functions such as warehousing, distribution, and collection, making these crucial facilities nodes of the regional market. Moreover, they have also other functions [14] that can be shortly summarized in:

- Rationalization of the freight through dedicated terminals that compose and unload the trains/barges;
- Optimization of the transportation fleet using dedicated equipment to minimize the handling time and thus maximize the revenues;
- Provide information and assistance services to the transport operators/freight forwarders to enhance the shipping experience;
- Crucial connection of the entire transport chain aimed to create a long-term strategy between the different transport modes, increasing the freight transport efficiency.

The infrastructures necessary to make inland terminals accessible have significant effects on the territory, impacting the surrounding traffic basins and thus the traffic flows of the regions. Indeed, the inland terminals may assume the role of load center, with a function like the transshipment hubs in maritime shipping networks. Even though this transshipment function is still marginal in most of the world, transshipment services are becoming more notorious in that locations where recent intermodal services have been improved [18].

In Italy, this logic has been introduced with the development of the so-called "*fast corridors*". The *fast corridor* indeed, allows the customs processes at the dry port, simplifying the entire procedure and relieving congestion of the ports making the rail

[10] *"dedicated transport services operated by rail (or barge) that maintain uninterrupted services between one point of origin and one point of destination, at a fixed time schedule and a fixed composition of vehicles"* [17]

transport more attractive. Nowadays, there are 16 dedicated corridors In Italy (*"fast corridors"*), 7 of them committed to road transport, and 9 used for rail transport.

Fast corridor – rail transport		**Fast corridor – road**	
Origin	*Destination*	*Origin*	*Destination*
Genova Voltri (TC 049Q)	Rivalta Scrivia (TC 85T)	Livorno (TC 063Y)	Interporto Prato (TC 264J)
Genova Voltri (TC 049Q)	Rivalta Scrivia (TC 31TM)	Livorno (TC 063Y)	Livorno (TC 381G)
La Spezia (TC 027V)	Rivalta Scrivia (TC 85T)	La Spezia porto (TC 027V)	Piacenza (TC 14157Q)
La Spezia (TC 027V)	Melzo-Milano (TC 34X)	Genova porto (TC 047X)	Piacenza (TC 14157Q)
La Spezia (TC 027V)	Rivalta Scrivia (TC 31TM)	Genova (TC 027V)	Piacenza (TC 14157Q)
La Spezia (TC 027V)	Padova (TC 316E)	Genova Voltri (TC 049Q)	Piacenza (TC 14157Q)
La Spezia (TC 027V)	Padova (TC 317F)	La Spezia porto (TC 030L)	Piacenza (TC 14157Q)
La Spezia (TC 027V)	Rubiera (TC 000259)		
Genova Voltri (TC 049Q)	Melzo (TC 34X)		

Table 2 Italy - active fast corridors [Source: Agenzia delle Dogane e dei Monopoli]

PART II

THE LOGISTIC NETWORK AND THE TRADE OF PIEDMONT REGION

1 DESCRIPTION OF SYSTEM

The strategic position of Piedmont region, located in the Padana valley at the intersection of two TEN-T European corridors (corridor 24 Rhine-Alps, and corridor 5 Mediterranean), gives to the territory a fundamental role in terms of relations, trade and economic flows. The region presents a capillary road network, homogeneously distributed in all the territory and easily accessible by all the major cities. The railway network extends in Piedmont for about 2660 km and it is owned in large part – 79% - by *Rete Ferroviaria Italiana S.p.A.* [19]. The *RFI* network is divided into three categories: core, complementary, and node lines and differs in terms of traffic density, infrastructure quality, and functionality (respectively, a connection between major cities, a connection of regional basins, and connection between core and complementary lines). The entire network is controlled and regulated by the infrastructure operator, which sells the availability of the railway infrastructure (*tracce)* according to the rules and the deadlines indicated on the network statement (*PIR*[11] *document*). In freight transportation, the lines are classified in according with their infrastructural characteristics, and the circulation of freight trains takes place in specific time slots according to the schedule defined in the railway timetable.

For what concerns the logistics system, the Piedmont region is well equipped with 8 logistic nodes connected to the most important freight corridors.

These nodes differ in terms of functionalities and activities:

- **Villanova d'Asti, Arquata Scrivia** (Alessandria) and **Rivalta Scrivia** mainly propose logistic and value-added services, offering terminal activities aimed to consolidate the flows. **Villanova d'Asti** is almost completely dedicated to logistic services related to the automotive sector (handling, line feeding, storage, packing, transport and shipment), while **Arquata Scrivia** mainly manages freight of the port of Genova (by truck, the railway connection is no more active). **Rivalta Scrivia** instead acts as a dry port for Genova and La Spezia's ports with important railway connections.
- **S.I.TO Orbassano** (Torino) offers logistic services through the managing company S.I.TO S.p.A., while **CIM Novara** is mainly specialized to intermodal transport;
- **Domodossola** and **Candiolo** (Torino) have exclusively terminal functions (intermodal transfer), while **Vercelli** also offers a stock service.

[11] *Prospetto Informativo della Rete*

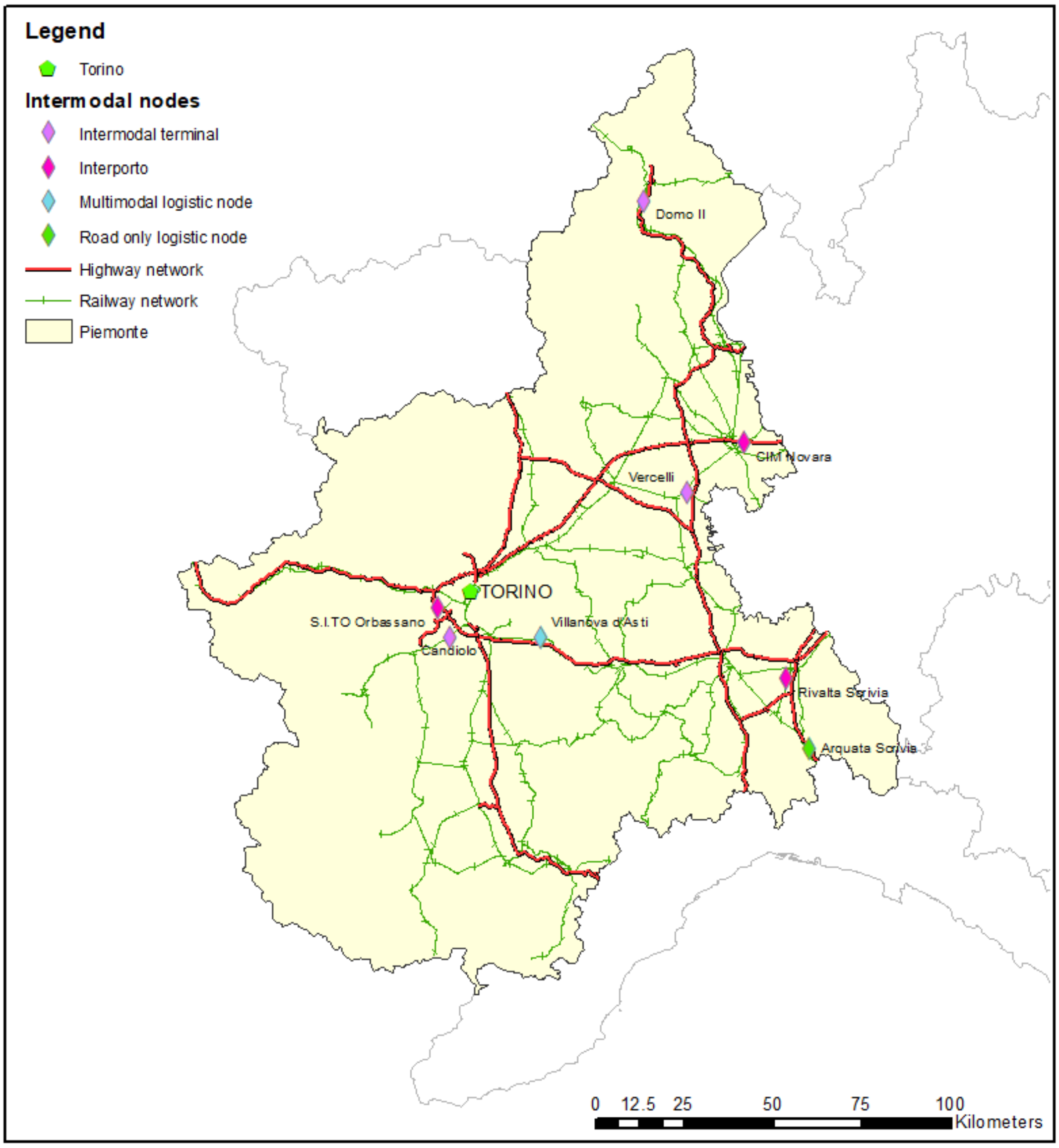

Figure 8 Intermodal nodes in Piedmont Region

In addition to this well-coordinated infrastructural and logistic network, the vicinity to the Ligurian ports, gives to the Piedmont region a key role for the maritime trade [19], [20]. However, despite the robust intermodal structure, the logistics companies and the transport operators consider the proximity to the Ligurian ports a factor in using road transport instead of intermodality.

According to the analysis carried out by PRMT[12] in 2020 indeed, almost 100% of goods moving in Piedmont or loaded in Piedmont and destined to other Italian regions use road transport (respectively 100% and 96%). The part of goods transported by rail instead, is higher in international relations due to the longer distances and the policies adopted in foreign countries such as Switzerland [21].

[12] *Piano Regionale Mobilità e Trasporti*

2 THE INTERNATIONAL TRADE OF PIEDMONT REGION

The geographic location of Piedmont near to the Italian borders determines freight volumes not only generated by the region itself but also in transit. In general, the traffic can be summarized into 3 specific categories:

- Transit flows (with O/D[13] outside the region);
- Internal-external and external-internal flows (with Origin or Destination inside the region);
- Internal flows (with Origin and Destination inside the region).

The volumes which belong to the first category use the core infrastructure, while the other flows are connected to the location of the companies, and they can be represented in a network scheme formed by logistic nodes, clusters, and corridors at regional and subregional scale. To achieve a sustainable future in line with the national and European objectives – see transport white paper (2011) and European Green Deal (2020) - it is necessary to know the different dynamics that can generate transport demand. The know-how of traffic flows, together with the geomorphological characteristics and the socio-economic variables of the region, are the first step to understanding the actual and potential freight demand.

Among the freight destined abroad, the Piedmont region is the 4th Italian region for export [20]; considering the different geographical destination areas, it emerges that ≃60% of the outcoming flows is directed to the partners of the European Union [22]–[26]. The regional market's principal destinations have been analyzed by studying the industrial districts' export-orientation using the provincial Istat. The analysis shows that France, Germany, and Spain (see attachment [1]-[6] for details) are the most relevant countries for export. Exports are significant also in Poland - due to the strong commercial connections with FCA group – Belgium, Austria, Netherlands, and Romania. The exports to non-EU countries instead, are headed by United States, China, and UK[14]. Also Turkey needs to be mentioned in this ranking, showing reliable trade due to mechanical products and transportation sector as in Poland.

The freight is mainly moved by truck, but for those volumes moved by rail, the intermodal nodes of the Piedmont region play a key function. Considering the international rail traffic, a short analysis of the different logistic nodes is provided:

In **S.I.TO. Orbassano**, the 48% of the rail traffic, regards international trains (the other are national trains) [20]; most of them are directed to Modane (FR) through the AFA (Alpine Rail Motorway) corridor Aiton-Orbassano. This connection provides regular service between France and Italy, guaranteeing an environmentally responsible trip and mainly transporting dangerous freight. Instead, the intermodal node of Candiolo provides almost exclusively international services (96% of the total traffic) towards Modane [20]. However, the number of trains of this terminal is reducing year by year due to the difficulties of crossing the border with France (Fréjus tunnel) and because of the congestion of Turin's node. **Domo II** also presents almost the totality of international traffic, representing the access to the Sempione tunnel. Another important connection is **Villanova d'Asti**, mainly characterized by transport of automotive components directed to Eastern Europe (Turkey and Poland) with a share of international traffic

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[13] *Origin-Destination*

[14] *Since 2020 the national statistic consider United Kingdom as non-EU country due to Brexit*

equals to ≃ 55% [20] ; the complementary component regards national transfers, and it is almost entirely covered by trains to and from Torino Orbassano (they are mostly the same trainsets returning from Eastern Europe that stop at S.I.TO). Finally, a relevant mention is necessary for **CIM Novara**, characterized by a share of international services equals to ≃95% of the total traffic [20]. The trains are mainly directed/originated to and from Northern Europe through Domodossola and Sempione tunnel, running just for short distances in the national territory (≃ 100 km between Novara and Domodossola and ≃ 200 km between Novara and Modane). Considering the **Vercelli** logistic intersections, this is not relevant for international transport; it shows around 60 trains/year (both international and national), making this node negligible for the analysis.

Although rail transport is relevant for international flows, road transport remains the principal transport mode. Every year, The Swiss federal office of transport (FOT), together with the European Commission, estimates the annual freight volumes crossing the Alps; in 2017 a total volume of 82.9 MLNt has been estimated, with a share of ≃53% between Italy and France and a share of ≃47% between Italy and Switzerland. These volumes are coherent with the Italian government's evaluation that in 2017 has registered a total terrestrial volume exchanged through the western alpine arc greater than 40 MLNt [27], with more than 20 MLNt between Italy and France (Table 3).

Freight terrestrial volumes through the western alpine arc	Traffic volumes [tonnes]
France – Italy	20 361 075
Spain – Italy	9 263 915
United Kingdom – Italy	4 282 345
Portugal – Italy	1 155 152
Benelux – Italy	130 203
France – Eastern European countries	1 935 059
Spain – Eastern European countries	5 139 518
Portugal – Eastern European countries	284 325
TOTAL	42 551 592

Table 3 Freight terrestrial volumes through the western alpine arc [Source: Elaboration of Quaderni dell'osservatorio -11 on ISTAT,Coeweb,Eurostat and Bundesamt data (2017)]

Analysing the transport mode used to cross the western alpine arc connections, the road haulage is the predominant one (Table 4), with a total of 40.7 MLNt (95.6 % of the total amount). This traffic is mainly distributed on the following crossing passes: Ventimiglia, Frejus and Mont Blanc, covering a share of 92.3% of the total traffic exchanged between the two countries.

Crossing place	Trucks [n]	Road [ton] (2017)	Rail [ton] (2017)	Rail [ton] (1997)
Fréjus	740 600	11 130 600	2 793 200	10 111 500
Ventimiglia	1 465 000	19 534 500	672 700	875 000
Monte Bianco	621 500	9 445 500	-	-
Monginevro, Moncenisio, Tenda, San Bernardo	56 700	584 600	-	-

Table 4 Actual traffic - Western alpine arc [Source: European Commission DG MOVE, FOT, Quaderni dell'osservatorio - 11 (2017)]

Among the different routes, Ventimiglia is generally preferred because of its affordability in terms of costs (no tool), making this route the most utilized.

A final remark regards the rail transport; comparing the actual rail traffic with the volumes of 20 years ago, a drop of $\simeq$70% occurred. This decline can be attributed mainly to the inadequacy of the service provided by the Fréjus tunnel.

Looking at the years 2018 and 2019 then, the number of goods carried across the western alpine arc was almost the same amount registered in 2017, reflecting the relatively modest GDP growth above all the European countries. The same conclusion occurs for the modal share that moved from 7.7% in 2017 to 7.8% in 2019 [28].

3 THE NATIONAL TRADE OF PIEDMONT REGION

As in the international trade context, the national freight flows of the Piedmont region are almost entirely transported by road. According to the analysis carried out by PRMT[15] in 2020, the goods moving in Piedmont or loaded in Piedmont and destined in other Italian regions use road transport respectively for 100% and 96% [19].

Since the distances are smaller with respect the international context, the national trade analysis has been evaluated by dividing the region into 4 quarters: North-West, South-East, South-West, and North-East, as suggested in the PRMT. The choice of this territory dimension between the municipalities scale and the regional scale is particularly suitable because it permits to observe the logistic dynamics and analyse each single quarters' freight transport flows. The next sub-paragraphs thus will study each sector's socio-economic and territorial condition, followed by a short analysis of its intermodal nodes.

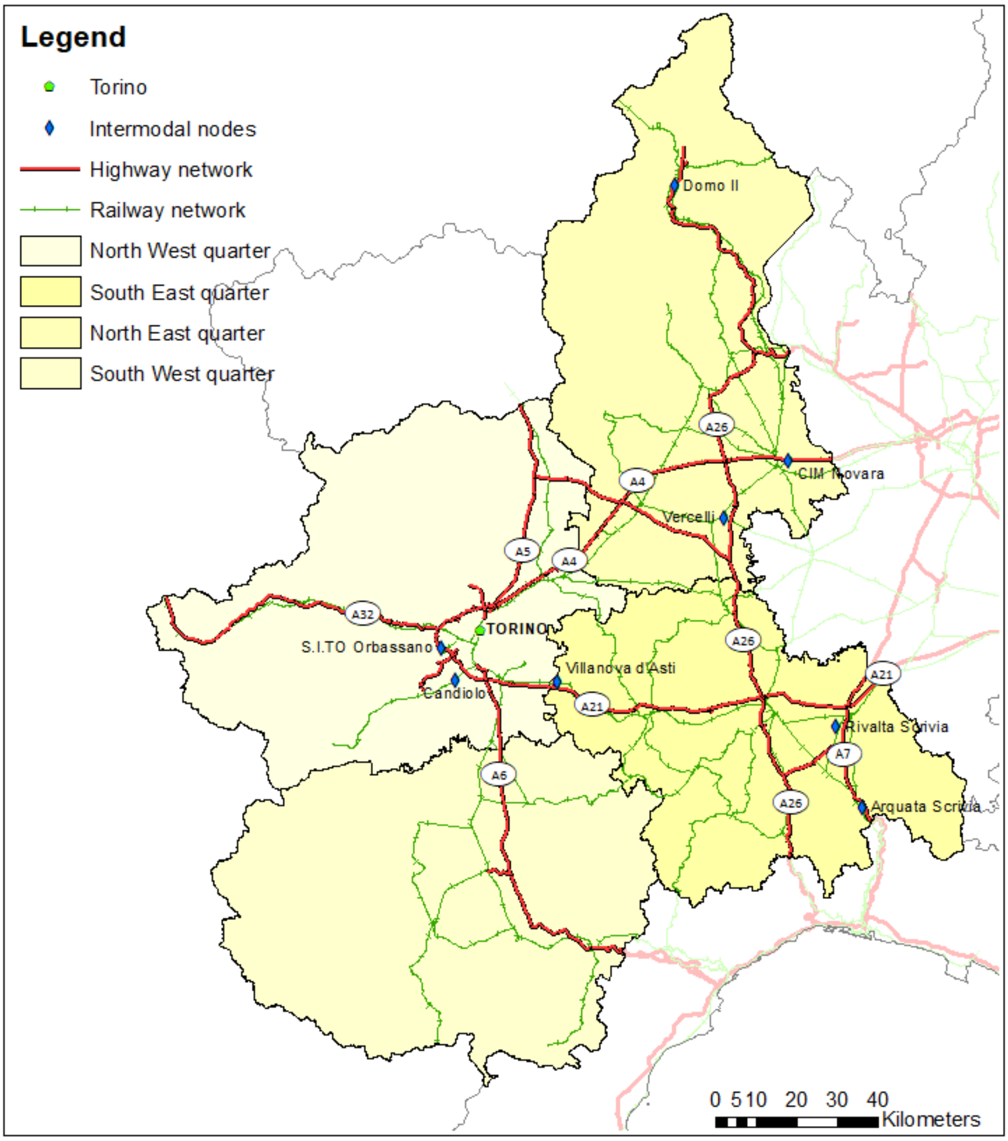
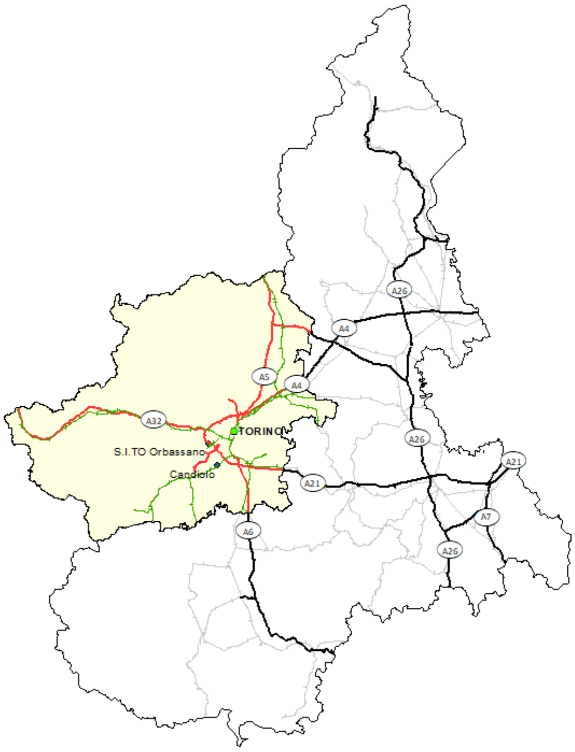


Figure 9 Quarters of Piedmont region

[15] *Piano Regionale Mobilità e Trasporti*

NORTH WEST QUARTER

The North-West quarter is located in between France, Valle d'Aosta and the provinces of Biella, Vercelli, Alessandria, Asti and Cuneo. The manufacturing companies are mainly located in Torino's metropolitan area, where the vehicle industry and engineering sector dominate. Torino presents a densely urbanized node with a lot of activities and a heavy infrastructure network as well as being a fundamental intersection with important highways such as: Torino-Trieste (A4), Torino-Aosta (A5), Torino-Savona (A6), Torino-Brescia (A21) and Torino-Bardonecchia (A32). The latter motorway A32 connects Italy to France through the Fréjus tunnel. Instead, the main railways lines are the ones directed to Milano, Genova (via Alessandria), Savona and Modane (FR).



As a result of this extended capillarity, the North-West quarter is the quarter that produce bigger freight volumes towards the national territory with > 34 MLN-TON (transported by road) originated or destinated to the metropolitan area of Turin [20] ; the node of Turin and its ring road indeed, result particularly congested with > 7 MLN heavy vehicles/year. According to 5T simulated data (2017), heavy vehicles' distribution is also relevant on the highway A21, A4, and A4/A5 branches [20]. In the North-West quarter the intermodal nodes of S.I.TO. Orbassano and Candiolo are located. They differ in terms of functionalities and activities:

S.I.TO Orbassano is an important generator and attractor of international and national traffic (also for the near Ligurian ports). The national rail traffic is relevant for regional destinations (particularly Cuneo and Vercelli) and Southern Italy destinations (Melfi, Fossacesia, Marcianise).

Candiolo terminal instead, manages almost exclusively international traffic with small flows to Torino and Cuneo due to the difficulties faced by the regional rail network to satisfy the European standards.

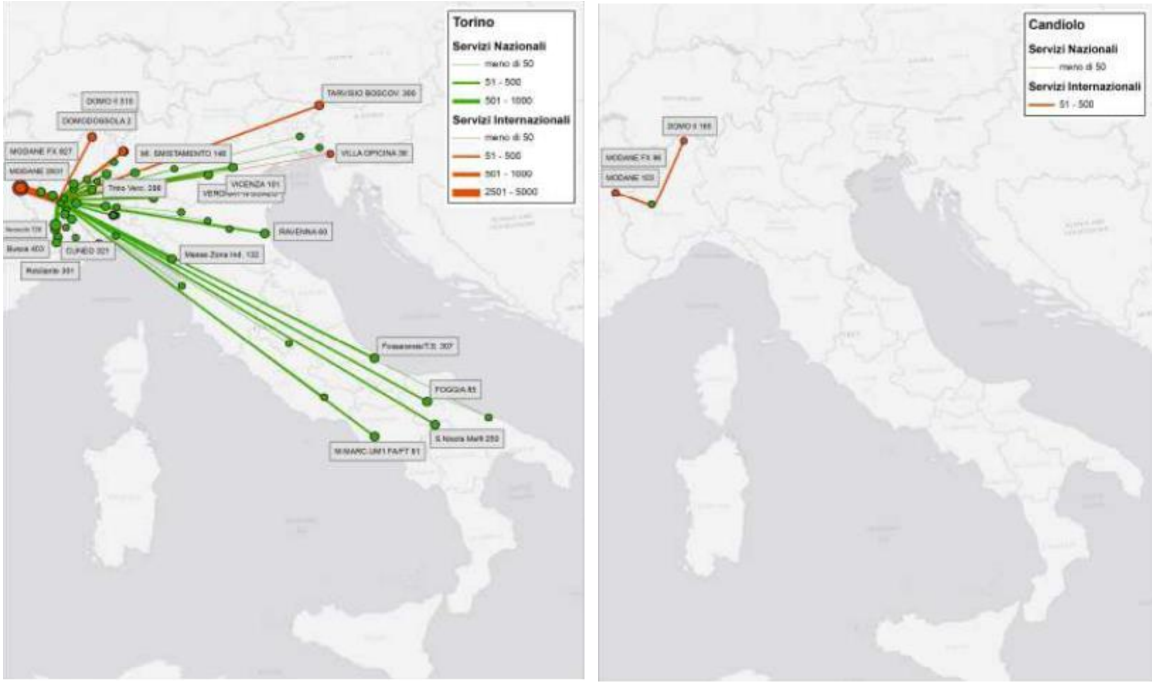
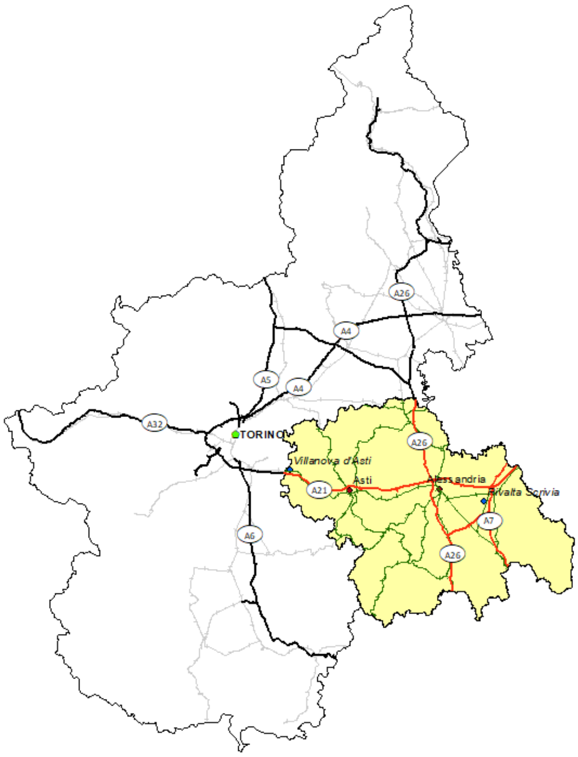


Figure 10 Freight trains from/to S.I.TO. Orbassano and Candiolo [Source: Piano Regionale Mobilità e Trasporti (2020)]

SOUTH EAST QUARTER



This quarter borders with three other Italian regions (Liguria, Emilia-Romagna, and Lombardia), and it is composed of Alessandria and Asti provinces. These two provinces have completely different realities; in Alessandria, there are companies more oriented to the manufacturing and logistic sector, while in the proximity of Asti, there are many small municipalities involved in the production of agri-food products [20]. As a result, the freight transport demand and the provinces' traffic volumes are different. In according with Istat (2016), Alessandria exchanges volumes mainly with Genova (2,7 MLN t/year), Milano (1,4 MLN t/year), Turin (1,4 MLN t/year) and Emilia Romagna (1,1 MLN t/year), while Asti has connections with Veneto (500 000 t/year), Emilia Romagna and Toscana [20]. The presence of the **Rivalta Scrivia** logistic node (in Alessandria's province) gives to the territory an important logistic function with significant highway connections such as Torino-Brescia (A21), Genova-Milano (A7), Genova-Sempione (A26), and many relevant secondary railway lines. According to 5T simulated data (2017), the heavy vehicles distributed in the highway network are relevant in the A21 direction of Piacenza and A7 direction of Genova.

As in the North-West quarter, the intermodal node **Rivalta Scrivia** works as a generator and attractor of traffic, especially for its proximity to the Ligurian ports. The strategic position of this facility distinguishes Rivalta Scrivia to the other intermodal nodes in the region, working as dry port for the ports of Genova and La Spezia. Although the break-even distance between Rivalta and Genova is not achieved (about 70 km), the use of railway connections *La Spezia-Rivalta Scrivia* and *Genova Voltri-Rivalta Scrivia* are supported through a special agreement *(fast corridor)* between the ports and the customs. The *fast corridor* allows the customs processes at the dry port, simplifying the entire procedure and relieving congestion of the ports, making the rail transport more attractive.

Villanova d'Asti, instead, is characterized mainly by international flows, with national share almost exclusively dedicated to the connection with Torino Orbassano. Significant railway flows are observed on the Torino-Alessandria and Novara-Alessandria-Genova (via Ovada) lines [20].

Figure 11 Freight trains from/to Rivalta Scrivia and Villanova d'Asti [Source: Piano Regionale Mobilità e Trasporti (2020)]

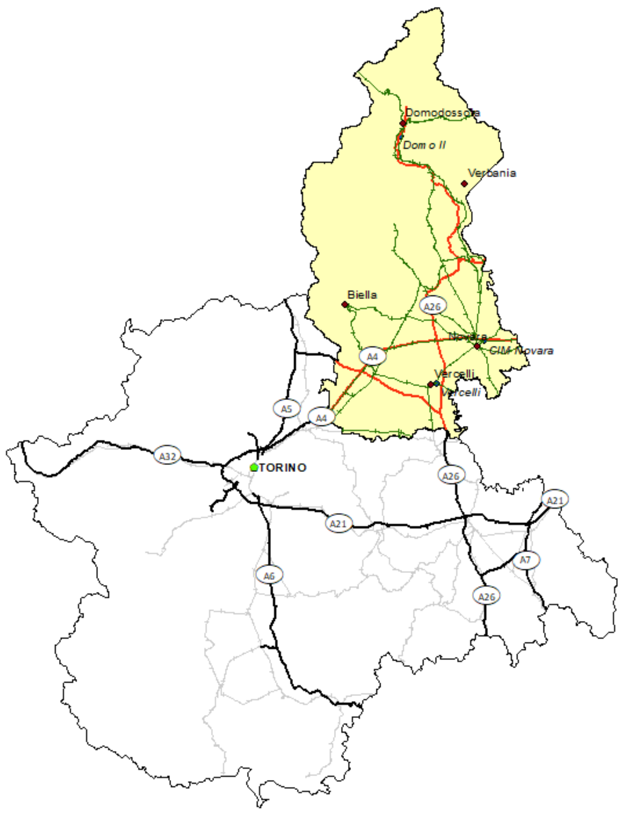
SOUTH WEST QUARTER

The South-West quarter presents the largest province (Cuneo) of the region, and it borders with the metropolitan city of Turin, the province of Asti, Liguria region, and France. The territory presents an infrastructural network below average that limits the development of the entire area; incomplete motorway connections (Asti-Cuneo) and some abandoned railway line indeed, make this quarter the less provided in terms of logistic services.

Despite of its low accessibility, the province of Cuneo is - after Turin - the one with the highest volume of road traffic destinated to the national territory. The distribution of the goods in this province – according to Istat (2016) - has the largest flows (> 1 MLN t/year) with Torino, Asti, Savona, Genova and Emilia Romagna region; the most significant flows are those with Liguria.

NORTH EAST QUARTER

This quarter is in a “hinge” position between the metropolitan areas of Turin and Milan. It is constituted by the provinces of Biella, Novara, Vercelli, and Verbano Cusio Ossola (VCO), and it borders with Switzerland and Lombardia region. Among the cities just listed, Novara is the one with the better infrastructural network and logistic service; its strategic position (at the intersection of two European corridors *TEN 5 Mediterranean* and *TEN 24 Rhine-Alps*) makes this node extremely attractive, as demonstrated also by the recent settlements connected to the luxury and the e-commerce sectors. Even the province of Vercelli is well connected to the infrastructural network through A26 and A4 motorways and the Torino-Milano railway line. The remaining provinces of Biella and VCO instead present weak accessibility. According to Istat data (2016) Novara observes traffic volumes > 15.5



MLN t, while the other provinces of the quarter reveal traffic < 10 MLN t but sill significant also with the Ligurian ports.

As already mentioned for S.I.TO and Rivalta Scrivia, even the logistic node of Novara generates and attracts road and railway volumes. However, as in Torino Orbassano, the traffic with the Ligurian ports is mainly characterized by road transport. Moreover, the vocation of **CIM Novara** to international services destined mostly to Northern Europe makes the Novara-Domodossola line particularly busy due to the traffic originated/destinated to the Lombardian terminals.

Domo II instead has important share of rail traffic, representing the access to the Sempione tunnel; however, since this gateway interrupts the *RFI* network, the effective O/D of the trains is not available because *RFI* provides only the O/D belonging to the national network.

Finally, the rail traffic of **Vercelli** is negligible with less than 60 trains/year.

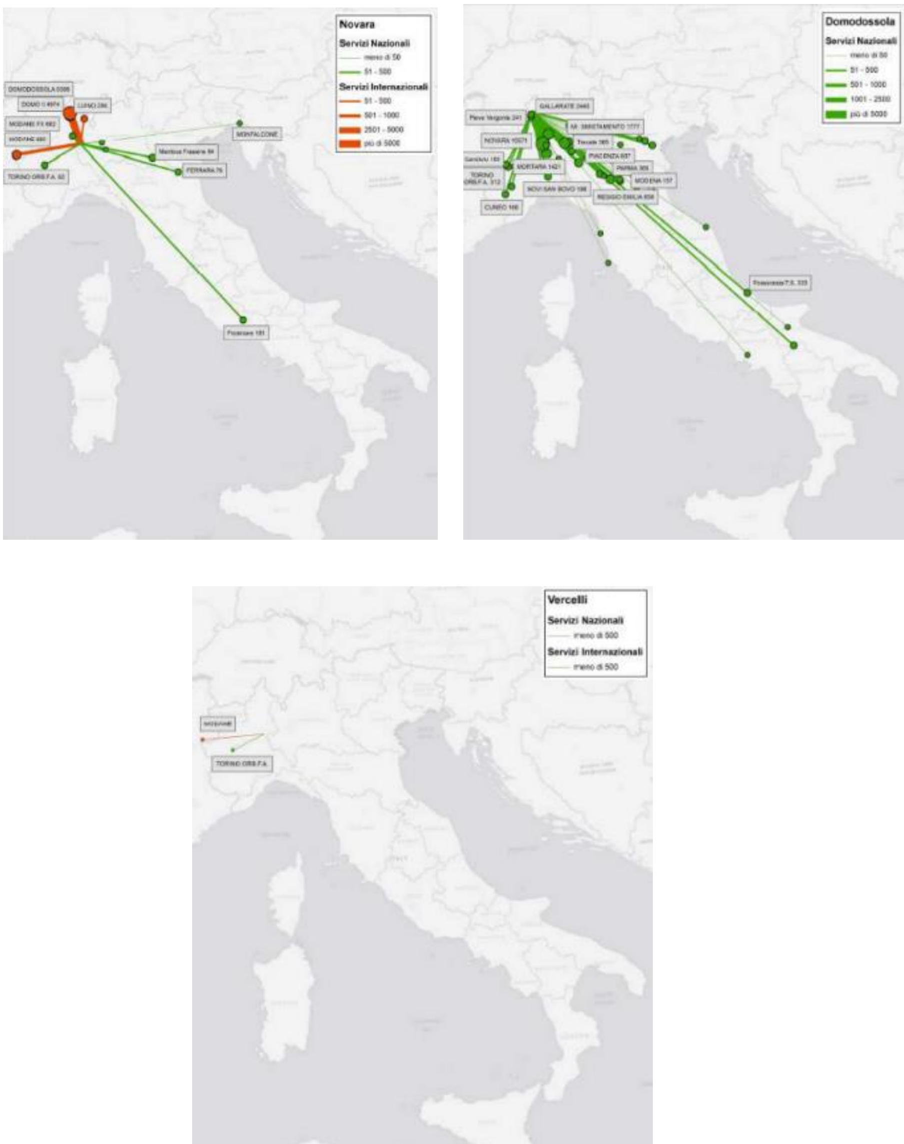


Figure 12 Freight trains from/to CIM Novara, DomoII and Vercelli [Source: Piano Regionale Mobilità e Trasporti (2020)]

To conclude this paragraph, a summary of the most congested roads in the overall regional territory is reported.

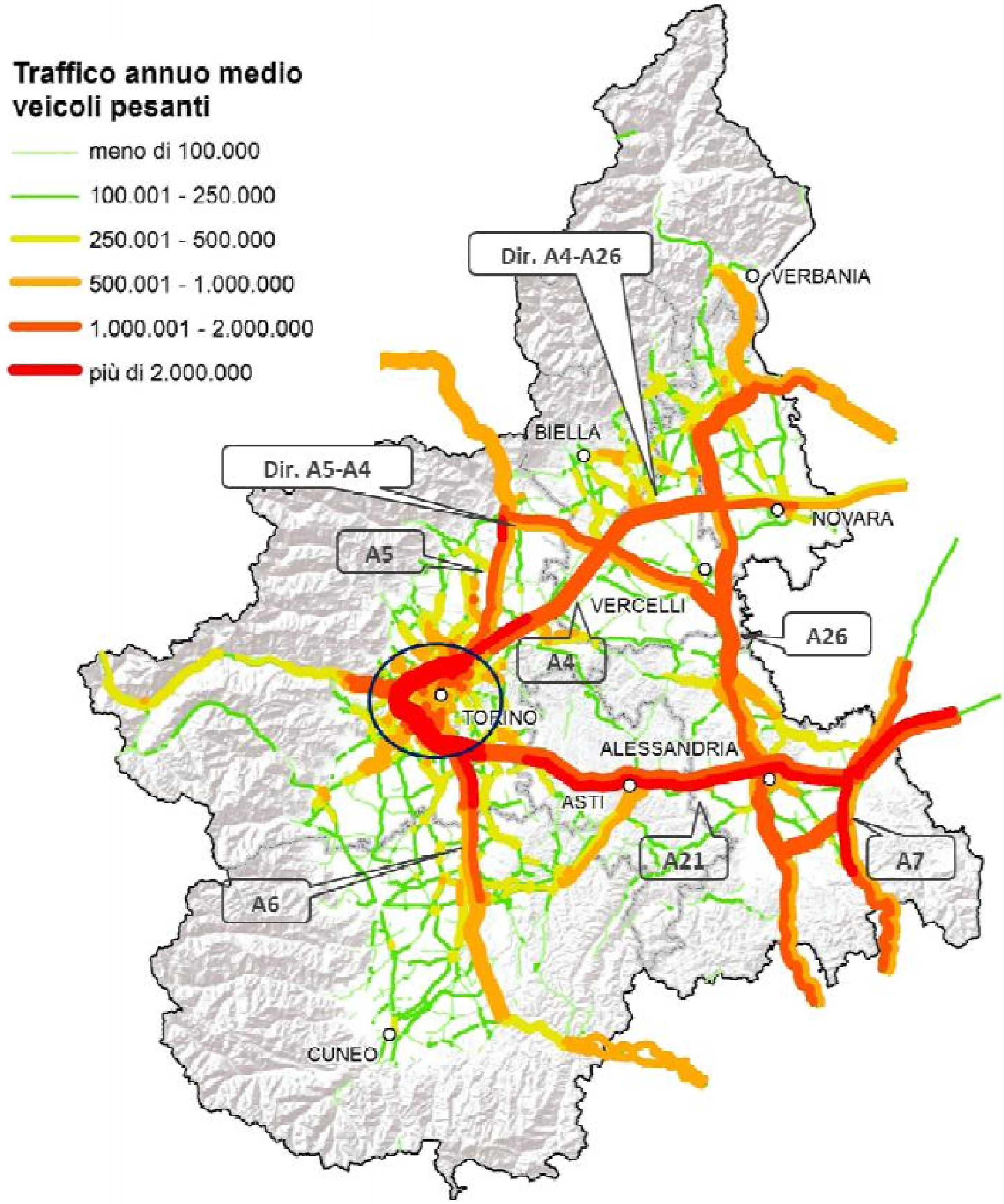


Figure 13 Average annual traffic of heavy vehicles [Source: SiTi elaboration of 5T simulation data (2017)

The picture follows the observations made in each quarter. It shows the distribution of heavy vehicles on the road network. The Turin node, the A21 direction of Milan, and the A7 direction of Genova result the most congested freeways. Highly stressed motorways also result the A4, the A21 direction of Turin, and A26 South direction.

4 THE CONNECTIONS WITH THE LIGURIAN PORTS'

The close position of Piedmont to the ports, establishes an important collaboration between the two regions; among the different ports, the most important volumes are those with the western Ligurian ports. Today, according to the government reform n.169 of 2016, the ports of Genova, Vado Ligure, and Savona are governed by the same entity: the Western Ligurian Sea Port Authority. This decree - a reorganization of the previous legislation n.84 of 1994 concerning the port authorities - promotes the cooperation between neighboring ports and simplifies the administrative procedures as a conclusive act of the European TEN-T policy. The Port Authority directs the port network. It inspects all the port activities, promotes the port system across international markets, and improves the collaboration among the different logistic service providers and the road/rail connections in the ports' catchment area. However, the single ports present various historical activities and infrastructure characteristics:

- The port of Vado Ligure, located at the West of the entire port system, combines innovation, automation, intermodal connectivity, offering a fully integrated logistics service. The installation of the new deep-sea container terminal by APM Terminal (December 2019) make this gateway the first semi-automated container terminal in Italy. The gateway is one of the most crucial fruit imports (especially bananas and pineapples) in the entire Mediterranean area, offering extensive dedicated facilities and value-added logistics services through the specific reefer terminal. The reefer terminal provides a total area of 24 000 sqm, equipped with 15 independent cells with controlled temperature for a total storage of 13 000 pallets and an annual container capacity of 250 000 TEUs where the fruits can be stock.
- Savona's port, presents more than 2 000 years of history related to the development of the city. Today, it is a crucial supply node of raw materials for the North-West companies [29]. The two ports (Savona and Vado) are distant 4 km each other, and they present a direct connection to Genova-Ventimiglia (A10) and Torino-Savona (A6) motorways as well as railway links directed to the coast and to the hinterland (Torino-Savona and Savona-Alessandria).
- Genova's port is one of the most critical nodes of the entire Mediterranean area and is a fundamental element for the industry since the Roman era. Today, the port presents a wide selection of specialized terminals, equipped to accommodate all the ships' classes, both freight and passengers. The port is connected to the coastal motorways Genova-Ventimiglia (A10) and Genova-Rosignano Marittimo (A12), and with the highways Genova-Sempione (A26) and Milano-Genova (A7). In addition to that, the Rhine-Alpes corridor – one of the busiest freight routes in Europe - connects the port of Genova with the Northern European ports.

Figure 14 Infrastructure network of Ligurian Ports

4.1 THE TRAFFIC VOLUMES OF THE LIGURIAN PORTS

In 2019, The Western Ligurian Sea Port transported a total volume of containers equal to 2'669'917 TEUs with an average containership size equal to 5 200 TEUs, highlighting the importance of this port system in the national economy. However, looking at the number of calls and the container flows, they are distributed heterogeneously between the gateways, with a strong inclination to Genova. Assoporti provides an idea of this imbalance, recording the total number of containers (TEUs) and the number of calls of the entire port system [30], [31]. In Genova's port, a total of 6 625 port calls and 2 609 138 TEUs have been handled, while for the ports Savona-Vado, the port calls stop at 2 482 and the volumes at 65 266 TEUs [31] [30]. In 2019, this imbalance even increased with a growth of the traffic destined to Genova's terminals (+1.0%) at the expense of Savona's gateways (-16.4 %).

Among the overall volume exchanged by the ports, it is important to consider the different nature of the traffic.

[TEU]	Western Ligurian sea							
	2018				2019			
HINTERLAND	Genova-Pra	Savona-Vado	Export Import	1 188 569 1 151 281	Genova-Pra	Savona-Vado	Export Import	1 185 608 1 166 048
	2 274 584	65 266	**Total**	2 339 850	2 298 330	53 326	**Total**	2 351 656
TRANSHIPMENT	Genova-Pra	Savona-Vado	Export Import	166 406 168 148	Genova-Pra	Savona-Vado	Export Import	159 261 159 000
	334 554	0	**Total**	334 554	317 045	1 216	**Total**	318 261
OVERALL VOLUME	Genova-Pra	Savona-Vado	Export Import	1 354 975 1 319 429	Genova-Pra	Savona-Vado	Export Import	1 344 869 1 325 048
	2 609 138	65 266	**Total**	2 674 404	2 615 375	54 542	Total	2 669 917

Table 5 Gateway volumes of Western Ligurian Sea: Import/Export and Transhipment [Source: Elaboration AdSP Mar Ligure Occidentale and Schede rilevazione movimenti portuali]

Analyzing the data reported in Table 5 it is possible to see the vocation of the entire port system to hinterland operations and its low transshipment functionality (≃12 %), confirming its classification to "gateway port" (see Figure 3).

4.2 THE RAIL TRAFFIC WITH PIEDMONT REGION

Analyzing the interregional flows, the volumes exchanged by trains present the more significant rail ratio with the most remote regions, confirming that the rail transport becomes more competitive with longer distances. Studying the different regions, although the Lombardia region exchanges with the port of Genova ≃50% of the port's total volumes, its rail ratio stops at 10 %. The Triveneto and Emilia Romagna regions instead show a bigger percentage of rail transport due to their remote position. Finally, the Piedmont region shows an important volume of overall traffic (> 460 000 TEUs) but with the lowest rail transport share.

Port of Genova					
	Total Volume		Train Volume		Rail ratio
	TEU	Weight [%]	TEU	Weight [%]	
LOMBARDIA	1 128 909	49.1%	112 706	36.6%	10.0%
PIEMONTE	461 628	20.1%	31 875	10.4%	6.9%
EMILIA ROMAGNA	236 094	10.3%	69 760	22.7%	29.5%
TRIVENETO	227 388	9.9%	91 402	29.7%	40.2%
OTHERS	243502	10.6%	1 982	0.6%	0.8%
TOTAL	2 297 521		307 725		13.4%

Table 6 Railway traffic of Genoa Port: Container volumes in different regions [Source: Elaboration of Analisi traffici - AdSP Mar Ligure Occidentale

Moreover, investigating the amount of full and empty containers embarked and disembarked on the entire port system (Table 7), it is possible to appreciate the balancing between those quantities at the western Ligurian ports' gateways.

[TEU] HINTERLAND	Western Ligurian sea							
	2018				2019			
		Embarking	Disembarking	Tot		Embarking	Disembarking	Tot
GENOVA-PRA	Full	1 057 828	663 895	1 721 723	Full	1 051 109	643 969	1 695 078
	Empty	101 602	451 259	552 861	Empty	108 602	494 650	603 252
	Total	1 159 430	1 115 154	2 274 584	Total	1 159 711	1 138 619	2 298 330
SAVONA-VADO	Full	36 127	29 139	65 266	Full	23 883	10 522	34 405
	Empty	-	-	-	Empty	3 545	15 376	18 921
	Total	36 127	29 139	65 266	Total	27 428	25 898	53 326
OVERALL VOLUME								
	Total	1 195 557	1 144 293	2 339 850	Total	1 187 139	1 164 517	2 351 656

Table 7 Gateway volumes of Western Ligurian Sea: Fill/Empty containers [Source: Elaboration of Analisi traffici - AdSP Mar Ligure Occidentale and Schede rilevazione movimenti portuali]

Analyzing in detail the table – with the data provided by the port authority – thus, we can see that a lot of empty containers transported by trains in the hinterland are empty and successively filled by manufacturing/industrial centers [32]–[34]. Indeed, the trains directed to the ports transport almost exclusively full containers, while in the hinterland direction the empty containers represent the 65% of the total volume. The only rail connection that guarantees rail traffic from Genova's port to the intermodal terminal in Piedmont in both the direction is the fast corridor Genova Voltri-Rivalta Scrivia. The other connections such as Novara and Alessandria as well as presenting a negligible traffic volume (88 trains/year) with respect the traffic volume of Rivalta Scrivia (1028 trains/year), are not balanced in the two directions. A final remark regards the connection with Domodossola; here, the traffic volume is significant (377 trains/year) with trains mainly dedicated to liquid bulk transport. However, since Domo II interrupts the *RFI* network, the effective O/D of the trains is not available because RFI provides only the O/D belonging to the national network.

The rail traffic of Genova's port with Piedmont region thus, is extremely weak and – except for Rivalta Scrivia – it is possible to conclude that are not sufficient volumes to justify the utilization of the rail transport. A similar situation appears for the Savona-Vado ports, with the Piedmont region that weighs for only 1% of the overall rail traffic with only 4 trains in the year 2020. As in the case of Genova, the more remote regions instead present rail flows more consistent.

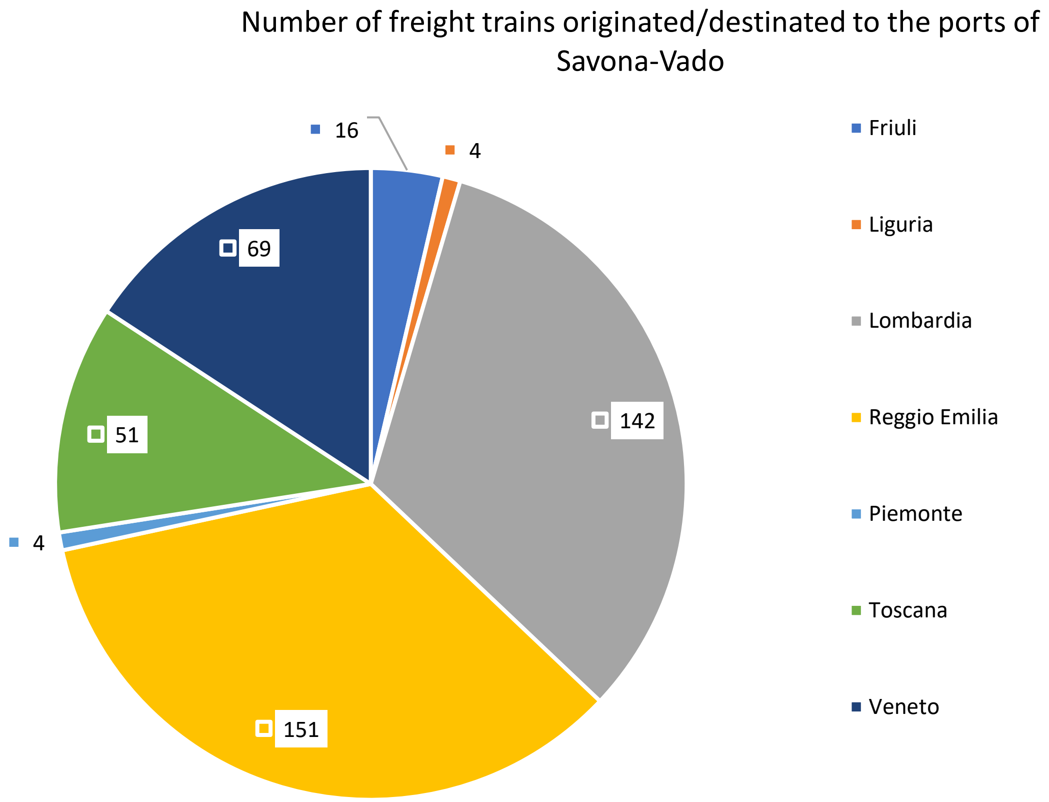


Figure 15 Freight trains originated/destinated to the ports of Savona-Vado [Source: Adsp Mar Ligure Occidentale (2020)

The Savona-Vado ports' rail traffic is almost completely scheduled on the fundamental line Savona-Genova and it is mostly dedicated to the trains generated by the new APM Terminal (10 trains/week) with Lombardia, Veneto and Emilia Romagna [35]. Instead, the volumes transported through the San Giuseppe lines are few (6-8 trains/year) and refer to liquid and solid bulk that stops at San Giuseppe di Cairo or continues in Piedmont.

The reasons for this lack in competitiveness to attract and generate rail traffic are several. A series of commercial factors and infrastructural deficiencies lead the companies to prefer the road haulage; the analysis of these aspects will be studied in PART III of this thesis.

5 ANALYSIS OF THE POTENTIAL DEMAND

In "The international trade of Piedmont region" the freight volumes exchanged through the western alpine arc have been estimated. Nowadays, these volumes are greater than 40MLNt with more than 20 MLNt exchanged between Italy and France; among these quantities, the road haulage is the predominant transport mode (95.6 % of the total amount) with 19 354 500 tonnes transported through Ventimiglia's route due to its affordability.

Since the traffic exists and it is increasing [27], [36] a real preoccupation regards the potential freight flows that will interest the connections with France and the inevitable congestion of Ventimiglia. Indeed, while the rail traffic is increasing in the Swiss passes, the opposite trend occurs on the French side. Looking at the future traffic flows forecasts, the "Osservatorio per l'asse ferroviario Torino-Lione" has provided 4 different scenarios of the western alpine arc [27]. Those scenarios suppose different demand elasticity evaluating a lower bound forecast for the future freight flows in the western alpine arc. Analyzing

Table 8, in the worst-case scenario, the traffic interesting the western alpine arc will be higher than 50 MLNt in 2030.

SCENARIO	2017	2030	2040	2050	2060
SCENARIO1 (minimum elasticity, stagnation of national economy with crisis)	44,1	50,2	50,1	55,1	55,3
SCENARIO 2 (minimum elasticity, low economic growth with crisis)	44,1	53,5	54,8	63,0	65,1
SCENARIO 3 (medium elasticity, medium economic growth with crisis)	44,1	57,8	59,7	72,5	75,9

Table 8 Traffic growth scenario in the western alpine arc [Source: Quaderni dell'osservatorio – 11 (2017)]

A more realistic analysis then, which fits better with the government's macroeconomic goals and the transport demand forecasts, shows a traffic volume of 61 MLNt in 2030 and 87MLNt in 2060 [47].

As a result of these forecasts, the expected flows in the western alpine arc in 2030 will be significant, with an inevitable impact on the transportation network. To avoid a future transport exclusively made by road, an adequate rail infrastructure network in line with the European standard and a transport strategy is necessary. In this context, the AV/AC Torino-Lione realization plays a fundamental role (**Error! Reference source not found.**).

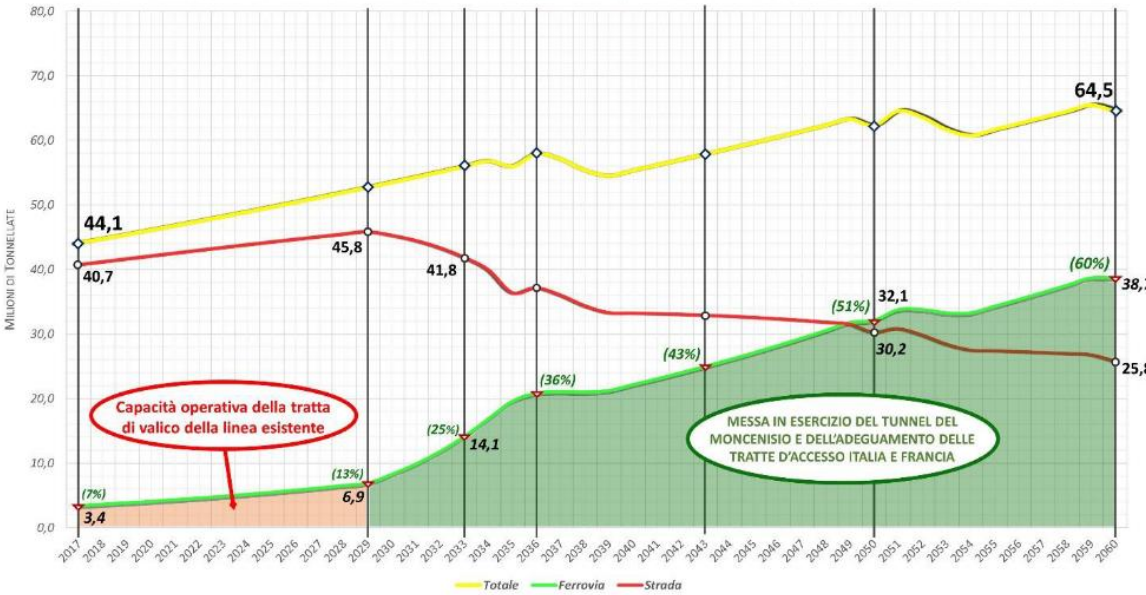


Figure 17 Traffic simulation along the Mediterranean corridor (2017-2060) and mode shift [Source: Quaderni dell'osservatorio – 15 (2019)]

The graph shows the demand growth and the modal share along the Mediterranean corridor in the future years, identifying 2050 as the transition from road transport to rail transport.

The introduction of the new AV Torino-Lione railway line is necessary to redistribute the volumes of the western alpine arc and relieve the road network's inevitable congestion [37]. Moreover, it offers a more sustainable transport mode, in line with the European white paper (30% of rail transport in 2030 and 50% in 2050 for distances > 300 km).

5.1 THE ROLE AND THE POTENTIALITY OF TORINO ORBASSANO

Torino Orbassano, located on the west side of Turin, is directly connected to the south ring road through a dedicated junction. This junction guarantees a fast connection with the national highway network, in particular with the A4 Torino-Milano, A21 Torino-Piacenza, A26 Torino-Savona, and A32 Torino-Bardonecchia. The logistic platform plays a key role both for the national and international trades (especially with France) as well as generating and attracting road traffic from and to the Ligurian ports. Today, the total volume of freight managed by Torino Orbassano is ≃4.9 MLNtonnes[16]; however, only a small part uses rail transport. The few trains generated are company trains for pre-determined clients (mono clients trains) located abroad or in the south of Italy.

[16] *Data: 2017*

THE ACTUAL PLATFORM OF TORINO ORBASSANO

The logistic platform of Torino Orbassano can be subdivided into three macro zones; in this short paragraph, a small description of each zone is provided:

- Torino Orbassano railyard;
- S.I.TO. freight village
- Centro Agro Alimentare Torino (CAAT)

Figure 18 Macrozones of Torino Orbassano [Source: Progettazione di terminali intermodali con funzione gateway: la piattaforma di Torino-Orbassano inclusiva dei traffici della linea Torino-Lione e del porto di Vado Ligure (2020)]

S.I.TO. freight village

S.I.TO. S.p.A. is a mixed company (private-public) and its role is to manage the logistic node of Torino Orbassano. The area has an extension of almost 3 000 000 sqm making S.I.TO. one of the bigger freight village of Italy, with more than 200 logistic operators and 900 000 sqm dedicated to warehouses.

The intermodal terminal *SITO Logistica,* located in the North-East part of Torino Orbassano (Figure 19 Terminal S.I.TO. Logistica [Source: L'interporto di Torino: logistica e intermodalità]Figure 19), extends over an area of 80 000 m^2 with a storage capacity of 112 000 TEU/year and 60000 m^2 dedicated. In 2017 the terminal managed 600 000 tons of freight for a total of 557 trains. The terminal provides 5 tracks used for the loading/unloading operations, with different characteristics and activities. 2 of them present a length of 550 m, while the others have a length of 460 m and 350 m.

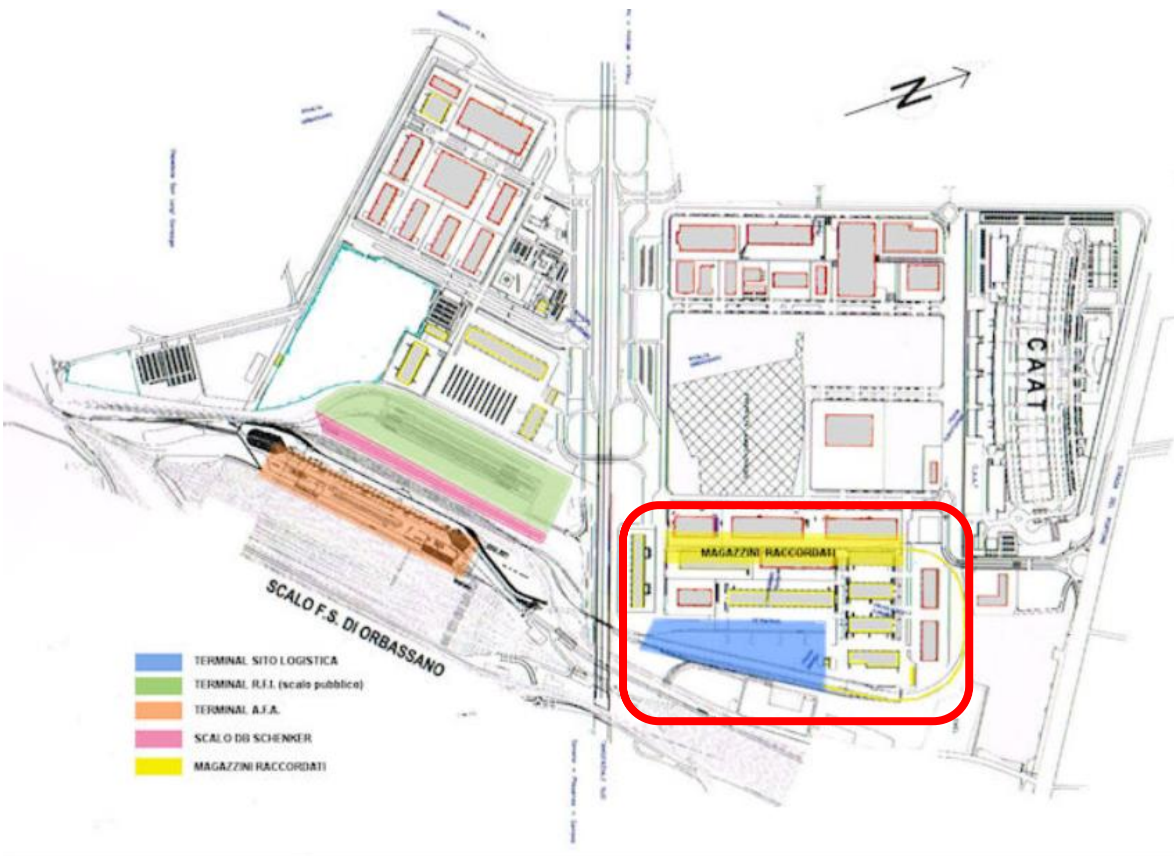


Figure 19 Terminal S.I.TO. Logistica [Source: L'interporto di Torino: logistica e intermodalità]

Centro Alimentare di Torino (CAAT)

CAAT , located in the Northern part of the Torino Orbassano logistic center, was built in 2002. Nowadays, it presents an area of 440 000 m^2 almost exclusively dedicated to the agro-business, with a total volume of ≃500 000 tonnes/year and a commercial value of 500/550 MLN€/year. The type of goods and the quantities managed by CAAT are shortly summarized in the following table:

		2017	2018
2017-2018	Category	[ton/year]	[ton/year]
	Fresh fruit	75673	208577
	Dried fruit	3873	4027
	Citrus fruit	181193	105287
	Vegetables	227908	211470
	Totale	488647	529361

Table 9 CAAT volumes and category [Source: De Paola (2020)]

However, the actual traffic interesting CAAT is transported by road due to the railway connection's technological limitations such as the impossibility to transport freight with the temperature-controlled container and the lack of an infrastructural connection with the S.I.TO. terminal.

Torino Orbassano railyard

Located in the South zone, the Torino Orbassano railyard is not a competence of S.I.TO. but it is property of RFI and Terminal Italia manages it. The terminal provides 5 operative tracks for the loading/unloading operations with intermodal units up to ≃500m; the terminal, however, is not expressively dedicated to the combined transport. There are other 5 railways managed by DB Schenker in the eastern area and mainly dedicated to the iron and steel industry.

In the south part, then, the AFA [17] terminal guarantees an efficient connection: Orbassano-Aiton. This service permits the transport of semitrailer, optimizing the loading and unloading activities using a special platform (Modalohr). A single track composes the terminal, and it is managed by Mercitalia Logistics – for the operations in the railway side- and SiTO Logistica spa – for the accessibility and the loading/unloading of the trucks -. The owner of the terminal instead is RFI.

Today, the rail service is essentially provided through the AFA terminal and the RFI terminal. The destination of the freight and the frequencies are the following:

- Aiton - 4-5 pairs of trains/week;
- Paris - 5 pairs of trains/week operated by Mercitalia Intermodal);
- Nola - 3 pairs of trains/week operated by ISC-NOI) ;
- Cervignano - 3 pairs of trains/week operated by Space Logistic .

In the last years, a Modalohr service destinated to Calais has been launched, with 5 trains/week.

Figure 20 Micro zones of Torino Orbassano railyard [Source: Progettazione di terminali intermodali con funzione gateway: la piattaforma di Torino-Orbassano inclusiva dei traffici della linea Torino-Lione e del porto di Vado Ligure (2020)]

[17] *Autostada Ferroviaria Alpina*

RELOCATION OF TORINO ORBASSANO TO GATEWAY FUNCTION

The position of Torino Orbassano with respect the future railway line Torino-Lione (scheduled for 2030) is extraordinarily strategic, and a proper requalification of the logistic platform could create the conditions for increasing intermodal transport in an area currently dominated by road haulage. The project "*Torino Intermodale*" provides a revision of the existing logistic platform to "gateway terminal" aiming to incentive the intermodal transport development through new international connections with the western European countries such as France and Spain. The relocation of Torino Orbassano to gateway terminal, as well as promoting the consolidation process, also impact on the freight demand side. The strategy aims to amplify the market demand and the potential clients through an infrastructural upgrade and integrated communication and information services aimed to converge the international traffic volume in the logistic node of Turin. The gateway concept adopts the hub-and-spoke model aimed to collect the cargo from its point of origin (the tips of the spokes) and transport it to a central processing facility (the hub) to speed up deliveries and reduce costs.

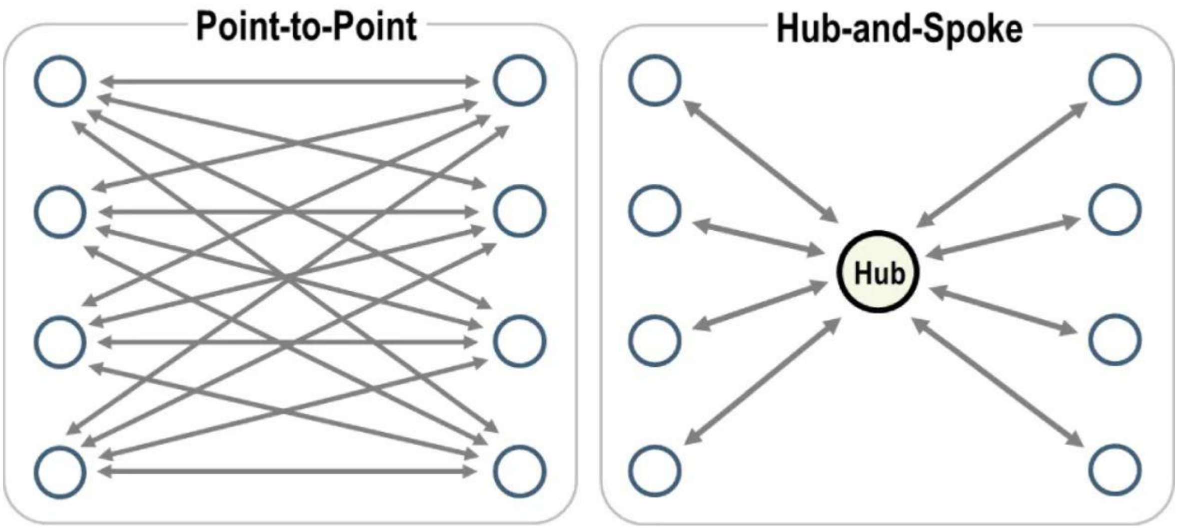


Figure 21 Hub and Spoke strategy

The implementation of a hub and spoke network – applied since the late 1980s both in maritime and air transport – is being proposed for the combined road-rail transport as an interesting opportunity. This, because it permits to concentrate the traffic in few principal nodes, linked with many radial connections to the secondary nodes achieving remarkable scale economy. Indeed, a significant reduction of the cost of transport on the primary connections due to the increase of the traffic flows in arrival and departure from and to some leading nodes can be attained.

Thereby, the so-called critical mass achievement is the first step to guarantee the gateway terminal concept. For this reason, the volumes generated in the Ligurian ports might have an essential role in the relocation project of Torino Orbassano, especially with the installation of the new APM Terminal in Vado Ligure, which intends to handle 40% of container traffic by rail when fully operational. Nowadays, a relevant market share originated in the Ligurian ports and destinated to Piedmont does not cross the Alps and remains in the national territory. In the last part of this thesis, a hypothetic consolidation of the demand will be assumed together with a series of improvements on the Savona-Torino connections evaluating the Torino Orbassano platform's potentiality.

Although the combined transport can be a valid answer to road congestion, it is necessary to ensure high efficiency of transport as well as lowering environmental impact in terms of emissions. In this context, the selection of the equipment and – more generally – the terminal layout significantly affects the productivity. In the intermodal field, reach stacker, straddle carriers, or gantry cranes are generally the most used equipment.

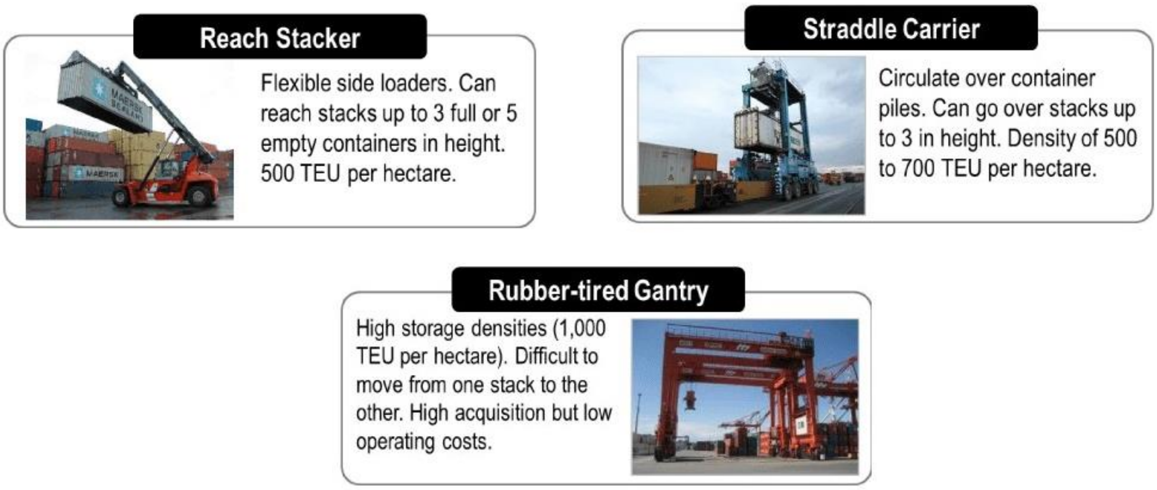


Figure 22 Example of intermodal equipment [Source: The Geography of transport system (2020)]

In the case analysed, the most functional equipment to improve the efficient of Torino Orbassano has proven to be the gantry crane [36]. Indeed, the utilization of a gantry crane within the logistic platform of Torino Orbassano has appeared the best solution for the terminal because it provides an optimal response to the gateway function, as the train-to-train transfer can be performed without intermediate means. Moreover, it allows the transfer for all the types of ITUs, with an high productivity and saving storage surface [38].

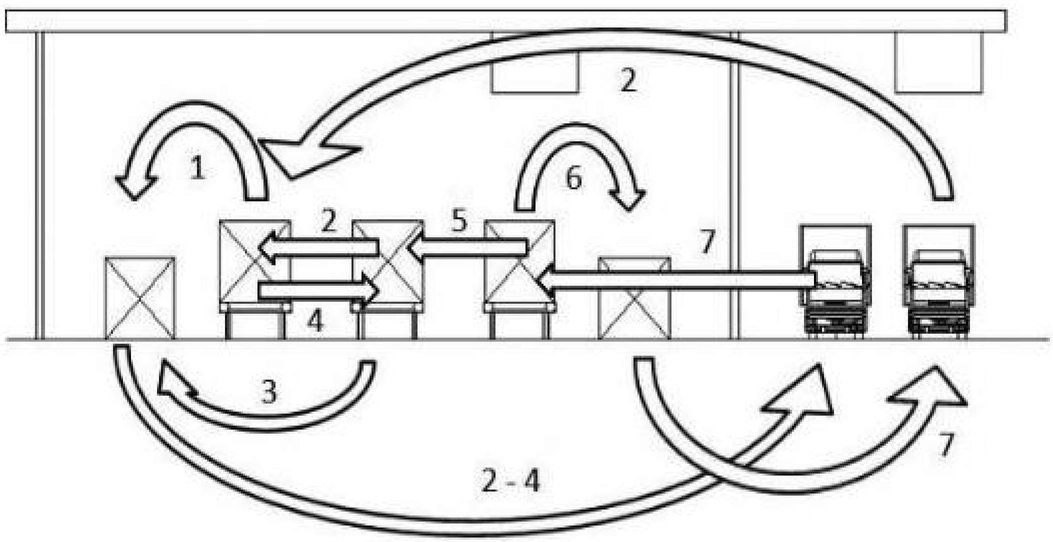


Figure 23 Load-unload scheme of the new "gateway" function [Source: Intermodal terminals with gateway function: simulation of their engineering on a case study (2013)]

PART III

THE TRANSPORT ALTERNATIVES COMPARISON OF THE SAVONA-TORINO CONNECTION

1 THE DRIVERS AFFECTING THE INTERMODAL DEVELOPMENT

Ports usually, in addition to road transport, offer a wide range of hinterland transport options such as rail networks or - in the case of navigable channels - waterway networks. The opportunities proposed by these transport alternatives allow accommodating cargoes of different nature and scale and the utilization of dedicated intermodal nodes. Although rail and waterway transports produce less pressure on the hinterland side and present many societal benefits, road transport remains the most utilized transport mode. The factors that negatively affect intermodal transport are several, and an infrastructural upgrade of the rail network is a necessary but not sufficient condition to guarantee an intermodal traffic demand.

In this chapter, intermodal transport's criticalities are analyzed following a systemic approach that considers a series of aspects that get out from the mere engineering field. 3 key drivers have been identified and adequately described in the following paragraphs.

DRIVERS	DESCRIPTION
Infrastructure factors	• inadequacy of rail connections; • insufficient interoperability of the first and the last mile;
Costs and quality factors	• high generalized costs for intermodal transport; • poor quality of service provided by the railway companies and unreliability of rail transport;
Organizational and commercial factors	• slow terminal operations; • non-efficiency and non-synchronization of the actors involved; • difficulties to reach the critical mass; • commercial contracts.

Table 10 Key drivers identification – non-competitiveness of intermodal transpor

1.1 INFRASTRUCTURAL DEFICIENCIES

For each railway line it is possible to evaluate the infrastructural characteristics, considering the following technical aspects:

- The presence of the electrification at 3000 V;
- The number of tracks (simple or double);
- The line's performance grade: they are 31 and can be directly read on the line dossier provided by *RFI*. They provide an indication of the slope, the deviousness, and the presence of gallery of each single railway line;

SAVONA - S.GIUSEPPE DI C. (via Altare): trazione elettrica cc 3000 V
Da Savona a S.Giuseppe di C. esercizio con CTC

Grado di prestazione	Ascesa ‰	Progressiva chilometrica	Distanza parziale	LOCALITA' DI SERVIZIO	Posto di blocco	INDICAZIONI DI SERVIZIO E PROTEZIONE P.L.	Numero e capacità binari
27	30	1,107		SAVONA (per Genova, via Ferrania)	22	2	«vari» 497-657
1	0	18,329	17,222	Altare	20		1 (390)
		24,375	6,046	(da via Ferrania) S.GIUSEPPE DI C.			«vari» (260-460)

SAVONA - S.GIUSEPPE DI C. (via Ferrania): trazione elettrica cc 3000 V
Da Savona a S.Giuseppe di C. esercizio con CTC

Grado di prestazione	Ascesa ‰	Progressiva chilometrica	Distanza parziale	LOCALITA' DI SERVIZIO	Posto di blocco	INDICAZIONI DI SERVIZIO E PROTEZIONE P.L.	Numero e capacità binari
24	25	1,107		SAVONA (per Genova, via Altare)	22	1	«vari» 497-657
		1,493 0,000	0,386	Cippo			
		5,664	5,664	Santuario	21	60	1 (259)
		16,279	10,615	PLA		Disp. com. km 13,451 Segn. km 16,210	
1	2	16,283	0,004	Ferrania			
		18,450	2,167	Bragno			
		19,107	0,657	PLA		Disp. com. km 13,451	
		19,196	0,089	PLA		Segn. Km 18,609	
		19,907	0,711	(da via Altare) S.GIUSEPPE DI C.			«vari» (260-460)

Table 11 Performance grade of a line [Source: RFI line dossier: Savona-San Giueppe di Cairo]

- The line's module: this has to be considered the maximum length of a complete train. Generally, the Italian railway network can be classified into four groups:

	module	<380 m
380 m <	module	<480 m
440 m <	module	<570 m
575 m <	module	< 650 m

Table 12 Module classification Italian railway network

- The loading gauge (gabarit): it refers to the maximum dimension (horizontal and vertical) that the railway stock can reach if loaded with ITU[18]. In this thesis, just the ITU with a maximum horizontal dimension of 2.50 m will be considered, with profiles classified from "00" to "80";

LINE PROFILE	MAXIMUM WIDTH	MAXIMUM HEIGHT	UTI TRANSPORTED	
P/C 80	2500 mm	4100 mm	Travelling freeway	
P/C 60	2500 mm	3900 mm		with Modalohr
P/C 50	2500 mm	3800 mm		with Modalohr
P/C 45	2500 mm	3750 mm	High Cube	
P/C 32	2500 mm	3620 mm	Swap body – semi trailers	
P/C 30	2500 mm	3600 mm	Container	
P/C 25	2500 mm	3550 mm	Container	
P/C 22	2500 mm	3520 mm	Container	

Table 13 Gabarit classification - Italian railway network

[18] *ITU: Intermodal Transport Unit*

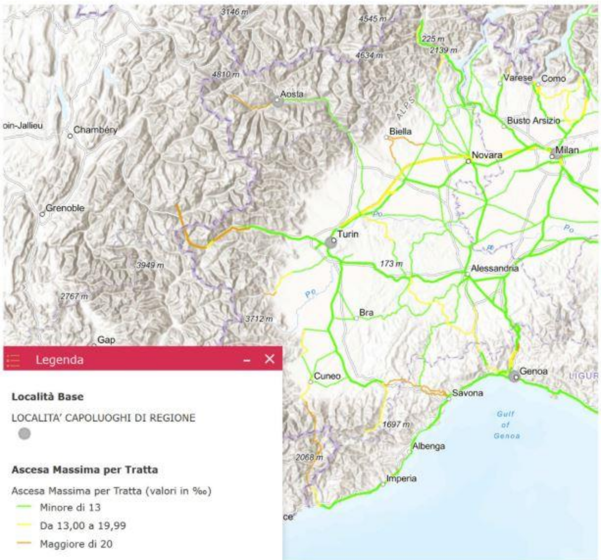
- The permissible axial weight: the lines are classified in 9 categories related to the maximum axial weight and the corresponding weight per linear meter. Some railway lines add an (L) indicating a speed limit on that railway line.

CATEGORY	MAXIMUM AXIAL WEIGHT [t]	MAXIMUM WEIGHT PER LINEAR METER [t/m]
A	16	4,8
B1	18	6,0
B2	18	6,4
C2	20	6,4
C3	20	7,2
C4	20	8,0
D2	22,5	6,4
D3	22,5	7,5
D4	22,5	8,0

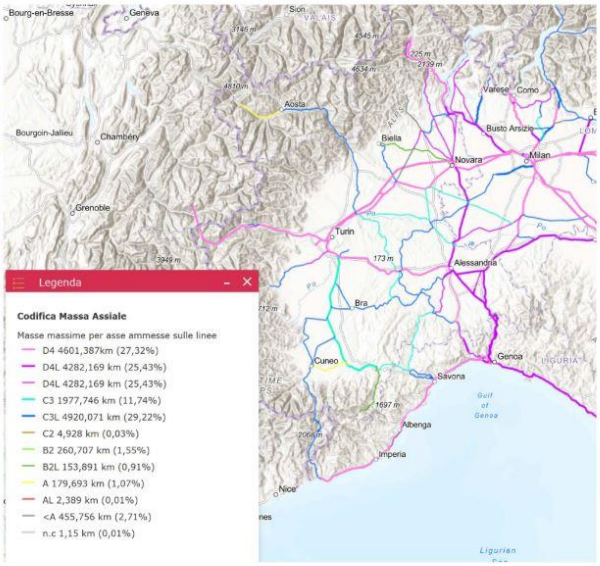
Table 14 Maximum axial weight - Italian railway network

Analyzing the Piedmont region's railway network, it presents significant infrastructural limitations, especially in the Ligurian ports' connections. The two secondary lines Torino-Savona and Savona-Alessandria (via Ovada) do not support more than 20 tonnes per axes (category: C3) as well as presenting restraints related to the train's module (up to 350m in the Savona-Fossano segment) and the gabarit (P/C 32). Moreover, the geomorphological profile between the two regions determines critical connections in the Apennine segment, with slopes up to 30‰ and 25‰.

Slope



Maximum axial weight coding



Gabarit coding

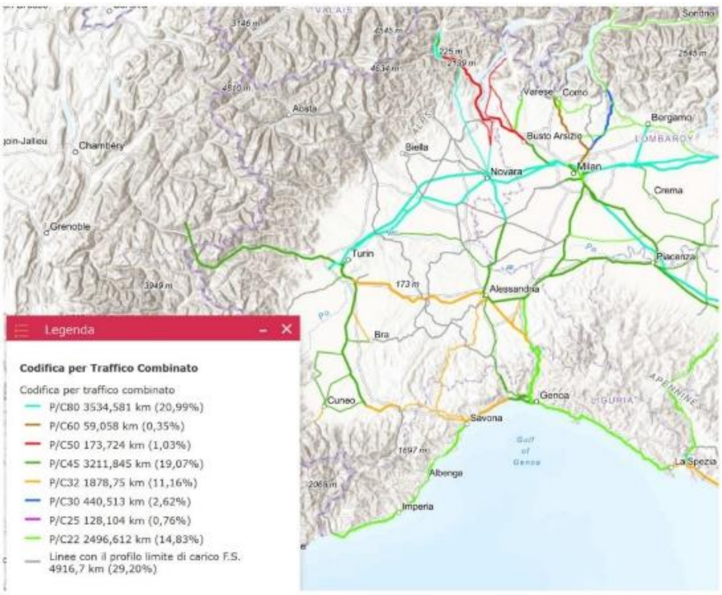


Figure 24 Railway network characterstics [Source: Rete Ferroviaria Italiana (2020)]

1.2 COSTS AND QUALITY FACTORS

A second factor regards the high generalized costs related to intermodal transport. As already partially described in the first part of this elaborate, from an economic perspective, intermodal transport becomes attractive only if its generalized costs are lower than the generalized costs of road haulage. In literature, the **break-even distance** is defined as *"the distance at which the costs of intermodal transport equal the costs of truck-only transport"* [39], and it is estimated to be in a range between 300km and 500 km.

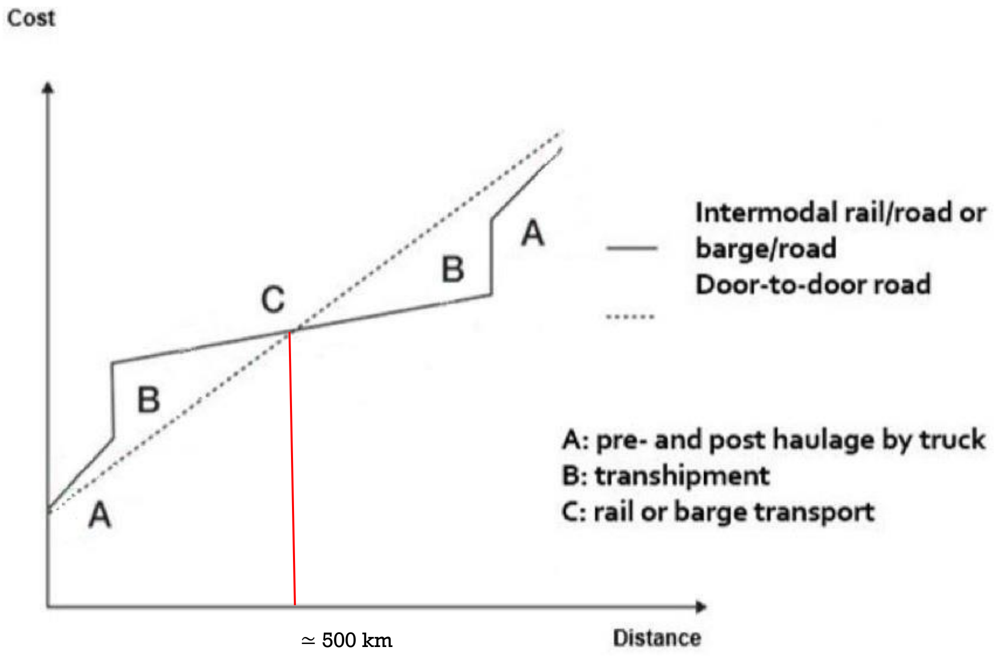


Figure 25 Intermodal transport: Break even distance [Source: Slides of freight transport management (2020)]

While in case of road haulage, the costs are determined by multiplying the unitary transport cost (€/km) times the distance (and added an eventual cost related to the highway tool), in case of intermodality (assuming a combined transport road-railway), more factors have to be considered [14]:

- **Pre and post haulage on truck (P_{preh} and P_{posth})**: it is not directly dependent on the distance, but it is a function of the service time, and it may assume high costs favoring the complete road transport;
- **Terminal operations (P_{term}):** it is related to the loading/unloading operations and management processes;
- **Railway traction (P_{rail}):** it is the most important parameter and the most sensitive because it depends on the number of the transported intermodal transport units (ITUs).
- **UTI's utilization (P_{ITU}):** usually, it is the less incident cost. The ITU - *containers* or *swap body* or *semitrailer* – generally owned by the shippers, has a daily price that considers amortization and maintenance. That cost is corrected with a factor to take into account the days of likely non-utilization;
- **Railway wagon's utilization (P_{wag}):** it contains the wagon's use, and it is calculated daily in the same way of the UTI's utilization;
- **Railway company's management (P_{manag}):** if a transport operator (shippers, hauler) manages a traffic quantity capable of filling the entire train, it may consider using a *company train*. On the other hand, if the full capacity is not

achieved, the railway operator offers a slot series (train path) between two or more terminals affordable by the railway's company. These train paths are successively sold to the transport operators that used the trains in specific time windows to reach the desired locations.

If the costs of these factors are known, the comparison between the intermodal transport and the road transport can be investigated; assuming for the road haulage and for the intermodal transport respectively the following parameters it is possible to find the economic equilibrium between the two transport modes:

- P_{road}: *road haulage cost* [€];
- D_{ro}: *door to door distance* $[km]$;
- P_{rok}: *cost per road kilometer* $[€/km]$;

The door-to-door road price can easily be calculated as:

$$\boldsymbol{P_{road} = D_{ro} * P_{rok}} \tag{1}$$

In the case of intermodal transport, the calculation is slightly more complicated because it is necessary to decompose the intermodal price P_{int} in different costs:

- P_{int}: *intermodal cost* [€];
- D_{rw}: *railway distance between terminals* $[km]$;
- P_{rw}: *costs per train kilometer* $[€/km]$;
- N: *number of ITU corresponding to the break even distance*

$$\boldsymbol{P_{intermodal} = P_{preh} + P_{posth} + P_{rail}/N + P_{term} + P_{ITU} + P_{wag} + P_{manag}} \tag{2}$$

With the railway traction component (P_{rail}) equal to:

$$\boldsymbol{P_{rail} = D_{rw} * P_{rw}} \tag{3}$$

The **economic equilibrium point** between the two transport modes is thereby:

$$\boldsymbol{P_{road} = P_{intermodal}} \tag{4}$$

The literature reports that generally, for short distances, intermodal transport's competitiveness is mainly a function of pre-haulage and post-haulage costs (they can affect up to 60% of the total price) [14]. As well as costs, the predominance of road haulage is related to other factors. The shippers and the companies consider road transport a better solution with respect to intermodality transport because of its flexibility, reliability, and cost factors. Moreover, the development of JIT[19] strategies has

[19] *Just In Time*

further intensified the transport market competition with growing in customers' needs and more customized service, advantaging the road haulage.

1.3 ORGANIZATIONAL/COMMERCIAL FACTORS

Although pre and post-haulage costs are essential, distance is not the only factor influencing intermodal transport attractiveness.

First, there are organizational problems related to the time spent in the port operations and the difficulties of efficiently synchronizing the different operators along the chain to increase the competitiveness of intermodal transport. The achievement of an integrated system requires both a vertical and horizontal integration to provide an alternative to the road haulage that is no longer dependent on the transport mode itself but by a strong collaboration between the transport operators and the logistic nodes. Nowadays, the transport activities do not share information, resulting in a disconnected logistic chain making intermodal transport non-competitive. Thus, it is not surprising that the only consolidated reality of intermodal transport for the Ligurian ports is Rivalta, where a portion of the Genoa ports traffic is directly "landed" to the inland terminal in a well-coordinated system. Indeed, this management procedure permits to carry out all the customs clearance operations and inspections in the Rivalta areas, with a relevant simplification process reducing times and costs. Customs clearance regards all the formalities and procedures required for goods entering and leaving a specific national territory; in the case of Rivalta, this customs procedure permits to transfer the containers arriving via sea through shuttle trains from the port terminal custom section to the Rivalta Scrivia one. Here, the containers are put into temporary custody warehouses managed by Rivalta Scrivia Inland terminal, speeding up the entire process [40]. However, these operations require the direct involvement of the shipping companies and high safety standards in terms of route integrity as well as the inland port assumption of any responsibility for the temporary container storage.

Another fundamental factor regards the commercial contracts signed. From point A to point B, the container movement can be controlled by the shipping line with a haulage contractor (*carrier haulage*) or directly consigned by the merchant using his own nominated haulage contractor (*merchant haulage*). In the case of *carrier haulage* (which is the predominant mode) the shipping lines are responsible for claims, liabilities, or damages that could happen to the container, determining the tendency to prefer road transport.

Moreover, the necessity to guarantee a critical mass to achieve economies of scale, lowering the fixed costs of transport, is crucial. Today - except for few cases – these volumes are not sufficient to justify company trains, and since a horizontal collaboration does not exist, the intermodality is not used.

2 THE CONSTRUCTION OF THE MODEL

Freight transport demand is a complex phenomenon that includes economic aspects (e.g. travel costs), technical aspects (e.g. travel times), lifestyle aspects, preferences of a specific individual or a company (e.g. preferences for a specific transport mode) and time factors (e.g. the same individual may at different times choose different transport modes). A model thus, is fundamental to try to establish and quantify a correlation between the driving forces of the transport demand and the effects of these factors on transport. However, as well as the possibility to use a deterministic or a probabilistic approach, different methods can be used to quantify the transport demand. In this thesis the well-known four step model has been used as reference to develop the research.

The 4-step model is not a method itself, but it is a complex process based on quantitative and qualitative processes. In principle, it has 4 phases with a certain number of assumptions in each of them.

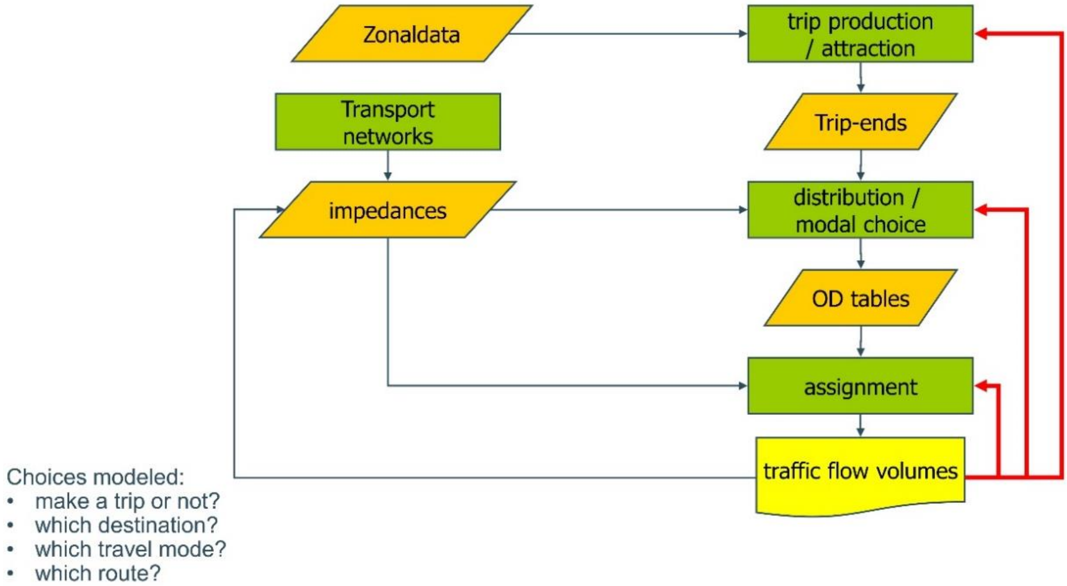


Figure 26 Choices in the 4-step transport demand model [Source: Slides of Traffic engineering (2019)]

There is another representation of this model, which permits to easily visualize the different phases. In the following figure indeed, the sequential 4-step model is illustrated, with a clear distinction between the steps and their order.

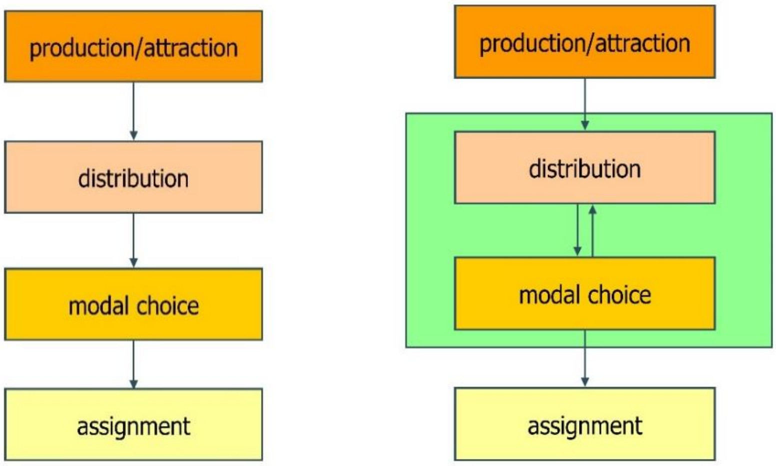


Figure 27 Sequential and simulataneous 4-step transport demand model [Source: Slides of Traffic engineering (2019)]

Over the years the position of the transport mode choice model has been discussed a lot. At the beginning transport mode choice was modelled as part of trip generation (*trip-ends model*) but since the destinations of the trips are not yet known at this stage, the network characteristics cannot be included in the model (so these models do not respond to policy decisions such as for example improvement capacity of the rail network). Therefore, in the following years, the transport mode choice was incorporate in the distribution phase, introducing the so-called *simultaneous choice model*. In the *simultaneous model*, modal split calculation and distribution are evaluated in combination, including the trip characteristics (e.g. travel time or travel cost) [41]. In this master's thesis the *simultaneous model* has been considered.

Although, the trip distribution and the modal choice are closely connected, to easily describe the 4-step model, we are going to introduce the 4 steps sequentially:

1. **Trip production/attraction**
   The first step regards the formation of a study area and a surrounding area of influence. In the study area the freight demand is classified in according to the various products and calculated at the production and consumption areas. In the area of influence instead, we only examine traffic flows that start or end inside the study area; if freight flows are exchanged between two external zones we will look only to that part of traffic that crosses the study area.
   Once the two areas have been defined, they are further subdivided into zones (internal and external). The number of zones and their size are significant parameters for the entire model. The zones indeed, should not be too large or a part of traffic might be not appear on the network, (intrazonal traffic with departure and arrival point in the same zone might be not analysed) neither too small, due to the numerous input data required, the high costs and the chance of mistakes [41]. The internal and external zone borders should coincide with the administrative units such as municipalities, countries, or provinces and with natural barriers. A general rule to subdivide the surrounding area of influence is to increase the size of the external zones with the distance of the study area, decreasing the number of relevant trips as the distance increases. Despite of the dimension of the internal and external zones and its amount, each of them has a fictitious point – called centroid – usually situated in the centre of gravity of the

single zone and from which departing and arriving trips are assumed to originate/terminate.

2. **Trip distribution**
   Freight demand is determined using the production-attraction model at the previous step. However, in this phase, we still ignore the origin and the destination of the trips within the network. The aim of this second step thus, is to distribute the traffic of the OD pairs considering their impedances (such as distances or travel costs ecc.); this goal can be achieved with the use of the ***Error! Reference source not found.***, where:
   - $\boldsymbol{T_{ij,p}}$ number of trips (or impedance function) for the goods (or category of products) p from origin zone i to destination zone j ;
   - $\boldsymbol{O_{i,p}}$ number of trips (or impedance function) for the goods p originating at zone i ;
   - $\boldsymbol{D_{j,p}}$ number of trips (or impedance function) for the goods p destinated to zone j .
3. **Modal choice**
   As well as the expected number of trips and the OD-pairs distribution, a third model is necessary to choose the transport mode. In freight transport (but also in the more general traffic demand model) we assume that a company or an individual q make a specific choice of transport mode m based on rational considerations, which means the maximization of the real (or perceived or observed) utility $U_{q,m}$ [42]. The utility $U_{q,m}$ for freight is generally function of various attributes of the specific transport mode such as transport cost or logistic cost, total transport (or transit) time, service frequency, carrying capacity, reliability and eventuality of damage [43].

4. **Route choice and assignment**
   The traffic assignment models are the last phase of the traditional 4-step traffic demand model. Once the transportation mode has been selected, it is necessary to determine the route by considering the alternatives and their characteristics. It is obvious that if the railway is chosen, the alternative routes are limited and the considerations include the capacity of the track, the travel time and other constraints such as the presence of passenger trains or delivery time. In case of truck, the alternative routes are larger and the optimum route can be assigned by means of a series of *static*[20] *assignment models* that consider (or not) the traffic conditions and (or not) the stochastic component.

Following the 4-step model structure, in this master thesis the freight demand generation has been evaluated towards an analysis of the production sites of the region; successively, the trip distribution and the modal choice have been analysed comparing the unitary transport costs and times related to both intermodal and road transport for a hypothetic container disembarked in one of the western Ligurian port terminals (respectively APM Terminal in Vado Ligure or PSA Terminal in Genova) and destinated in the Piedmont region. Finally, with the aim of fostering the competitiveness of intermodal transport, a number of scenarios have been assessed, assuming both interventions on the transport demand side and on the supply side.

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[20] *They assume that transport demand and supply are time-independent. This means that traffic flows do not changes over time and thus the transport demand remains constant over a sufficiently long-time window.*

2.1 FREIGHT TRANSPORT DEMAND GENERATION – THE INDUSTRIAL DISTRICTS

Freight transport demand covers various goods and products produced and consumed worldwide. It provides a dense infrastructural network where any available transport mode (road, rail, sea, air, inland waterways, combined transport) is used. Given the significant number of consumers, the distances between the production and the consumption of the goods, and the complexity of the phenomenon, freight transport is closer to economic activity than to passenger transport [43]. Moreover, with respect to passenger demand, freight transport depends on more quantitative (and thus measurable) variables such as the locations of production plants, the distribution nodes, the availability of transport mode, the transport costs, the delivery time, etc. The great majority of freight demand models belong to the *aggregate* kind (see [44],[45],[46],[47]) with a model that does not respond to change because of the actor behaviors or individual choice. Still, it is based on the zonal aggregation approach, considering each zone as a whole. According to the literature [41] [43], the drivers that mainly influence the production and the attraction of goods are the following:

- Employment ;
- Company turnover ;
- Economic growth rate ;
- Size of an industrial complex ;
- Type of company ;
- Accessibility of a company ;
- Population (which represents the consumer market).

In this master thesis, the freight demand has been assumed generated by the Piedmonts industrial districts' locations and their production plants localization. The concept of industrial district was used for the first time by Alfred Marshall at the end of XIX century and redefined by Becattini in 1990 as *"a socio-territorial entity characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area"*.

In according to the direction of studies and research of *Intesa San Paolo* (2020), the industrial districts in the Piedmont region can be subdivided in:

- 12 traditional districts (wine of Langhe, Roero and Monferrato, sweets of Alba and Cuneo, coffee and chocolate of Torino, industrial refrigerator of Casale Monferrato, taps and valves of Cusio-Valsesia, rice of Vercelli, hazel and fruit of Piedmont, textile machines of Biella, jewellery of Valenza, industrial robot and machines of Torino, textile of Biella);
- 1 "special district" related to the automotive industry;
- 2 technological centres (aerospace and ICT).

The districts are widely distributed in the whole region and strongly heterogeneous in terms of activities (e.g. agribusiness districts such as the rice of Vercelli and the wine of Langhe,Roero and Monferrato, or mechanical districts such as the industrial refrigerator of Casale Monferrato or the taps and valves of Cusio-Valsesia). However, the monitoring of the industrial districts is particularly challenging because the data information is available only at the provincial level, making the analysis and location of the district only possible in an approximative way. Since this analysis aims to evaluate a likely traffic demand generation and the competitiveness of intermodal transport, just the industrial districts located in the upper half of Piedmont – and thus with a relevant distance from the Ligurian port - have been analyzed.

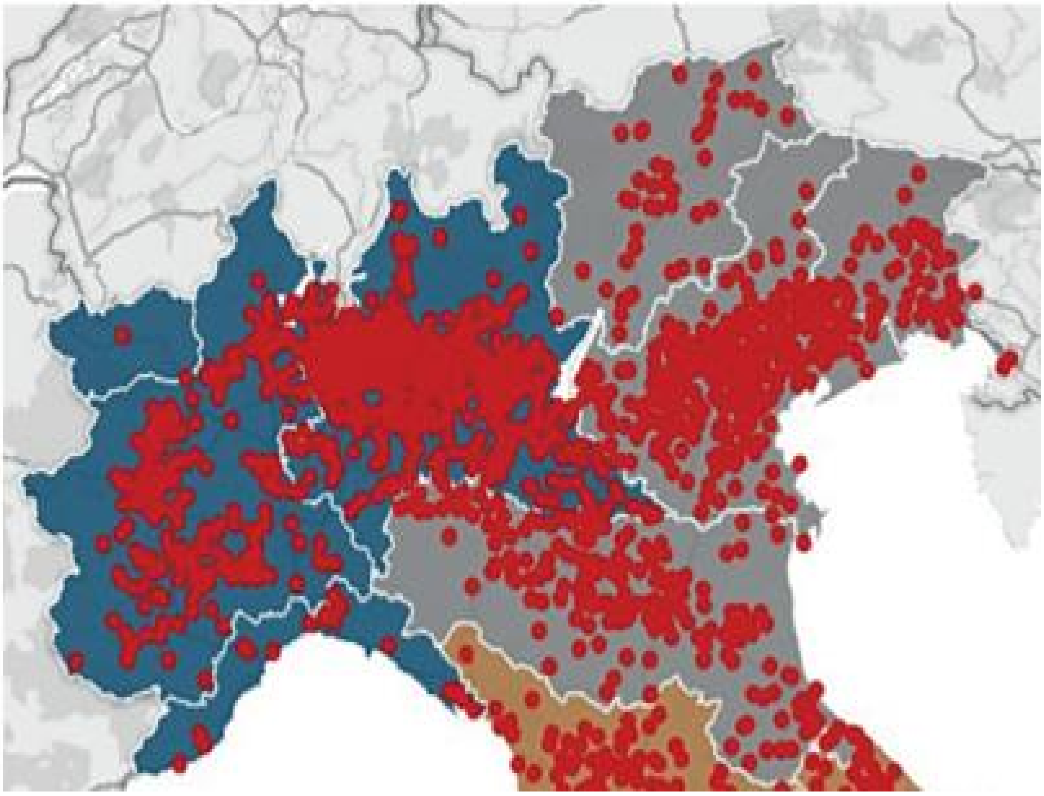


Figure 28 Italian medium size companies' localization [Source: Mediobanca (2017)]

Coffee , confectionery and chocolate of Torino

In Piedmont region, the coffee and chocolate industry represent an excellent productive cluster, with many decades of experience. The database provided by *Camera di Commercio* (2020) registers 198 companies belonging to the ATECO Classification 10.82 (production of cocoa, chocolate, candies) and C 10.83 (coffee and tea production) in Piedmont region . Among them, 124 companies are located between the province of Turin (100) and Cuneo (24) [48].

Analyzing the dimension of the companies, the output of the analysis reveals that 75% of the firms are micro-companies (less than 10 employees); the remaining part is constituted by small companies 23 (10-49 employees) and medium and big companies (1 %).

Shaping and industrial robot of Turin

The mechanical industry has always been a fundamental district for the economy of Turin. The analysis of the "*Shaping and industrial robot of Turin*" district thus, is limited to the study of the ATECO classification C28.41 (fabrication of shaping machines for metal forming), C28.49 (fabrication of other shaping machines), and C28.99 (fabrication of special machine NCA[21]). The automotive industry will be evaluated separately in the next paragraph.

Nowadays, the local units registered in the Turin's province with the mentioned ATECO classifications are [49]:

ATECO Classification	Local units
C 28.41	45
C 28.49	50
C 28.99	127

Table 15 Local units of the mechanical district of Torino [Source: CCIAA - Infocamere (2020)]

A survey made by *Camera di Commercio* (2017) shows that 38.3% of the industries belonging to the "Shaping and industrial robot of Turin" district present a turnover greater than 1 MLN€. The companies' size is mainly micro with less than 10 employees (≃ 45%) or small industries with 11-50 employees (40%).

Automotive industry

The most crucial sector in the overall regional territory is undoubtedly the automotive industry. This sector belongs to the city of Turin since 1899, the year of FIAT firm's foundation. The fusion in 2014 of FIAT S.p.A. with the Chrysler Group changed the company's name in Fiat Chrysler Automobilities (FCA), making the firm the 8th automotive group per vehicles purchased. In 2020 then, a further fusion with the industrial group Peugeot S.A. occurred. The new company – Stellantis – will be the 4th automotive group among the global best-selling cars.

Assuming the ATECO classification C.291 (Fabrication of motorized vehicles) and C.293 (Fabrication of accessories for motorized vehicles and their engines) representative of the district, it appears that 87.8% of the companies belonging to these ATECO classifications are located between the province of Torino (79.4%), Asti (7.3%) and Cuneo (13.2%).

Taps and valves of Cusio-Valsesia

The taps and valves district is located in the North-East part of Piedmont and it occupies a large area that contains the province of Novara and a small part of Vercelli's province. However, the most intense production is in the Cusio's region, especially within the municipalities surrounding *Lago d'Orta* (between the province of Novara and Vercelli) with a heavy concentration of taps and valves companies.

Textile machines of Biella

The Biella's district is one of the older districts in the entire world. It is worldwide recognized as Italian excellence to produce textile in the clothing sector. The development of the district has been conditioned with the geomorphological characteristics of the territory; its position near the Alps and freshwater rivers supported the sheep's livestock. The advent of globalization and the recent international

[21] *Non Codificato Altrove*

settlements then, impacted the district leading to the closure of several activities. However, many production sites are still in function along the "wool road" between Biella and Borgosesia. Recently, the know-how of the district has determined the opening of the Chinese "Xinao textile", which has selected Verrone (Biella) as the hub for its European expansion [50].

Household products of Omegna

The last district analyzed is the household products of Omegna. It is located in the VCO province Piedmont, particularly in the city of Omegna. As in the case of the textile district, globalization has radically changed its nature. During the Italian economic boom in Omegna there were companies such as *Alessi, Bialetti, Girmi,* and *Lagostina* with products that perfectly fit the Italian lifestyle and globally recognized as the "Made in Italy" symbols. However, the solid reality of the small and medium companies could not compete with the international players. Thus, during the globalization period, a lot of firms closed or were englobed by multinational corporation. The result is that prestigious name such as *Bialetti* o *Girmi* have relocated their production plants in countries where the labour cost was lower, maintaining in the district just planning and quality control activities. Today, only the companies that focus on a specific sector or that are part of a multinational corporation are still located in Omegna.

The picture below identifies the position of the analysed industrial districts in the region.

Districts	Area
Coffee and chocolate	Torino
Shaping and industrial robot	
Automotive	
Taps and valves	Cusio-Valsesia
Households products	
Textile and textile machines	Biella

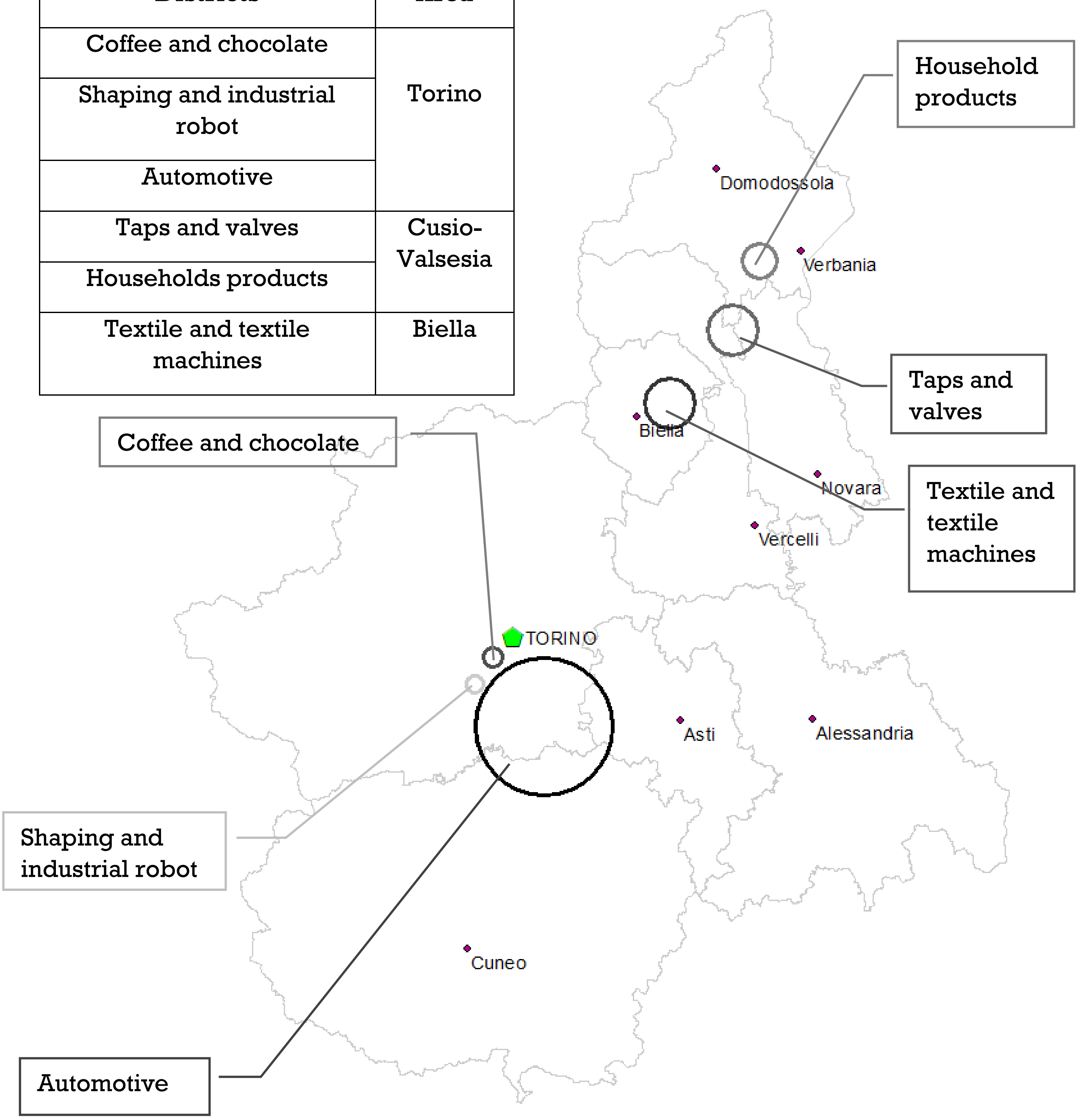


Figure 29 Industrial districts localization

2.2 Transport model comparison - description and calibration of model's component

The model compares the unitary transport costs and times related to both intermodal and road transport for a hypothetic container disembarked in one of the western Ligurian port terminals (respectively APM Terminal in Vado Ligure and PSA Terminal in Genova) and destinated in the Piedmont region. Assuming a freight traffic demand generated by the industrial district location, three destinations have been identified (Torino, Biella, San Maurizio d'Opaglio). In the model, the assumption is that the cargo will reach the hinterland destination using two possible logistic platforms: S.I.TO. Orbassano or CIM Novara. In the following scheme, a representation of the model is provided.

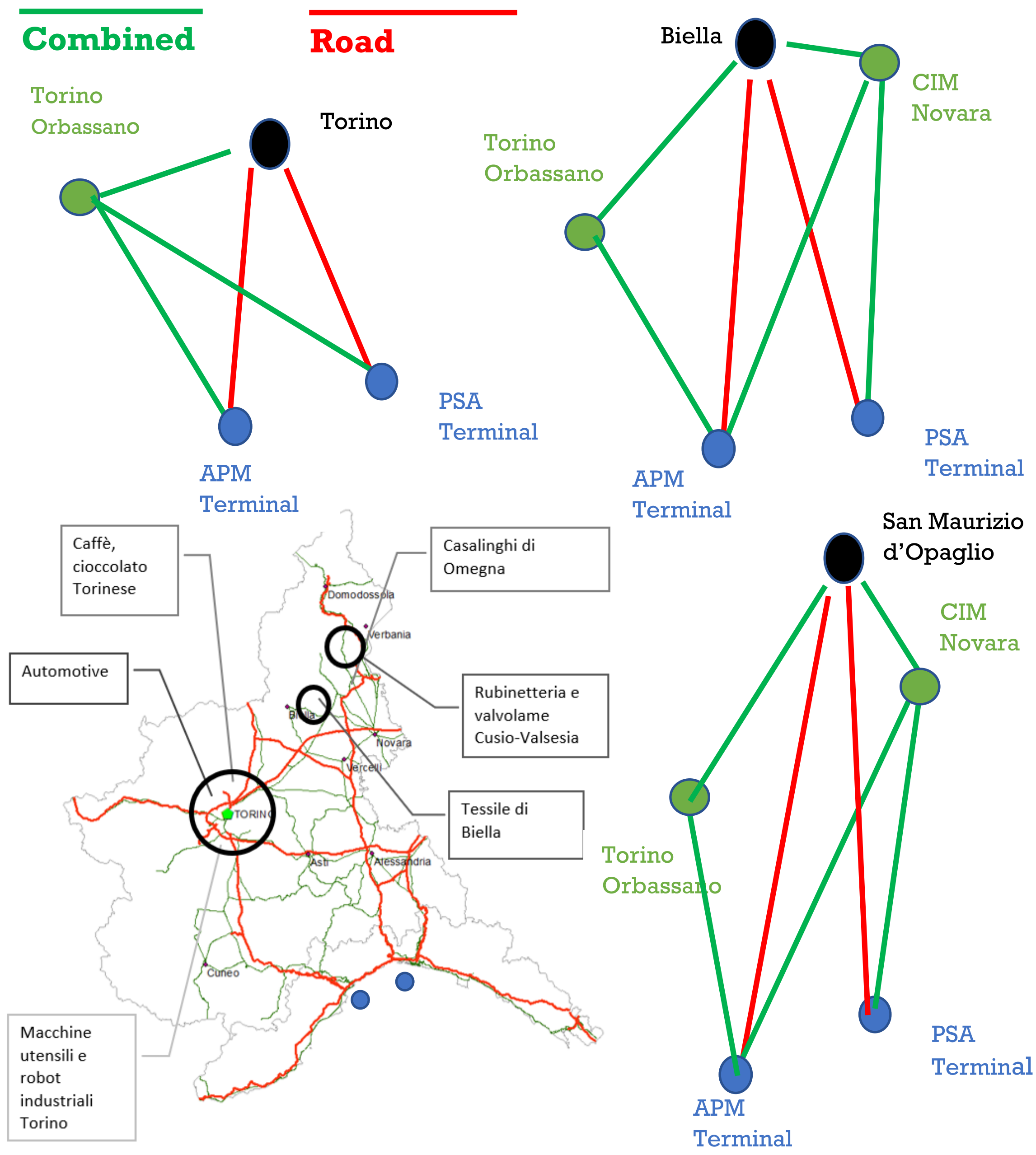


Figure 30 Schematization of the model

ROAD HAULAGE

The road haulage presents only a few elements to model because of the simplicity of the structure.

TRANSPORT COSTS ELEMENTS

The transport costs analyzed are the following:

Terminal Handling Charge [€/TEU]

It consists of all the shipping lines' costs for the loading or unloading of the containers in a container terminal. For the sake of simplicity, terminal charges are assumed to be independent of vessel size and dwell time; the costs considered are the maximum proposed by the terminals.

Road transport cost [€/TEU]

The evaluation of this cost assumes a truck with an average annual mileage of 100000 km as suggested by the data of the Italian *Ministero delle Infrastrutture e dei Trasporti* (2020). Subdividing a truck's costs into fixed and variable costs (Table 14) the unitary transport cost has been evaluated [€/km]. The value established is **1.05 €/km**, in line with the unitary cost provided in the literature.

Fixed costs [€/km]					Variable costs [€/km]	
Purchase [€/km]	Depreciation [€/km]	Employee [€/km]	Insurance [€/km]	Annual stamp [€/km]	Maintenance [€/km]	Tyres [€/km]

Table 16 Fixed and variable costs of road transport

Tool [€/TEU]

The tool price has been determined using the website *autostrade.it.* The website offers the possibility to evaluate the tool price for different vehicle characteristics and different destinations. Considering a 3-axis truck, the tool's costs have been established for all the OD pairs.

TIME ELEMENTS

For what concerns the time elements in road haulage, only two voices have been considered: the truck turnaround and the transit time to reach the destination. The container discharge time, the documental, and the customs procedure have been neglected.

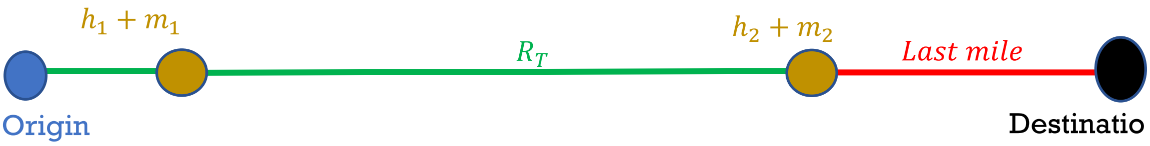
Truck turnaround [h]

It consists of a truck's total time in the terminal area from gate-in to gate-out for picking a container. It includes the time from the arrival, loading, and unloading of containers, inspecting a truck, completing documentation, and exit from the terminal.

Transit time [h]

It corresponds to the interval needed for a container to be delivered once it has been picked up from the point of departure. In this case, the departure point is the exit of the terminal.

Combined transport



The analysis of the combined transport is more complicated because of the impossibility of offering a door-to-door service. In intermodal transport, the same loading unit is loaded to more transport modes, presenting a more segmented structure with respect to the road haulage. The following aspects have been considered:

- Handling and shunting operations of the train at port ($h_1 + m_1$);
- Railway traction (R_T);
- Handling and shunting operations of the train at the final terminal ($h_2 + m_2$);
- Last-mile ($Road$).

Before evaluating the single factors affecting the intermodal transport, a series of assumption regarding the characteristics of the train are necessary. These assumptions are required to respect the railway line's technical limitations in terms of maximum axial weight, module length, and performance grade (see 1.1). These constraints, as well as affecting the length of the train and the maximum axial weight, determine a maximum towed mass, evaluated as a minimum of three factors:

$$\begin{array}{c} Maximum \\ towed \\ mass \end{array} \quad MIN \begin{cases} railway\ line\ constraint\ (f\ of\ the\ performance\ grade) \\ locomotive\ constraint\ (f\ of\ the\ locomotive\ performance) \\ normative\ constraint\ (1600\ t) \end{cases}$$

In the model the following characteristics for a **full loaded train** have been assumed:

Locomotive characteristics			
Locomotive:	**E655**	Length [m]	18.3
		Mass/axes [t]	20
Railway wagon characteristics			
Railway wagon:	**Sgnss**	Length [m]	21.8
		Tare [t]	22
		N of axes	4
UTI characteristics			
UTI:	**Container**	Container	
		Dimension	20'
		Weight [t]	14

TRANSPORT COSTS ELEMENTS

The transport costs analyzed in the combined transport are the following:

Terminal Handling Charge [€/TEU]

It consists of all the shipping lines' costs for the loading or unloading of the containers in a container terminal. For the sake of simplicity, terminal charges are assumed to be independent of vessel size and dwell time; the costs considered are the maximum proposed by the terminals.

Handling and rail shunting at port $(h_1 + m_1)$

The disembarked container is generally stocked in a specific terminal area if the terminal knows that it will be transported by train. Nevertheless, the internal rail park within the terminal container is not electrified and a diesel locomotive is necessary to haul the wagons from the internal to the external rail park. This operation – called *rail shunting* - is provided by a specific operator (shunting company) in a monopolistic market, and it is an expensive operation both in terms of costs and time [51].

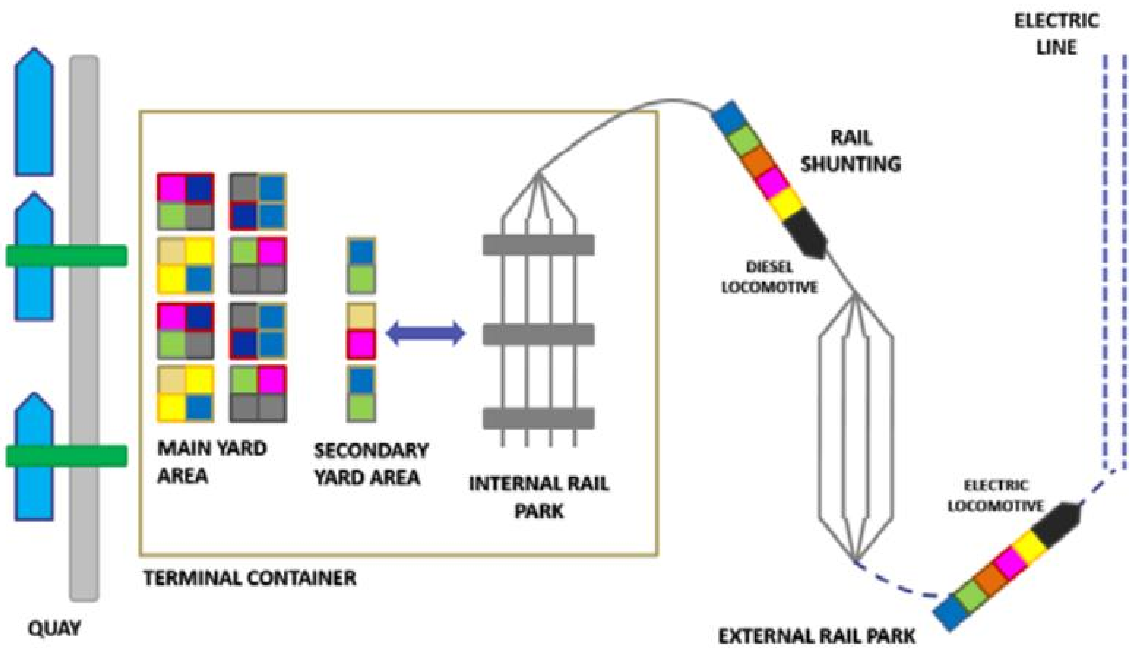


Figure 31 Rail transport in seaports [Source: Studio comparativo sulla gestione e sull'utilizzo del trasporto ferroviario containerizzato nei porti. Uso della System Dynamics. (2010)]

Railway traction (R_T)

After the rail shunting operation, the railway carrier (MTO) manages the rail transport on the electrified national network (there are no more monopolistic conditions, and many operators can perform the railway traction). Thus, the railway traction is the cost to transport the train from the external rail park to the final terminal. In this model, the railway traction cost has been calculated as the sum of two elements:

1) The price that the MTO has to pay to the rail infrastructure manager (RFI) to use the track, calculated as sum of two components provided by the PIR document:

$$A\ (infrastructure\ use) + B\ (ability\ to\ pay) \qquad [€/\ train\ km] \tag{5}$$

2) The unitary transport cost per train$[€/train\ km]$.
   Considering the railway traction, the UTI's rent, the railway wagon utilization, and the personnel costs.

Handling and rail shunting at the final terminal $(\boldsymbol{h_2 + m_2})$

As in the port terminal case, it is related to the loading/unloading operations and management processes. As well as the terminal's lifting operation, it is necessary to add the terminal costs related to the shunting operations. These costs have been provided by the reference terminal (CIM Novara and S.I.TO.) as costs per train and depend on the number of transported containers $[€/train\ km]$.

Last-mile $[€/\boldsymbol{TEU}]$

The cost is related to the road transport necessary to move the goods from the inland terminal to the final destination. It is calculated as a regular road transport cost (see TRANSPORT COSTS ELEMENTS).

TIME ELEMENTS

The time elements in combined transport are numerous. Although the container discharge time, the documental, and the customs procedure - as in the case of road haulage - have been neglected, other aspects affect the time operations, especially in the port and final terminals.

Loading operations [h]

It consists of the total time spent to load the railway wagons in the terminal's railway internal park. These operations are very time-consuming because they depend on the equipment used to load the train and are incline to significant downtimes.

Shunting operations [h]

Once the wagons in the internal rail park is fully loaded a diesel locomotive transport the complete train to the external rail park. This operation needs a significant amount of time, and is subjected to considerable delay (for instance, if the train is incorrectly assessed). In this thesis, the eventual delays are not considered.

Transit time – railway traction [h]

It corresponds to the amount of time spent moving goods from the external rail park to the final terminal.

Unloading and shunting operations [h]

The same operations already described but in the final terminal.

Road transport [h]

It corresponds to the amount of time needed for the last mile.

3 BASE SCENARIO AND NEW SCENARIO ANALYSIS

The base scenario presents an OD matrix with the unitary costs and times of each OD pair. Analyzing the results, appears that the combined transport is not competitive with the road haulage in the connections with the Ligurian ports, presenting a disparity in price between 12 and 56€/TEU and a divergence in time even more significant.

Impedance c_{ij}^{m} [€/TEU]		Torino	Biella	San Maurizio d'Opaglio
Genova Voltri (PSA Terminal)	Combined	359	397	418
	Road	347	353	368
Vado Ligure (APM Terminal)	Combined	412	435	455
	Road	356	414	407

Time c_{ij}^{m} [h]		Torino	Biella	San Maurizio d'Opaglio
Genova Voltri (PSA Terminal)	Combined	8:38	9:21	11:01
	Road	2:15	2:20	2:22
Vado Ligure (APM Terminal)	Combined	9:35	10:18	10:37
	Road	1:48	2:21	2:25

The APM-Torino pair records the major difference in terms of unitary cost. In the actual conditions the combined transport - to be competitive with the road transport –, should decrease its total costs of 56€/TEU and radically optimizing the time operations.[22]The following table reports the output characteristics of a potential train running at full capacity along the two possible routes (via Altare and via Ferrania):

		APM Terminal – Torino (via Altare)	APM Terminal – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	870	1040
	f (performance locomotive)	**650**	**730**
	f (normative)	1600	1600
Length of train [m]		236.3	258.1
Number of wagons		10	11
Number of TEUs transported		30	33

Table 17 Output analysis - Actual scenario

[22] *The time for the handling and shunting operations of the final terminal (CIM Novara and S.I.TO. Orbassano) has been assumed 1:30 h for both.*

NEW SCENARIOS DEFINITIONS: APM TERMINAL -TORINO

To relaunch the competitiveness of intermodal transport, in line with the objectives of the Transport White Paper (2011) and the European Green Deal (2020), some scenarios have been evaluated, with both interventions on demand and supply side. These scenarios also consider a potential increment of the intermodal traffic provided by the opening of the Turin-Lyon rail connection (expected in 2030) and the new semi-automated container terminal's operational regime at the port of Vado Ligure which intends to handle 40% of container traffic by rail. In the following table, a summary of the supposed scenarios is provided.

Scenario N	Interventions on the supply side	Interventions on the demand side	Traffic growth assumptions
Scenario 0 (actual)	-	-	NO
Scenario 1	-	PROMO catalogue active	NO
Scenario 2	550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active	YES
Scenario 3	-	Road pricing	YES
Scenario 3(1)	550 m module on the railway line	PROMO catalogue active ; Road Pricing .	YES
Scenario 3(2)	550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active ; Road Pricing .	YES
Scenario 4	550 m module on the railway line ; New generation high performance trains .	Road Pricing	YES
Scenario 4(1)	Plant upgrades in Orbassano logistic platform ; 550 m module on the railway line.	PROMO catalogue active ; Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 4(2)	Plant upgrades in Orbassano logistic platform ; 550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active ; Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 5	Shuttle service	Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 5(1)	Shuttle service ; 550 m module on the railway line .	Road Pricing ; PROMO catalogue active ; Demand concentration on Torino Orbassano .	YES
Scenario 5(2)	Shuttle service ; 550 m module on the railway line ; New generation high performance trains.	PROMO catalogue active ; Demand concentration on Torino Orbassano .	YES

Table 18 New scenarios description

3.1 SCENARIO 1

Scenario N	Interventions on supply side	Interventions on demand side	Traffic growth assumptions
Scenario 1	-	PROMO catalogue active	NO

In this scenario, the freight trains run along the railway line Savona-Torino in a specific scheduled time with a "special tariff". The PROMO catalogue's activation guarantees a cost equals to 0 of the B component (see eq. *(5)* ability to pay) in the segment Savona P.Doria-Fossano.

Train characteristics		APM - Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	870	1040
	f (performance locomotive)	**650**	**730**
	f (normative)	1600	1600
Length of train [m]		236.3	258.1
Number of wagons		10	11
Number of TEUs transported		30	33

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	408	1:48	=

Table 19 Output analysis - Scenario 1

Running the analysis, the output of this scenario does not modify the trains' capacity neither the time along the railway lines but decreases the cost of the combined transport of 4€/TEU.

3.2 SCENARIO 2

Scenario N	Interventions on the supply side	Interventions on the demand side	Traffic growth assumptions
Scenario 2	550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active	YES

In this scenario, the freight trains run along the railway segment Savona Parco Doria - Fossano with the PROMO catalogue active; moreover, improvements on the Turin-Savona railway line, and on the rolling stock, are assumed. The railway line intervention assumed is related to technological updates (signaling and distancing system), giving the possibility to run trains up to 550 m on the railway line. Moreover, the rolling stock updates presume the use of new generation high-performance trains that can transport a higher mass on the railway line. The introduction of these modern trains has been modelled with a rise on the trains' fixed costs, for an overall railway traction costs increment of ≃45%.

Train characteristics		APM - Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	**870**	**1040**
	f (performance locomotive)	>1040	>1040
	f (normative)	1600	1600
Length of train [m]		301.7	345.3
Number of wagons		13	15
Number of TEUs transported		39	45

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	384	1:48	=

Table 20 Output analysis - Scenario 2

Despite of the technological updates and high-performance trains, the combined transport remains particularly high with respect to road haulage.

3.3 SCENARIO 3 – 3(1) -3(2)

Scenario N	Interventions on the supply side	Interventions on the demand side	Traffic growth assumptions
Scenario 3	-	Road pricing	YES
Scenario 3(1)	550 m module on the railway line	PROMO catalogue active ; Road Pricing .	YES
Scenario 3(2)	550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active ; Road Pricing .	YES
Scenario 4	550 m module on the railway line ; New generation high performance trains .	Road Pricing	YES

In these scenarios 3-3(1)-3(2), a hypothetical highway toll's increment has been assumed. The figure below reports the three scenarios already analyzed (Scenarios 0-1-2) and identify the increment of the highway toll necessary to achieve the transport alternatives' balancing in terms of costs.

HIGHWAY TOOL (actual 18.9)	SCENARIO 3	SCENARIO 3(1)	SCENARIO 3(2)
	+56 €	+51 €	+48 €

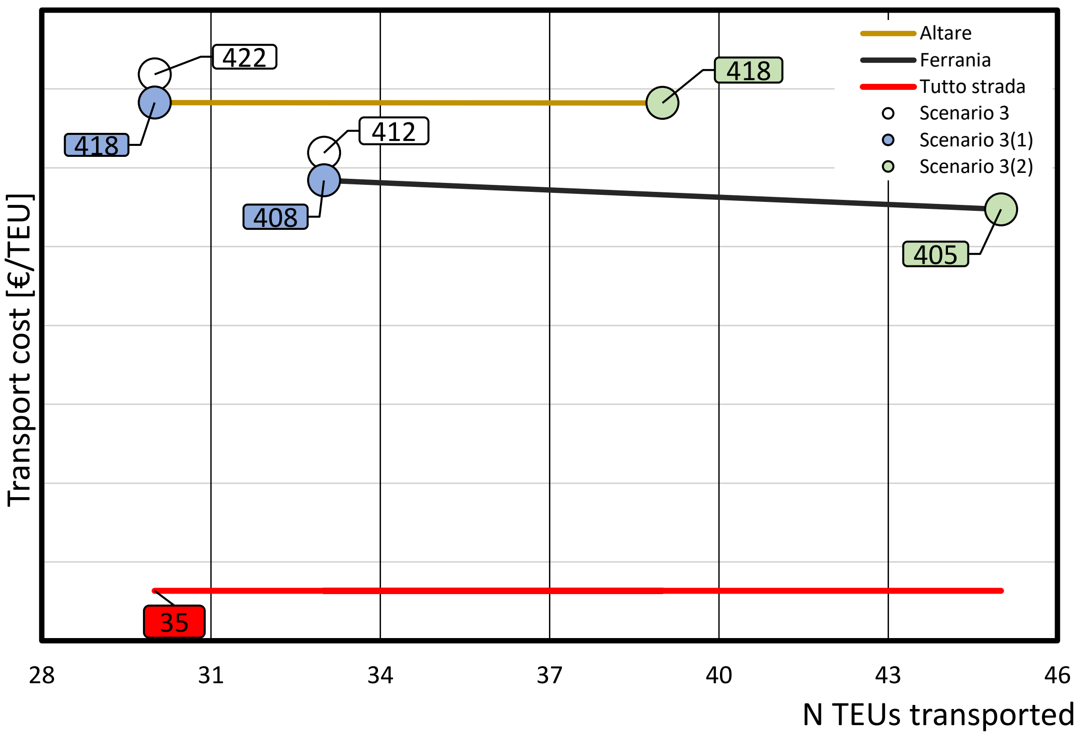


Figure 32 Scenarios 3-3(1)-3(2) comparison

3.4 SCENARIO 4 – 4(1) – 4(2)

Scenario N	Interventions on the supply side	Interventions on the demand side	Traffic growth assumptions
Scenario 4	550 m module on the railway line ; New generation high performance trains .	Road Pricing	YES
Scenario 4(1)	Plant upgrades in Orbassano logistic platform; 550 m module on the railway line.	PROMO catalogue active ; Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 4(2)	Plant upgrades in Orbassano logistic platform ; 550 m module on the railway line ; New generation high performance trains .	PROMO catalogue active ; Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 4	550 m module on the railway line ; New generation high performance trains .	Road Pricing	YES

An additional intervention on the supply side in scenarios 4-4(1)-4(2) has been assumed. Specifically, the production plants are considered directly connected to the Torino Orbassano platform by rail services presuming a *last-mile* cost equals to 0.

SCENARIO 4 – 4(1)

Train characteristics		APM – Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	870	1040
	f (performance locomotive)	**650**	**730**
	f (normative)	1600	1600
Length of train [m]		236.3	258.1
Number of wagons		10	11
Number of TEUs transported		30	33

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	387	1:48	⬇

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	391	1:48	⬇

Table 21 Output analysis - Scenario 4-4(1)

SCENARIO 4(2)

Train characteristics		APM - Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	**870**	**1040**
	f (performance locomotive)	>1040	>1040
	f (normative)	1600	1600
Length of train [m]		301.7	345.3
Number of wagons		13	15
Number of TEUs transported		39	45

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	384	1:48	⬇

Table 22 Output analysis - Scenario 4(2)

Even in this group of scenarios, the combined transport does not result competitive to the road haulage, although the gap is reducing. Thus, as in the previous case, an increment of the highway tool has been assumed to achieve the economic equilibrium point (see Costs and quality factors).

HIGHWAY TOOL (actual 18.9)	**SCENARIO 4**	**SCENARIO 4(1)**	**SCENARIO 4(2)**
	+35 €	+31 €	+27 €

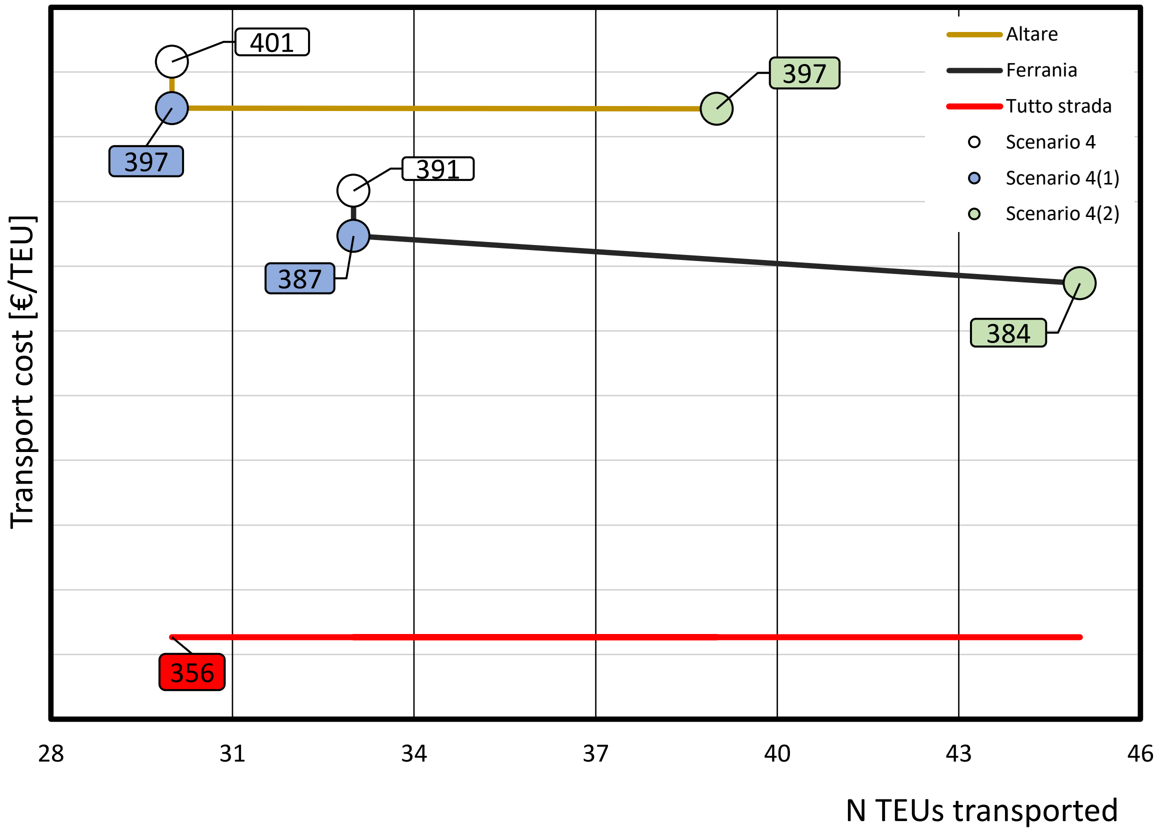


Figure 33 Scenarios 4-4(1)-4(2) comparison

3.5 Scenario 5 – 5(1) – 5(2)

Scenario N	Interventions on supply side	Interventions on demand side	Traffic growth assumptions
Scenario 5	Shuttle service	Road Pricing ; Demand concentration on Torino Orbassano .	YES
Scenario 5(1)	Shuttle service ; 550 m module on the railway line .	Road Pricing ; PROMO catalogue active ; Demand concentration on Torino Orbassano .	YES
Scenario 5(2)	Shuttle service ; 550 m module on the railway line ; New generation high performance trains.	PROMO catalogue active ; Demand concentration on Torino Orbassano .	YES
Scenario 5	Shuttle service	Road Pricing ; Demand concentration on Torino Orbassano .	YES

Finally, in these scenarios, a shuttle service is proposed as an additional intervention to the 0-1-2 scenarios. The continuity of a shuttle service has been modeled by decreasing the terminals' handling costs. In the last scenario 5(2), the use of high-performance trains has been assumed.

The introduction of a service shuttle needs a substantial consolidation of the traffic demand making these scenarios – more than the others –valid only in a hypothetical increment of the rail traffic. This increment might be achieved with a mixed intermodal traffic management model with a superposition of the regional and international volumes and an upgrade of the Torino Orbassano logistic platform to "*gateway*" function (see 5.1).

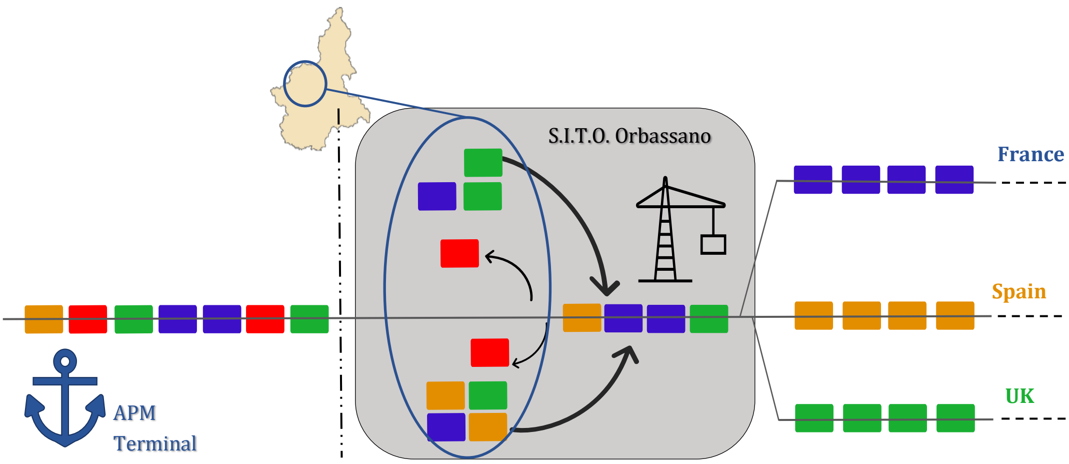


Figure 34 Schematization of mixed intermodal traffic management model and Torino Orbassano's "gateway" function

SCENARIO 5 – 5(1)

Train characteristics		APM – Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	870	1040
	f (performance locomotive)	**650**	**730**
	f (normative)	1600	1600
Length of train [m]		236.3	258.1
Number of wagons		10	11
Number of TEUs transported		30	33

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
361	361	1:48	⬇⬇

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
357	357	1:48	⬇⬇

Table 23 Output analysis - Scenario (1)

SCENARIO 5 (2)

Train characteristics		APM - Torino (via Altare)	APM – Torino (via Ferrania)
Max Performance line		27	24
Max axial weight [t]		20	20
Max towed mass [t]	f (performance grade)	**870**	**1040**
	f (performance locomotive)	>1040	>1040
	f (normative)	1600	1600
Length of train [m]		301.7	345.3
Number of wagons		13	15
Number of TEUs transported		39	45

Costs [€/TEU]		Time [h]	
Road	Combined	Road	Combined
356	354	1:48	⬇⬇

Table 24 Output analysis - Scenario 5(2)

This configuration might guarantee an efficient rail service increasing the competitiveness of intermodal transport both on the cost and time side. In the last assumption, the use of high-performance trains makes the combined transport even more affordable with respect to the road haulage in terms of costs.

HIGHWAY TOOL (actual 18.9)	SCENARIO 5	SCENARIO 5(1)	SCENARIO 5(2)
	+5 €	+1 €	-

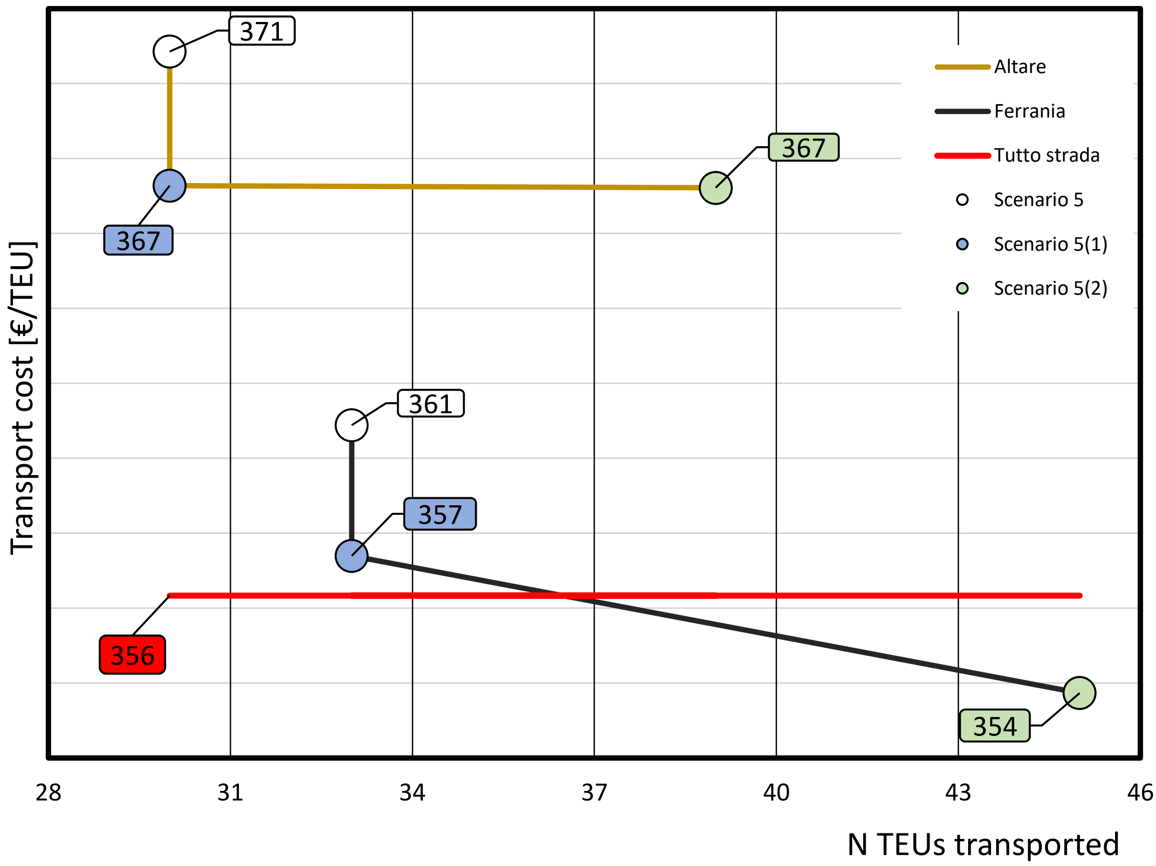


Figure 35 Scenarios 5-5(1)-5(2) comparison

4 CONCLUSIONS

This Master's thesis investigates intermodal freight traffic development opportunities between the Piedmont region and the Ligurian ports. The actual criticalities of intermodal transport, identified in infrastructural, technological, organizational, and commercial factors show a freight transport dominated by road haulage in this area. The model developed in this thesis highlights these criticalities, confirming the less attractiveness of intermodality with respect to road haulage both for costs and times.

Nevertheless, the recent opening of the new semi-automated deep-sea container terminal at the port of Vado Ligure (Savona) - which intends to handle 40% of container traffic by rail when fully operational - and the future opening of the Turin-Lyon railway line (scheduled for 2030) could create the conditions for increasing intermodal transport. Focusing on the Torino-Savona connection, among the scenarios evaluated, the only solution that effectively might improve the intermodal transport competitiveness is the one with a shuttle service between Torino and Savona. This solution guarantees a decrease in the port and inland terminals' handling costs and a coordination between the supply chain's tiers, also improving the time efficiency. Moreover, the use of high-performance trains ensures better services and the possibility to transport more UTIs on the railway line. On the other hand, a shuttle service needs a robust consolidation of the intermodal traffic demand. Thus, an update of the Torino Orbassano logistic platform to "*gateway*" function is necessary to superpose the regional and international volumes. This upgrade indeed, might create the conditions to guarantee a continuous rail service with the savonian ports and relaunch the competitiveness of intermodal transport between the two regions.

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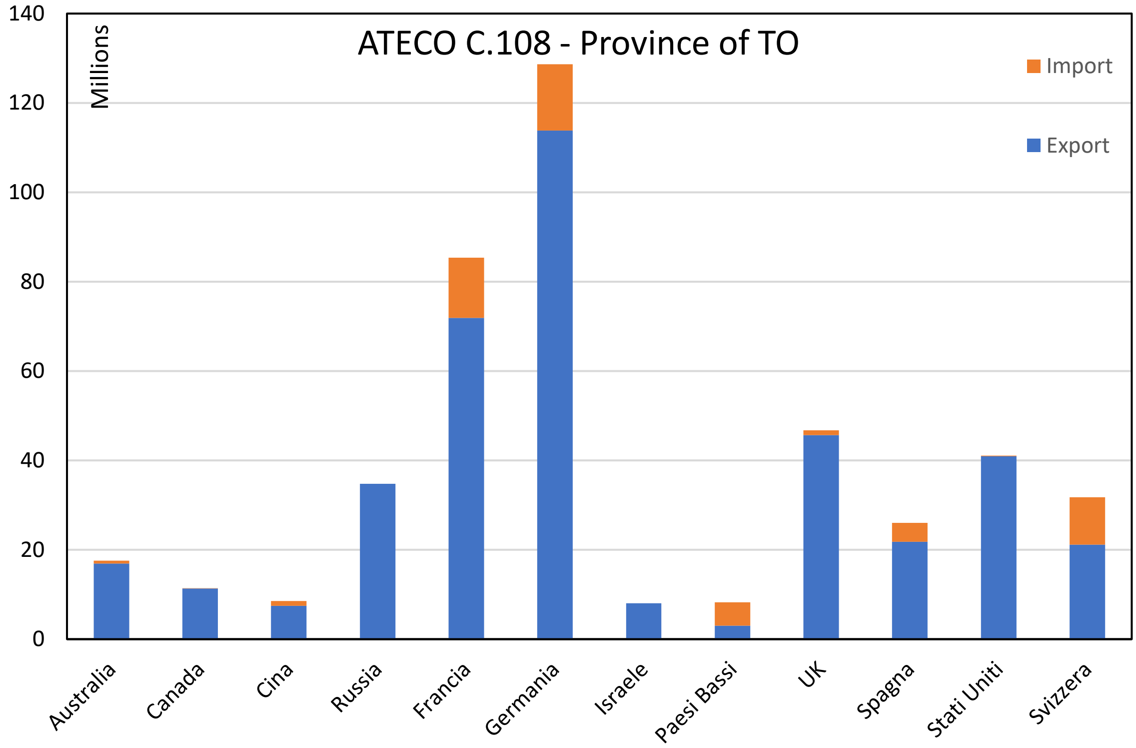
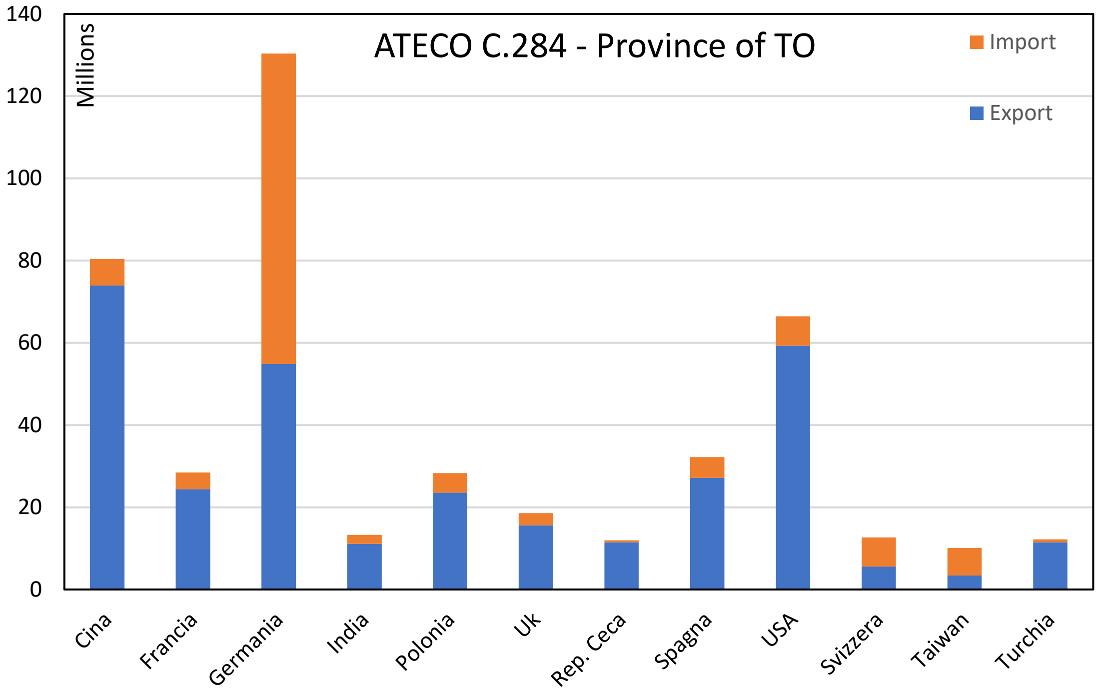
ATTACHMENTS

ATTACHMENT [1] – RELEVANT UE AND EXTRA-UE COUNTRIES FOR COFFEE, CONFECTIONERY AND CHOLOCTE OF TORINO DISTRICT

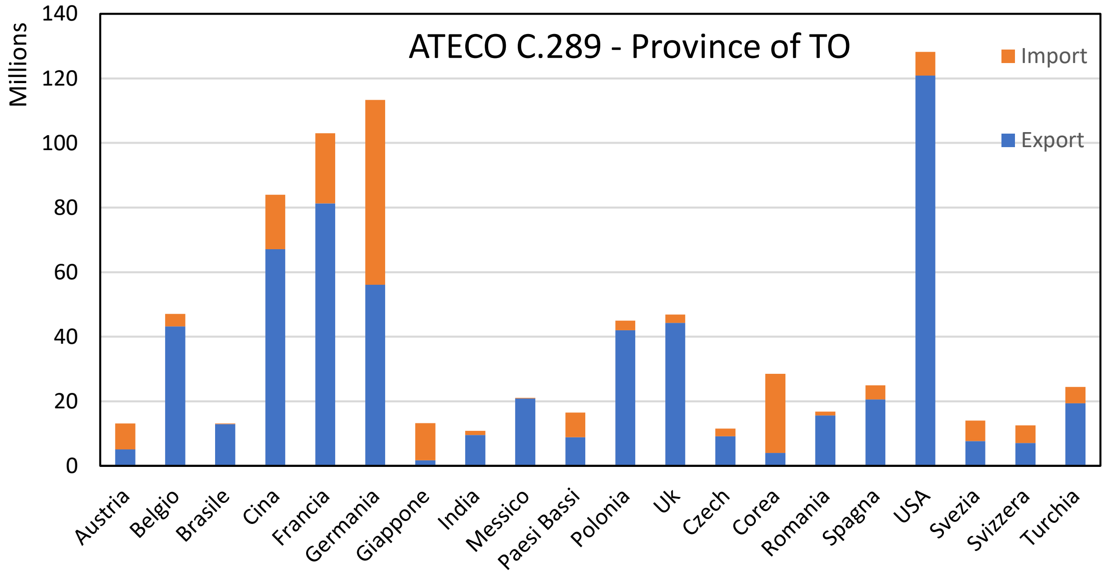


Relevant UE and Extra-UE countries for ATECO C.108 [Source: Istat data (2018)].

ATTACHMENT [2] - RELEVANT UE AND EXTRA-UE COUNTRIES FOR SHAPING AND INDUSTRIAL ROBOT OF TORINO

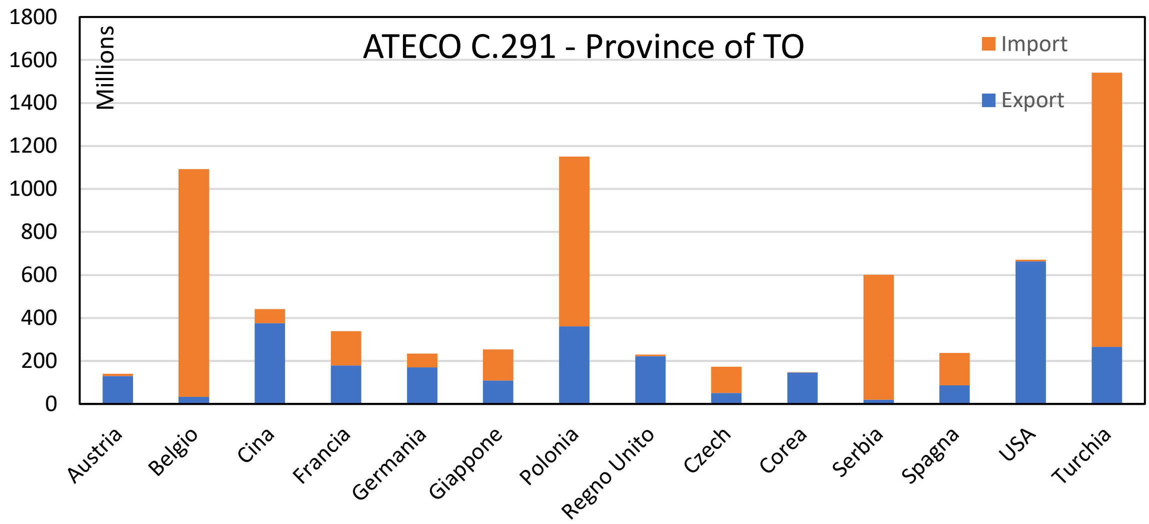


Relevant UE and Extra-UE countries for ATECO C.284 [Source: Istat data (2018)].

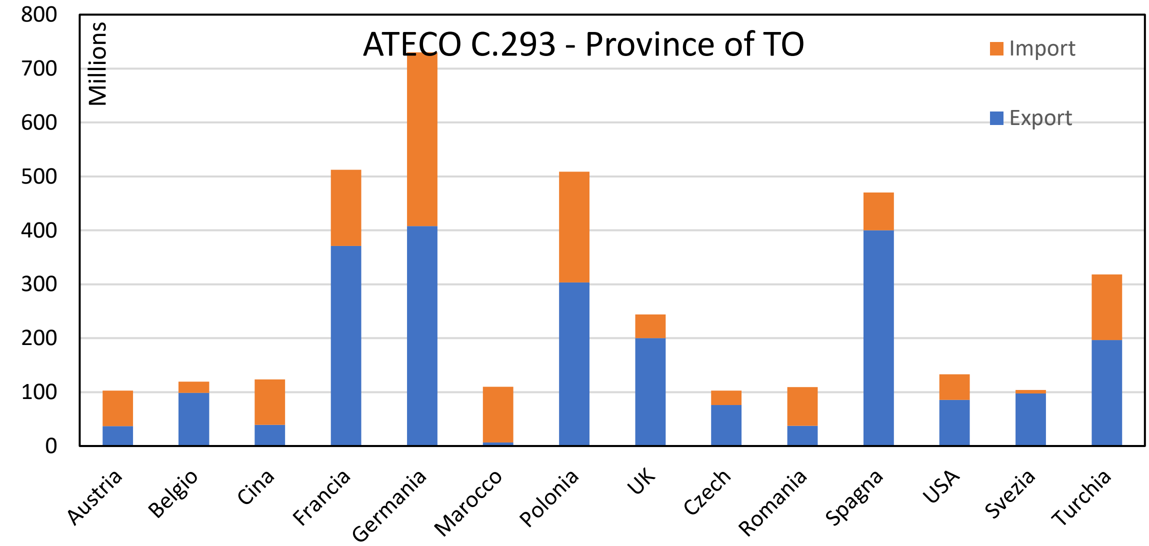


Relevant UE and Extra-UE countries for ATECO C.289 [Source: Istat data (2018)].

ATTACHMENT [3] - RELEVANT UE AND EXTRA-UE COUNTRIES FOR AUTOMOTIVE DISTRICT

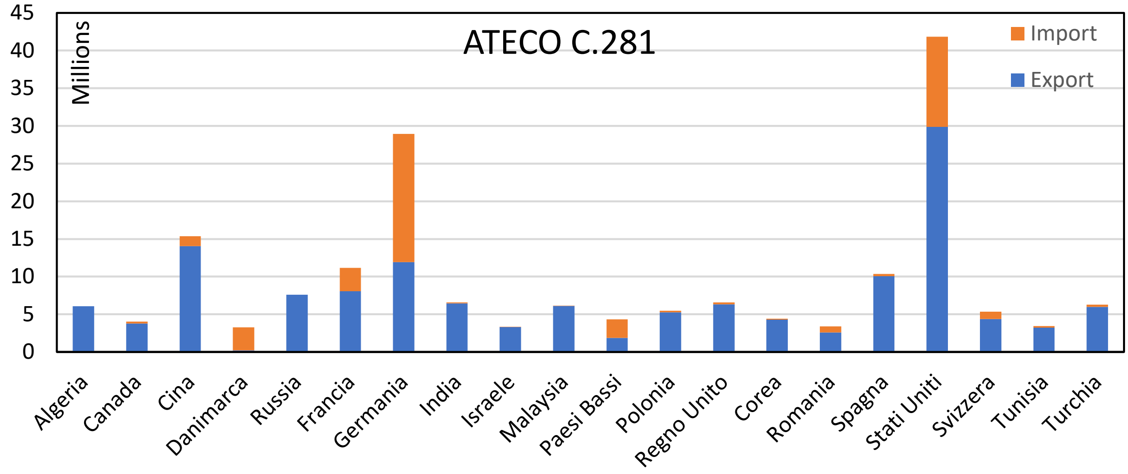


Relevant UE and Extra-UE countries for ATECO C.291 [Source: Istat data (2018)].



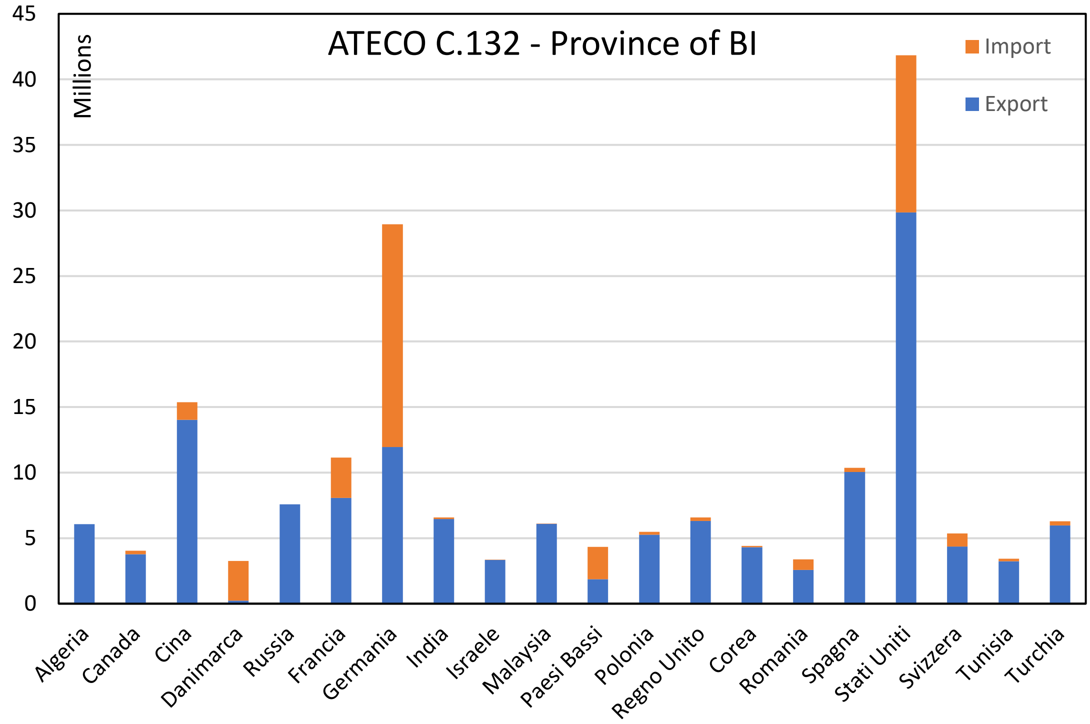
Relevant UE and Extra-UE countries for ATECO C.293 [Source: Istat data (2018)].

ATTACHMENT [4] - RELEVANT UE AND EXTRA-UE COUNTRIES FOR TAPES AND VALVES DISTRICT



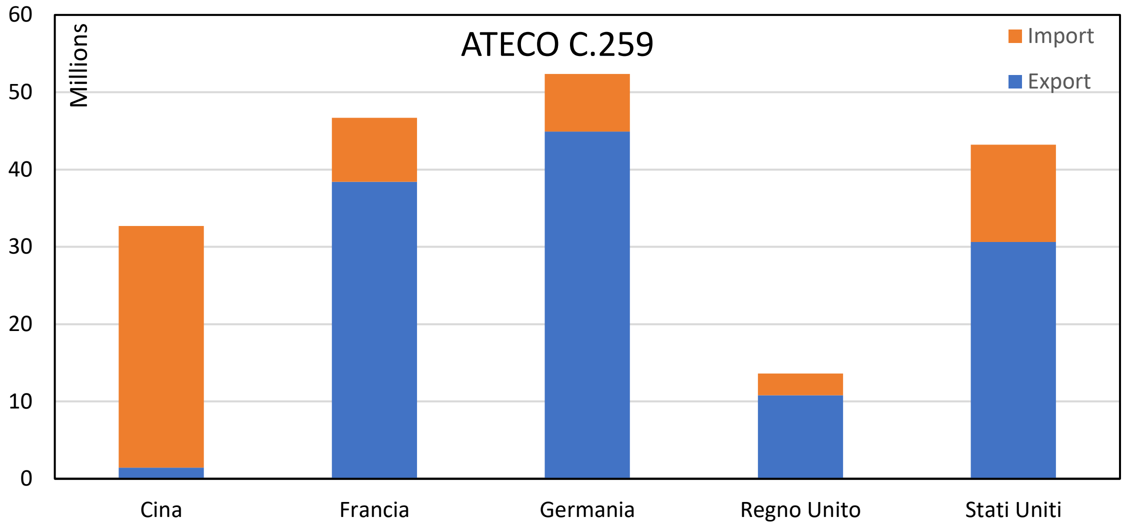
Relevant UE and Extra-UE countries for ATECO C.281 [Source: Istat data (2018)].

ATTACHMENT [5] - RELEVANT UE AND EXTRA-UE COUNTRIES FOR TEXTILE DISTRICT



Relevant UE and Extra-UE countries for ATECO C.132 [Source: Istat data (2018)].

ATTACHMENT [6] - RELEVANT UE AND EXTRA-UE COUNTRIES FOR HOUSEHOLD PRODUCTS



Relevant UE and Extra-UE countries for ATECO C.259 [Source: Istat data (2018)].