Analysis and quantification of the contribution of the FENIX Project to environmental sustainability (Genoa municipality and along the Rhine-Alpine Corridor)

Dissemination level:	PU
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Annex of the FENIX Deliverable 5.1: Common Evaluation Framework

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TABLE OF CONTENT

FIGURES

TABLES

1. INTRODUCTION

1.1. Targets of the study

The FENIX Project aims to define methods and tools to create a federation of platforms and/or systems used by the various operators involved in the logistics activities, in order to facilitate the exchange of data. Federation is enabled through the use of specific “connectors” that must be implemented by platform owners.

Project FENIX, which was conceived with the intention of responding to the digital transition goals of the European Union, actually also responds to the ecological transition goals. In fact, thanks to FENIX, it is possible to obtain a data exchange between the private and the public sector and this data exchange can have beneficial effects on the environment, as it is possible to see in the following chapters.

In the current design phase, the project considers only the transport-logistic aspect and therefore the actors and recipients of the various pilot cases are the transport operators. However, the aspect of the transferability of FENIX to other contexts in which the stakeholders are public transport planning bodies, such as the Regions or other local bodies of areas where there are ports or infrastructures in general, are not neglected. In fact, the system doesn’t place any constraints on the type of actors that can connect once it has developed its own FENIX connector.

The UC10 of the ITA 2 pilot demonstrated the interest that a public administration could have in acquiring some data from transport and logistics operators for planning and for short-term intervention purposes in order to optimize mobility and reduce the negative externalities produced, at various levels especially from road traffic.

Therefore, the purpose of this work is precisely to estimate the benefits for a public administration that may derive to the connection to the FENIX network. The assessment of these benefits is not carried out in absolute terms, but with regard to a very pressing issue today, namely that of environmental sustainability. These benefits will therefore be quantified in terms of positive environmental impact.

The estimates illustrated below are part of the pilots relating to the Rhine-Alpine Corridor: pilot ITA 2 and pilot DE.

Starting from Genoa and the assessment of the impact of the truck traffic generated by the port near the port gates and the benefits that the municipality of Genoa could have from use of data about the time of the entrance and the exit of the trucks that the port of Genoa could make available on FENIX, for example by intervening on the traffic light regulation of the sections that connect the nearest motorway toll gate to the port gates (chapter 3), the methodology has been extended to other logistic nodes along the Rhine-Alpine corridor that have similar characteristics to the port of Genoa, in particular as regards the location with respect to the urban centre (chapter 4).

1.2. Contract reference

FENIX stands for "A European FEderated Network of Information eXchange in Logistics." FENIX is an action 2018-EU-TM-0077-S under the Grant Agreement number INEA/CEF/TRAN/M2018/1793401, effective from 01 April 2019 until 31 March 2023.

It is a contract with the Innovation and Networks Executive Agency (INEA) under the powers delegated by the European Commission.

Communication details of the Agency:

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2. EXECUTIVE SUMMARY

In the FENIX Project (A European Federated Network of Information eXchange in LogistiX in the following simply FENIX network), some analyses (UC10 pilot ITA 2 Milan/Genoa/La Spezia) have been developed in order to understand what are the benefits that a public administration could have in connecting to the FENIX network through the appropriate connectors. For these analyses some public administrations of the North-West of Italy that is the main reference basin of the sites of ITA2 pilot (Genoa, La Spezia, Malpensa, and CIM terminal in Novara) were interviewed.

These investigations have revealed that the FENIX Project, initially created to serve exclusively the - entirely private - world of logistics and transport, presents numerous elements of interest also for a public administration, thus promoting synergy and collaboration between the two worlds. Knowledge of the routes and the estimated times of arrival (and of exit) of trucks from a logistics terminal could help the public administration to better manage their territories in the organization of heavy traffic, so that this creates the least possible impact on the overall mobility.

On these bases, the main objective of this work is to try to numerically quantify these benefits, in terms of improvement of mobility and reduction of CO_2 emissions due to the traffic of heavy vehicles directed to the port of Genoa.

The greater fluidity of traffic is the basic element used in this evaluation to quantify the overall benefits. It is therefore hypothesized that a Municipality, thanks to the use of some data available in the FENIX network, can intervene to make traffic more fluid with therefore lower emissions of pollutants, with the consequent generation of positive externalities.

Starting from what was defined in the MemEx study on the possible levels of involvement of the municipality of Genoa or the Liguria Region within the federation of platforms created by FENIX, the analysis maintains the distinction between "Territorial Area", i.e. the reality outside the port coinciding with the urban portion of the city of Genoa around the port and "logistics area" or the port area that can provide some data via FENIX. The assumption is that the first area may have an interest in some data available in the FENIX network present in the port, thus developing its own connector.

Within the port of Genoa, the players in the logistics chain exchange information through its Port Community System Eport, which has digitized most of the documentation. The drivers who collect/deliver the goods are accredited through a PIN that is provided to them by the company through a virtual booking system. This operation already makes it possible to have an initial database on the number of vehicles foreseen per day which could be of interest to the office of the municipality which manages mobility.

To evaluate a possible benefit deriving from lower emissions in relation to an optimization of urban traffic management (with reference to the last road mile) it was necessary:

A. Identify in detail which routes were most representative of the incidence of traffic in the urban area facing the port accesses;
B. Estimate the distribution of heavy vehicles at the reference port gates of the Prà Voltri and Sampierdarena basins, starting from the total number of 5,500 vehicles per day provided by the Port Authority;
C. Define the variables to be considered in the process of elaborating the reference estimates, such as the average speed of heavy vehicles in urban areas, waiting times for traffic lights, the subdivision of vehicles by emission category.

This evaluation assumes that the optimization intervention is mainly aimed at the systematization of information oriented to the traffic management in the city area: therefore, the motorway section and paths inside the terminals are not considered.

In the current scenario, the traffic of heavy vehicles generated by the port of Genoa produces around 7.2 tons of CO_2 per day. A traffic regulation intervention through the regulation of traffic lights made with a predictive analysis on the basis of the data obtained within the FENIX network would lead to a reduction of these emissions to approximately 6.8 tons (saving therefore 0.4 tons per day).

At the conclusion of the analysis, the evaluation of the effects was carried out in terms of the emission differential deriving from an optimization of the routes of heavy vehicles between the port area and the motorway accesses. Overall, therefore, the annual CO_2 saving would be around 120 tons (300 working days per year), accompanied by around 40 tons less fuel consumption. The monetary value of this reduction in emissions has been quantified at approximately 170,000 euros/year, mainly connected to less congestion, greater safety and less pollution.

The added value of the applied methodology is the transferability to other contexts that present characteristics similar to the Genoa area thus allowing for estimates to be made, for example at the TEN-T corridor level such as the Rhine-Alpine corridor.

Therefore, some intermodal terminals (freight centres) with characteristic similar to the port of Genoa, located along the Rhine-Alpine corridor were individuated among those belonging to the core network. Five terminals were selected, one for each Country crossed by the corridor (with the exception of Switzerland):

- Novara: Italy;
- Strasbourg: France;
- Duisburg: Germany;
- Antwerp: Belgium;
- Rotterdam: the Netherlands.

For each of these, the container terminal closest to the city centre was identified, given that this is where the greatest interference with private traffic occurs and a regulatory intervention by the city administration could be desirable. In the absence of data provided directly by the managers of these terminals, the number of trucks per day was estimated starting from the annual container handling statistics.

The extension of the methodology and the application of the calculation used for Genoa made it possible to quantify an overall annual saving of the five terminals of about 351 tons of CO_2 and more than 118 tons of fuel.

Therefore, at the level of the Rhine-Alpine corridor (including the port of Genoa) the annual saving is more about 471 tons of CO_2 and more than 158 tons of fuel.

The estimates made are necessarily conservative due to the lack of real data by the terminal operators, but they are examples of the potential benefits generated by the use of the information that could be made available by the FENIX network. The savings for the community in terms of harmful emissions and the reduction of costs for companies linked to supplies could be even greater and produce a multiplier effect along the entire corridor, the more the possibility of entering the FENIX network.

3. THE REFERENCE CASE STUDY: THE PORT OF GENOA

In this work, it is investigated how the FENIX network can have beneficial impacts on the environment. To do this, it was decided to consider one of the relevant corridors of European freight transport, namely the Rhine-Alpine corridor. This is one of the main European corridors and connects first-rate port realities such as Genoa and Rotterdam. To carry out this evaluation it was decided to start from Liguria, in particular from the port of Genoa, and then gradually extend the results along the entire corridor. For this reason, in the next paragraphs we will go into detail about the reality of the Ligurian capital.

The evaluation in question can be considered a further study of two studies carried out in the context of the Italian pilot site Milan/Genoa/La Spezia which, as will be seen, tried to identify which data exchanged potentially available in the FENIX network might be of interest for a Region or a local Authority in order not only to improve long-term mobility planning, but also to increase its short-term intervention capacity to reduce the impact of heavy vehicle traffic on the overall organization of the city.

3.1. Preliminary studies

In the context of the Italian pilot site ITA2, some studies have already been carried out aimed at understanding what could be the benefits deriving from the use of data made available by FENIX for a public administration, which may be Regions, or Municipalities. In particular, the following two works are worthy of note:

- UC10: Scale up and transferability plan, produced by Fondazione LINKS;
- UC10 (bis): Definition of the environmental context functional to the collaboration between operators, definition of connection gaps, identification of operator needs, produced by MemEx.

The results obtained are the starting point for the estimates illustrated below, since they allow us to have an initial indication of what data the FENIX network could make available to local administrations responsible for planning the strategies and investments in infrastructure and transport.

3.1.1. Use Case 10: Scale up and transferability plan

The study describes the results of a series of hearings with the representatives of the Lombardy, Liguria and Piedmont Regions for infrastructure and transport planning. The discussions revealed which data can be made available by the FENIX network with the aim of realizing public interests.

The analysis clearly indicates that among the needs of the regions there is an interest in environmental issues, namely to understand the link between the flows of goods and the environmental impact and also, and above all, the link between the location of logistic infrastructures and the related cost in terms of effects on the environment. This is the main driver that is also relevant for this analysis.

The study also lists the uses of the data provided by FENIX network with the aim of bringing added value to a public administration. For the purposes of this research, the information reported in the study relating to "data traffic on infrastructure" is relevant; this is a type of data that originates from the regional need to know the effective use of infrastructures and which thanks to FENIX data could be refined, leading to the acquisition of the knowledge of the data on load peaks acting on certain nodes.

Even the data on the Origins and Destinations of the goods can be used by a public administration for its own purposes and the work in question shows us how this data can be refined by providing precise and detailed information regarding the load units handled (for example, vehicles with containers, vehicles with swap bodies, other types of vehicles, etc.).

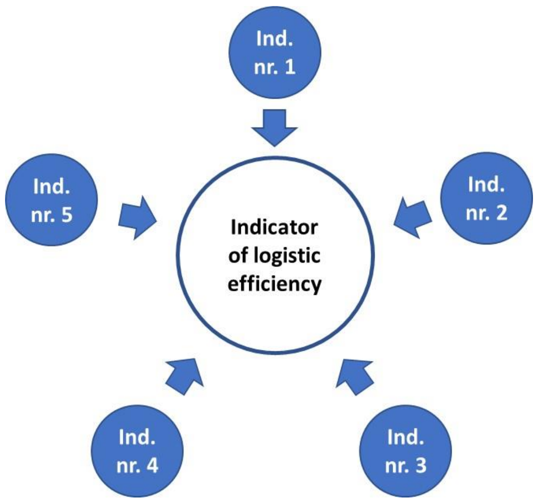

Figure 1: KPI for local/regional administration possible thanks to FENIX Projects
(Source: Fondazione LINKS)

In addition to environmental issues, the study reports that there is a further interest on the part of the Regions in identifying an overall indicator of logistical efficiency that can be comparable between them, as shown in Figure 1. This, as it can be seen, is only one of the possible KPIs thanks to the "territorial" use of FENIX data.

3.1.2. Use Case 10 bis: Definition of the environmental context functional to the collaboration between operators

The work carried out by the MemEx restricts the analysis to the Liguria Region only [Use Case 10 (bis)] and starts from the assumption that, to date, the scope of implementation of the FENIX Project is exclusively the logistic context. However, there are many data belonging to this area that may also be of interest for contexts not related to the pure logistics field.

The MemEx study introduces therefore a subdivision of the two possible fields of application into "Territorial Area" and "Logistic Area". This subdivision appears very useful to the targets of this assessment. The first is the one outside the scope of the FENIX Project (at least at the actual stage), i.e. not currently logged such as local authorities, the municipal police, public road transport operators, but that could consider connecting in order to obtain useful data. The second is constituted by the actors of the transport and logistics that are the stakeholders on which the FENIX Project is focused.

Between the “Territorial Area” and the “Logistic Area”, an exchange of data can take place, and indeed it is desirable, in order to pursue strategies useful to the community, as shown in the following Figure 2.

This subdivision of the two areas will also be maintained in this study.

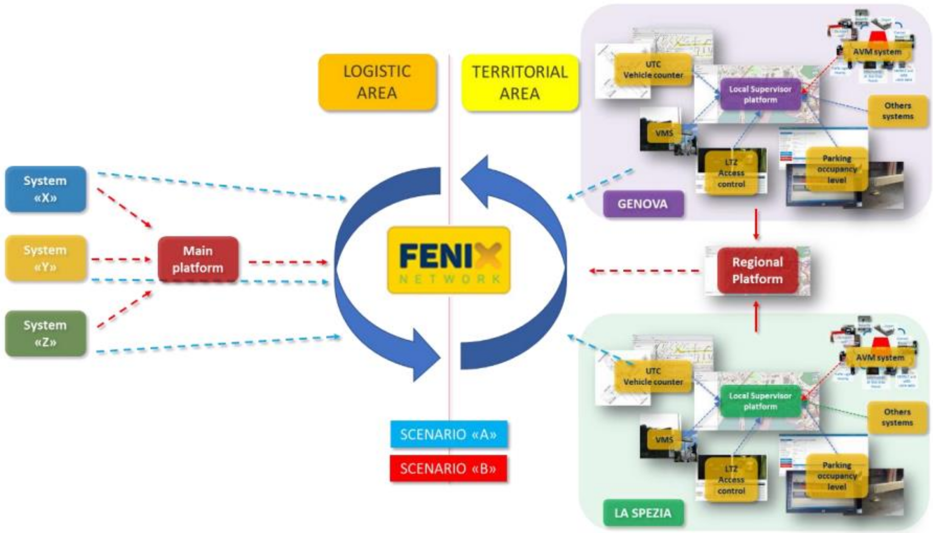

Figure 2: Scenarios of data exchanging between “Logistic Area” and “Territorial Area”
(Source: MemEx)

3.2. The port of Genoa

The port of Genoa is one of the largest Italian ports for the amount of total traffic (more than 48.8 million tons of goods handled in 2021, Table 1), for the number of shipping lines that calls it (more than 150 that connect it with other national, Mediterranean and all main coastal areas of the world) and for the vast range of complementary services it is able to offer (from repairs to shipbuilding, to telecommunications and data processing systems).

GOODS	TONS		
	IN	OUT	TOTAL
Total throughput	**29,166,233**	**19,665,376**	**48,831,609**
Liquid bulk	11,262,449	1,781,422	13,043,871
Dry bulk	2,482,104	240,430	2,722,534
General cargo	15,421,680	17,643,524	33,065,204
Containerized	*10,412,765*	*12,659,294*	*23,072,059*
Ro-Ro	*4,607,634*	*4,874,259*	*9,481,893*
Other general cargo	*401,281*	*109,971*	*511,252*

Table 1: Figures in tons related to port of Genoa
(Source: Elaboration on Assoporti and Ports of Genoa data)

All this makes Genoa the reference port for the production and consumption areas of Northern Italy, but also of Central Europe: in particular Switzerland, Germany and Austria.

The port has eighty (80) moorings on 21,900 meters of quay, depths up to 18 meters and 7,000,000 square meters of areas with more than 140,000 square meters of warehouses. The twenty-nine (29) specialized terminals allow the handling of all the main product categories: solid and liquid bulk, conventional goods, perishables, steel, forest products, Ro-Ro and containers (Table 2).

Year 2021	TEUs
Hinterland	*2,211,035*
Transhipment	*346,812*
Total TEUs	**2,557,847**
Ro-Ro units	**380,384**

Table 2: Figures in tons related to port of Genoa
(Source: Assoporti)

In particular, containers (more than 2.5 million TEU in 2021) are accommodated both in the terminals of the Sampierdarena basin and in the Prà Voltri basin.

Also important are the services for passengers (ferries and cruises) with five dedicated terminals.

The ship repair and maintenance industry is very active, with establishments located in the eastern part of the port while in the oldest area of the port, close to the historic centre, there are tourist facilities (Aquarium, Sea Museum) and services for boating and leisure.

The Port Authority of Genoa is planning investments for the next few years for over 2 billion euros, mostly derived from the PNRR, destined to change not only the internal structure of the port but also to have repercussions on the viability and on the part of the city around the commercial port. Furthermore, thanks to the construction of the New Breakwater, it will be possible to safely access larger container ships. This infrastructure will allow the Genoese port to intercept new traffic which will necessarily have repercussions on the movements for sending and receiving goods to/from the reference markets of Northern Italy and Europe.

3.2.1. The "Logistics Area" of Genoa

The exchange of data between the players in the logistics chain in the port of Genoa takes place through the Port Community System (PCS) Eport. In about 16 years of activity, Eport has digitalized the exchange of all the main documents involved in the import/export and transhipment processes relating mainly to containerized goods but also to other types and loading units.

From several years, the obligation of an access pass (Port Authority badge) has been extended to all road transport, also with the issuance of daily permits, and procedures and operational functions have been implemented for the management of the entry and exit of goods, heavy vehicles and people at port gates that require the possession of a permit from the Port Authority.

The active and integrated players in the system are identifiable, up to the introduction of the appointment, in the freight forwarders, shipping agents and terminals while until the introduction of the intermodal appointment the road haulage players had not been involved.

In order to complete traceability and to better synchronize the delivery and collection of goods, the "Road Transport Journey" has been introduced, i.e. notification of the arrival of the goods and the driver.

The "Road Transport Journey" is briefly constituted by:

- Identification of the vehicle (plate);
- Driver identification (Port Authority badge number);
- Time reference (time and expected date of arrival at the port);
- Goods to be delivered and warehouse / terminal of destination;
- Goods to be picked up and warehouse / pickup terminal.

The Journey is therefore a basic unit that binds vehicle and driver to the goods managed for all cycles (import, export, containers, various goods, ro-ro, bulk, empty containers).

The journey also constitutes a virtual binder which, fed by the various actors, contains the digital documentation necessary for passage, transport and terminal.

The withdrawal code (PIN) is a sequence of alphanumeric characters uniquely associated with a container and issued by the shipping line at the conclusion of the release. The availability of the PIN allows to dematerialize the delivery order. It is the responsibility of the shipping company to communicate the PIN to the terminal via the PCS in an encrypted and digitally signed way. It is always the responsibility of the company to make the PIN generated in support available to the freight forwarder and in a manner consistent with the release methods in use. The start-up of the PIN communication system will be carried out progressively to the consolidation of road transport journey. Figure 3 summarizes the scheme for obtaining the intermodal appointment via PIN.

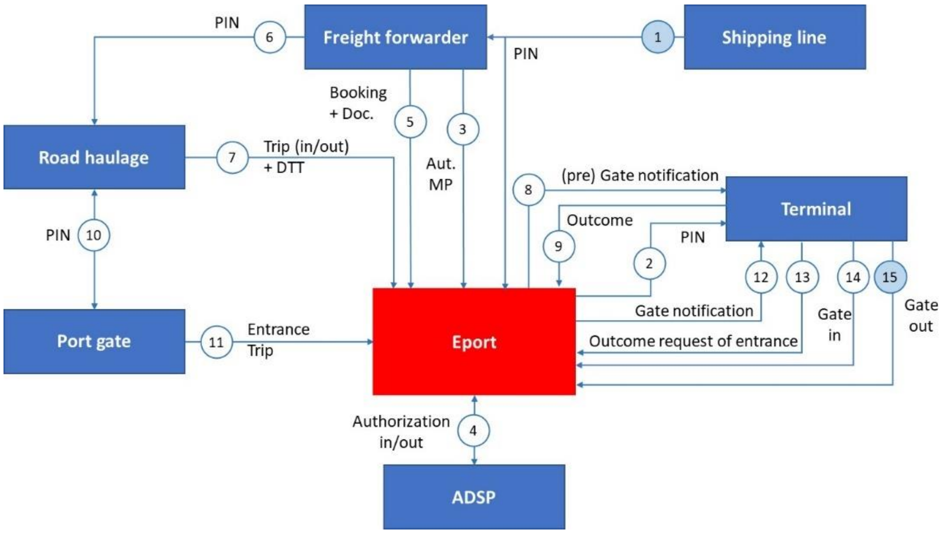

Figure 3: Scheme of the intermodal appointment through PIN
(Source: Hub Telematica Scarl)

Road transport operators, showing up with the travel forecast, has visibility:

- State of the goods (if it can be collected / delivered);
- Documents attached by other parties in the chain (such as T1, MP in / out authorizations, delivery orders);
- Booking made at the unloading by the line to the terminal (unloading order);
- Presence of the reservation upon collection by the forwarder (delivery / delivery note and its validity).

Diversified functions are available for the communication of the withdrawal PIN (telematic agency release). With the communication of the trip, the transport is traced from the entrance of the port areas to the gate out of the terminals.

Thanks to the intermodal appointment and the forecast of arrival of the vehicle, provided by the hauler, it is possible to know in advance from the PCS of the port of Genoa how many vehicles are expected to arrive at a certain port gate and at a certain time. This is of fundamental importance for this case study.

If these data from the PCS of the port of Genoa were made available in the FENIX network, another FENIX user, belonging to the "Territorial Area" (which could be the municipal administration) could know in advance how much traffic is expected and therefore can plan mobility within the municipality in the best possible way.

3.2.2. The "Territorial Area" of Genoa

The main stakeholder belonging to the "Territorial Area" of the city of Genoa is the municipal administration. The task of the administration is to promote the interests of its community and the balanced social, cultural, and economic development, taking into account in its choices the vocation of Genoa as a maritime, mercantile, industrial, tourist and entrepreneurial city.

One of the factors of greatest attention, therefore, is the impact of road traffic flows generated by the port. The O/D matrix of the movements of goods in the area of the municipality of Genoa elaborated in the PUMS (Piano Urbano della Mobilità Sostenibile: Urban Plan for Sustainable Mobility) estimates a flow of around 90 thousand vehicles per day, of which around 65% is made up of heavy vehicles which exchange goods outside the municipal area.

At present, as communicated by the mobility sector of the Municipality of Genoa, there is no exchange of data between the port and the municipality regarding the daily flow of trucks and the routes used to reach the port gates from the motorway toll gates. If, on the other hand, the municipal administration were part of the FENIX network, it could know the data on the flows of heavy vehicles to/from the port and therefore could implement appropriate interventions, even in real time, to streamline and secure overall traffic by acting, for example, on traffic light management near port gates[1].

Figure 4 shows the data exchange scheme for traffic light management from the Port Community System of the Genoa port and the traffic management platform of the Genoa Municipality.

This data exchange is the basis for quantifying FENIX's contribution to environmental sustainability.

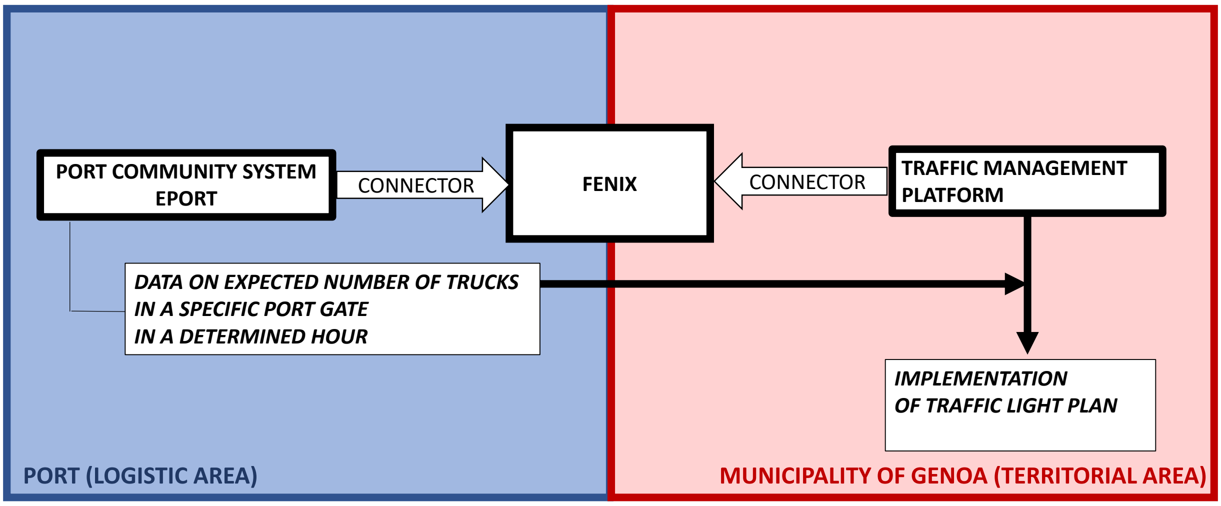

Figure 4: Data exchange between port and municipality of Genoa for traffic light management

[1] In this regard, the mobility sector of the municipality of Genoa was contacted in the preliminary phase of the study. Information on the daily flows of trucks heading to the port would be very useful for managing overall city mobility. The representative of the sector said he was interested in possibly being involved in the project.

The fundamental premise for this evaluation is that, thanks to the data exchange, through FENIX connectors, between the Port of Genoa and the Municipality of Genoa, it is possible to rationalize traffic with the appropriate regulation of traffic lights.

In fact, as it was described, the port of Genoa can know in advance the arrival of heavy vehicles at a specific port gate; the municipal administration can obtain this data and can adjust the traffic lights in advance by giving priority to heavy vehicles, smoothing their journey. All this translates into a speeding up of the travel times of heavy vehicles and consequently in a shorter emission time of the same.

It is well known that one of the effects of road congestion is precisely the reduction in the speed of the vehicles (Struyf et al., 2020) with therefore a longer driving time and consequently with the generation of higher emissions. Therefore, thanks to the use of FENIX it is possible to limit road congestion.

The study aims to evaluate the difference in CO_2 emissions in the following two scenarios:

- Travel time without FENIX: is the travel time "motorway tollgate-gate of the port of Genoa" of trucks in the event there is no data exchange between the port of Genoa and the municipality of Genoa, therefore without any optimization of the traffic light plan;
- Travel time with FENIX: it is the travel time of the trucks from the "motorway tollgate-gate of the port of Genoa" assuming a data exchange via FENIX between the port of Genoa and the municipality of Genoa in order to allow the appropriate preventive regulation of the traffic lights.

CO_2 emissions will be calculated based on travel time.

3.3. Evaluation of the heavy vehicles traffic of the port of Genoa

In the following, the estimation of the reduction of emissions obtained through the smoothing of traffic by regulating the management of the traffic light network will be made by taking into account only the heavy traffic generated by the port of Genoa, ignoring the potential reduction of CO_2 emissions produced by light vehicles. Consequently, only the section of the port including the commercial terminals will be analysed.

Figure 5: Gates of the commercial section of the port of Genoa and related motorway toll gates

As already described, the commercial port of Genoa extends into two main basins, the Prà Voltri basin and the Sampierdarena basin. There are five access gates: one relating to the port of Prà (Prà gate) and four relating to the port section of Sampierdarena (Ponente gate, Etiopia gate, San Benigno gate and Albertazzi / Passo Nuovo gate). The position of the gates is shown in Figure 5, which also shows the nearest motorway toll gates.

The urban area of Genoa is accessible through four motorways, as shown in Figure 6:

- A26, Genoa - Gravellona Toce, to the North West;
- A10, Genoa – Ventimiglia, to the West;
- A7, Milan – Genoa, to the North;
- A12, Genoa – Rome, to the East.

The Genova Prà motorway toll gate and the Genova Aeroporto motorway toll gate are on the A10 motorway, while the Genova Ovest one is located on A7 motorway.

Figure 6: Motorway accesses to the area of Genoa
(Source: elaboration on Viamichelin data)

According to the Port Authority of Genoa, 5,500 heavy vehicles are loaded daily in the commercial port distributed among the gates in the Sampierdarena section as in Figure 7.

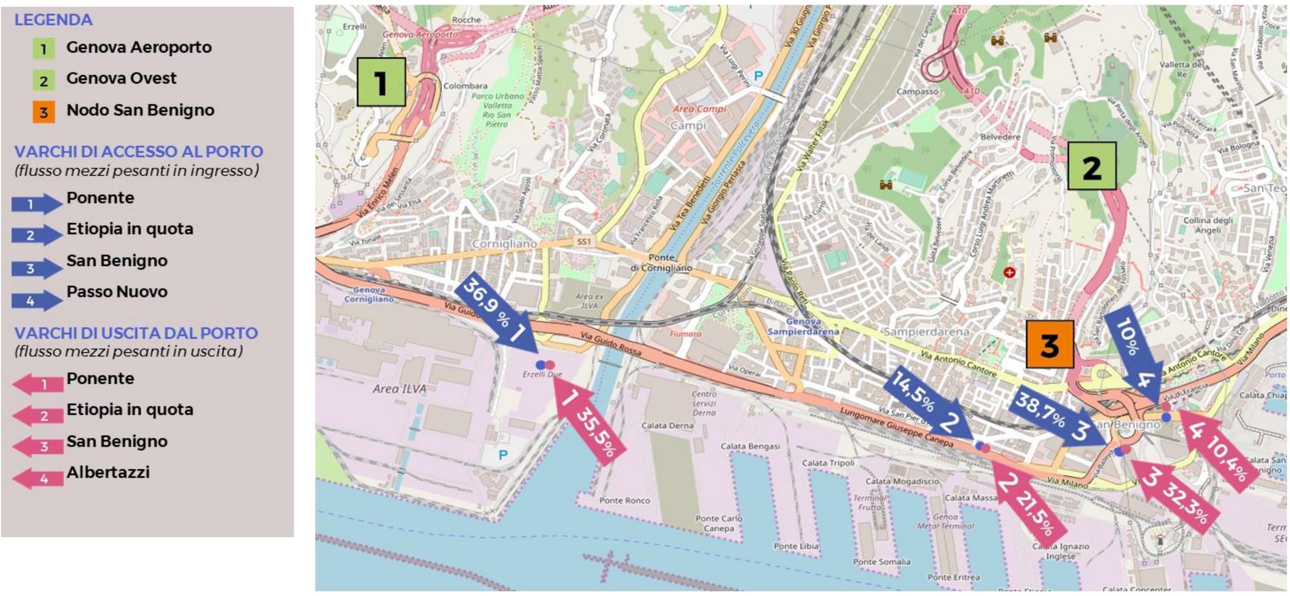

Figure 7: Share out of the heavy vehicles in the gates of Sampierdarena section of the port of Genoa
(Source: Ports of Genoa)

Starting from the total number of vehicles, a subdivision into vehicles entering and vehicles leaving the port was created, a subdivision that coincides with the division between goods for export and goods imported through the port of Genoa. Therefore, the total number of vehicles was re-measured on the basis of the percentage (by weight) of imports and exports of the total goods handled. As for 2021, this percentage is 60% import and 40% export[2].

Furthermore, a division was made between the traffic of the Prà section and the Sampierdarena section, again on the basis of the total tons handled. This share is 25% in Prà and 75% in Sampierdarena[3].

On the basis of these percentages and the breakdown provided by the Port Authority shown in Figure 7, the heavy vehicles entering and leaving the port have been divided and distributed for the five gates, as shown in the Table 3.

		25%	75%				
		PRA'	SAMPIERDARENA				
			PONENTE	ETIOPIA	SAN BENIGNO	ALBERTAZZI/PASSO NUOVO	**TOTAL**
60%	IMPORT	825	881	535	802	257	3,300
40%	EXPORT	550	607	239	639	165	2,200
	TOTAL	**1,375**	**1,488**	**774**	**1,441**	**422**	**5,500**

Table 3: Port of Genoa - daily heavy vehicles per gate
(Source: elaboration on Ports of Genoa data)

[2] Year 2021, Inbound 29,17 M t, Outbound 20,41 M t. Source: Port of Genoa, Traffici ed Avviamenti al lavoro dell'Autorità di Sistema Portuale del Mar Ligure Occidentale 2021, p. 17.

[3] Year 2021, Prà 12,53 M t, Sampierdarena 37,04 M t. Source: Port of Genoa, Traffici ed Avviamenti al lavoro dell'Autorità di Sistema Portuale del Mar Ligure Occidentale 2021, p. 4.

3.4. Urban road routes of the heavy vehicles to/from the port

The analysis focused on defining the urban routes made by heavy vehicles serving the port by quantifying the distance between the entrance gates at the port gates and the nearest motorway toll gate. As can be seen, the routes certainly appear to be quite short, however it must be taken into account that both the routes taken within the motorways and the routes taken within the port terminals have not been considered in the context of this analysis. It is therefore evident that, since the port gates are rather close to the motorway toll gates, the routes have rather reduced kilometric distances.

In the specific case of Genoa, five main routes have been identified, on which the estimated daily incoming/outgoing flow of heavy vehicles has been calculated, as summarized in Table 4 and defined more in detail in BOX 1.

The calculation of heavy vehicles passing through the individual gates takes up the estimates made in the previous chapter and shown in the Table 4.

Route	Path	Distance (m)	Vehicles/ day (nr.)	%
1	Genova Prà motorway toll gate – Prà gate	1,000	1,375	25%
2	Genova Aeroporto motorway toll gate – Ponente gate	2,770	1,488	27%
3	Genova Aeroporto motorway toll gate – Etiopia gate	4,000	774	14%
4	Genova Ovest motorway toll gate – San Benigno gate	1,900	1,441	26%
5	Genova Ovest motorway toll gate – Albertazzi/Passo Nuovo gate	1,700	422	8%
		Total vehicles	**5,500**	

Table 4: The five routes identified and the related number of heavy vehicles

Once the routes were identified, the distances estimated and the proportional share of the number of heavy vehicles assigned to the various routes selected, it was necessary to define an optimization hypothesis derived from the use of data obtained with FENIX (see Figure 4), that is, a synchronization of the traffic light system such as to allow a "green wave" to vehicles entering/exiting the port.

Knowing in advance the number of heavy vehicles arriving at a certain gate and the estimated times, it is possible to synchronize the traffic lights in order to allow greater traffic flow of these vehicles by eliminating the stops at traffic lights in the urban road section between a motorway exit (toll gate) and the related gate of the port and therfore the associated emissions.

The analysis of the previous highlighted routes (Table 4) has therefore made it possible to identify the presence of a traffic light in three of the five routes, more specifically in sections 3, 4 and 5 as illustrated in Figure 8, in Figure 9 and in Figure 10.

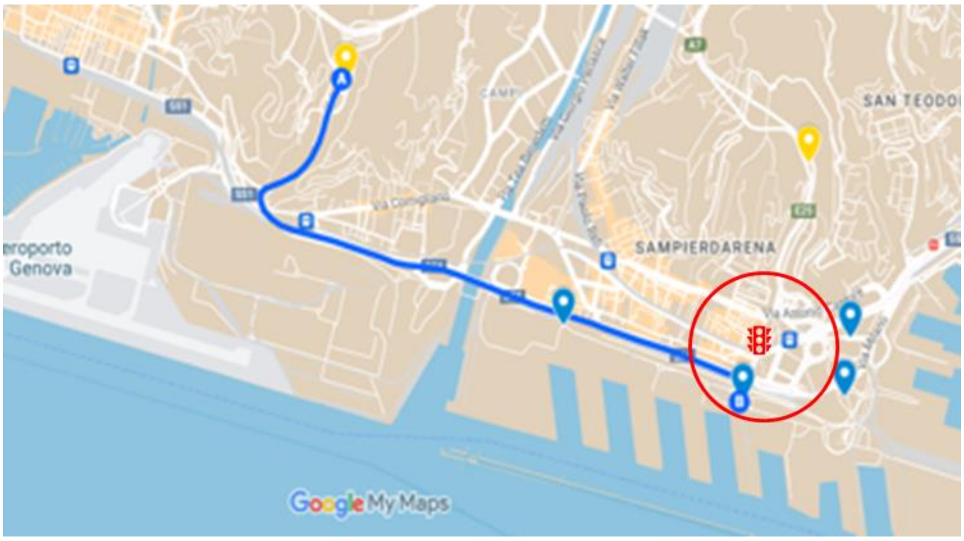

Figure 8: Traffic light system along the route 3, Etiopia gate
(Source: elaboration on Google data)

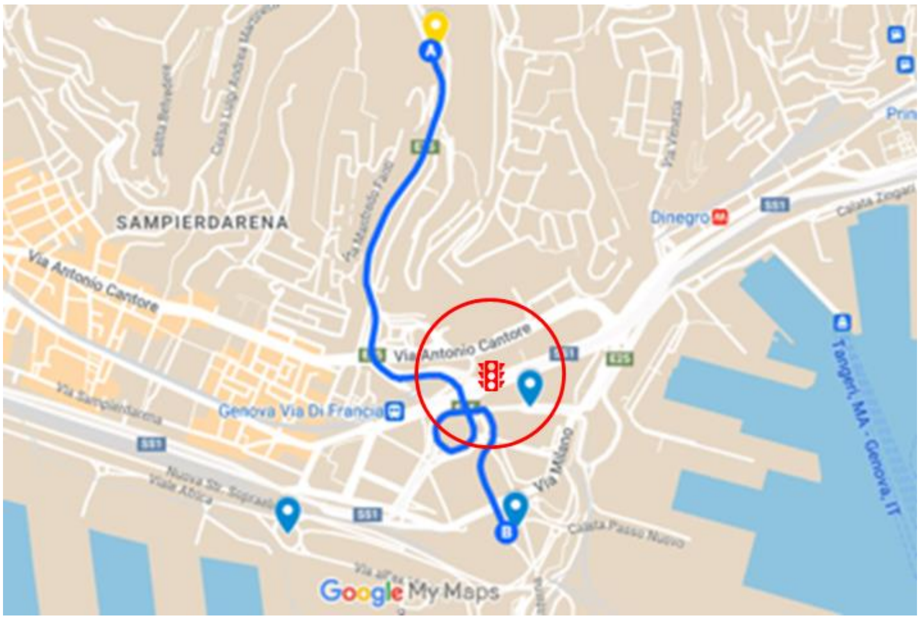

Figure 9: Traffic light system along the route 4, San Benigno gate
(Source: elaboration on Google data)

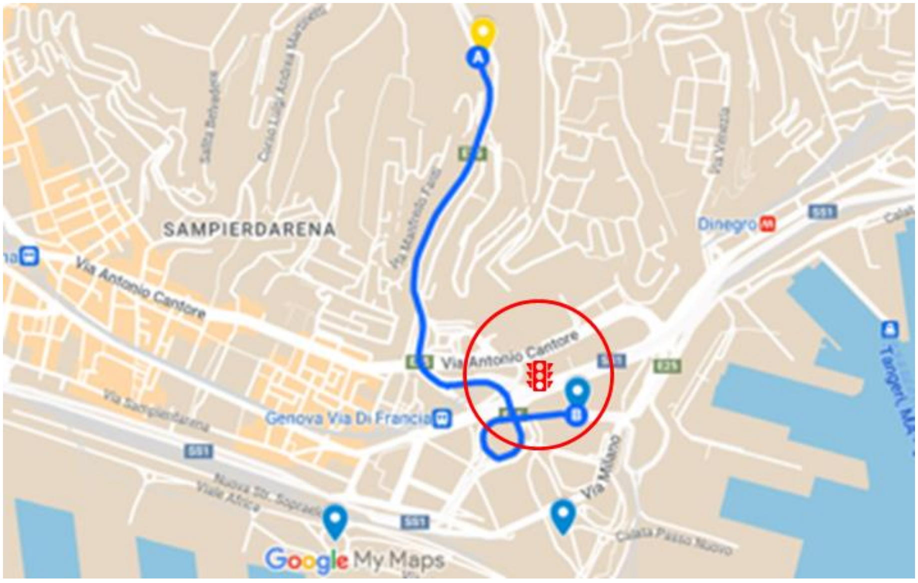

Figure 10: Traffic light system along the route 5, Albertazzi/Passo Nuovo gate
(Source: elaboration on Google data)

3.5. Parameters for the CO_2 emission calculation

In this chapter, the parameters that will be used for the calculation of CO2 emissions such as the average speed in urban areas, the average waiting times at traffic lights, the type of fuel and the emission category of the trucks, are described and sized.

Average speed of heavy vehicles in urban areas

This data is necessary in order to calculate the average travel times of the road sections identified by the routes previously described and also to be used to calculate the hypothetical additional distance traveled in the waiting period at the red light.

To this scope, since there are no precise estimates relating to these speeds, an average speed of 20 km/h (5.56 m/s) was used, derived from a hypothetical intermediate figure evaluated on the basis of:

- from 23.2 to 24.1 km/h calculated for cars in the Genoese Urban Mobility Plan of 2010[4] and in the PUMS of 2019[5];
- 17.8 km/h, estimated in the 2020[6] Rome Urban Plan for Sustainable Mobility.

[4] Comune di Genova, Direzione Mobilità, Piano Urbano della mobilità Genovese, gennaio 2010.
[5] Città metropolitana di Genova, Piano urbano della mobilità sostenibile, luglio 2019.
[6] Roma, Piano Urbano della mobilità sostenibile, Volume 1, 2020.

Traffic light waiting times

From an initial analysis, the absence of a specific regulated code relating to traffic light waiting times was evident, in the face of general indications derived from the practical applications of the various bodies that manage the regulation.

It was therefore deemed necessary to refer to sources as official as possible that could provide data regarding traffic light expectations.

A more precise indication was provided by the Italian Ministry of Transport of 6 July 2007, n. 67906[7] only with reference to the duration of the yellow light (which – notoriously – is capable of triggering fines for failure to comply with the red light) for a duration between 3 and 5 seconds.

As far as red is concerned, the analysis indicates that the average duration of red is 48 seconds compared to the 29 generally granted to green.

The red light duration was considered equivalent to a forced stop&go of 48 seconds, subsequently transformed into further potential distance based on the previously estimated average speed while the yellow time was not considered in this evaluation, since it is considered an integral part of the deceleration/acceleration phase.

Subdivision of vehicles per emissions cathegory

Starting from the distribution of the passages through the port gates made in Table 4, a further subdivision of the vehicles was made by Euro emission class as shown in Table 5. The estimate was made on the basis of the ACI fleet statistics. For the methodology and details of the calculation of the values contained in the table, please refer to BOX 2 at the end of the chapter.

The number of 5,550 vehicles, provided by the port, in this subdivision is rounded in 5,506, in order to respect the differentiation by heavy vehicles. Furthermore, only diesel-powered vehicles were taken into consideration.

[7] Nota 16/07/2007, n. 67906 - Ministero dei Trasporti, Tempi della durata del giallo ai semafori

Emission class	National average composition (source ACI)	Vehicles (nr.)					
		Route 1	Route 2	Route 3	Poute 4	Route 5	Totale
Euro 0	0 %	-	-	-	-	-	-
Euro 1	0 %	-	-	-	-	-	-
Euro 2	0 %	-	-	-	-	-	-
Euro 3	0%	-	-	-	-	-	-
Euro 4	23 %	313	339	176	328	96	1,252
Euro 5	29 %	394	427	222	413	121	1,577
Euro 6	49 %	669	724	377	701	206	2,677
Vehicles (nr. rouded)		**1,376**	**1,490**	**775**	**1,442**	**423**	**5,506**

Table 5: Port of Genoa - Heavy vehicles traffic per route and per emissions class
(Source: elaboration on ACI data)

Heavy vehicle emissions

For the average values of traffic emissions by sector, fuel and type, reference was made to the INEMAR 2019 database of ARPA Lombardia.

The values reported in the Table 6 are related to heavy vehicles beyond above 3.5 tons and powered by diesel. The choice of those two values was done considering all the hypoteses described in the BOX 2.

Legislative type	Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS
	g/km	mg/km	mg/km	mg/km	mg/km	mg/km	g/km	mg/km	mg/km	mg/km	mg/km	mg/km
Euro 0	178	1.1	7,379	758	50	1,913	528	30	2.9	322	363	414
Euro I - 91/542/EEC Stage I	161	1.0	5,196	361	56	1,144	477	6.8	2.9	234	275	328
Euro II - 91/542/EEC Stage I	170	1.0	6,210	258	55	1,048	502	7.5	2.9	157	200	255
Euro III - 1999/96/EC	193	1.2	5,382	255	60	1,397	570	5.6	2.9	175	220	279
Euro IV - COM(1998) 776	176	1.1	3,521	32	3.8	656	521	15	2.9	79	123	182
Euro V - COM(1998) 776	194	1.2	3,578	38	4.4	1,140	574	50	11	95	141	204
Euro VI - Reg EC 595/2009	197	1.2	378	27	4.4	153	582	46	9.0	62	109	172

Table 6: Macro pollutant emission for the different Euro class of vehicle (powered by diesel)
(Source: INEMAR, banca dati ARPA Lombardia)

These values were therefore used to evaluate the emissions of heavy vehicles in transit in the city routes described in the previous paragraphs. The blue highlighting of some of the data shown in the table is functional for differentiating the reference unit values (g and not mg) at a glance.

As mentioned in BOX 2, the field of analysis is restricted only to vehicles of a type equal to or greater than Euro 4, in consideration of the access bans in the considered municipality.

Reference period

The estimate of the impacts at the annual level was carried out considering 300 days of activity of the port of Genoa out of the 365 days per year.

3.6. Comparison of the two scenarios: current and FENIX

Two scenarios were considered: the <u>current scenario</u> (also called "without FENIX" scenario) corrispondenting to the actual situazion (traffic flow otimization based on data about the time of entrace/exit of the heavy vehicles in/from the port of Genoa) and the <u>FENIX scenario</u> (also called "with FENIX" scenario) where thanks to thanks to the data exchange on the FENIX network between the Port of Genoa and the municipal administration an optimization of traffic flows of heavy vehicles is realized.

In both scenarios, the emissions of various macro-pollutants were calculated on a daily and annual basis and the values obtained were then compared.

3.6.1. Emissions in the current scenario

Combining the composition of the vehicle fleet described in the previous paragraphs with the overall distances estimated, the values of emissions for the scenario in the absence of traffic flow optimizations possible with the availability of data in the FENIX network were calcualted (Table 7 – current scenario).

		Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS
	Nr. Vehicles	g	mg	mg	mg	mg	mg	g	mg	mg	mg	mg	mg
EURO 0	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 1	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 2	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 3	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 4	1252	510,537	3,193	10,219,166	93,748	11,029	1,902,543	1,511,586	42,085	8,417	229,582	357,870	527,081
EURO 5	1577	708,320	4,388	13,085,092	137,861	16,090	4,166,912	2,097,169	182,474	40,225	345,932	515,607	745,619
EURO 6	2677	1,219,672	7,448	2,346,859	164,485	27,311	946,564	3,610,600	287,383	55,863	384,833	674,078	1,065,118
	5,506	**2,438,529**	**15,029**	**25,651,117**	**396,094**	**54,430**	**7,016,020**	**7,219,355**	**511,942**	**104,505**	**960,347**	**1,547,555**	**2,337,819**

Table 7: Emissions in the current scenario

As result from the above table, the daily emission of the different macro pollutants produced by the heavy vehicles in the urban road section of the their path to/from the Genoa port in the current scenario are

- 2,438 kg of fuel (diesel);
- 25.6 kg of NO_X;
- 7.0 kg of CO;
- 7.2 tons of CO_2

The details of these calculations are in the Table 20 (BOX 3).

3.6.2. Emissions in the FENIX scenario

Starting from the variables described in the previous paragraphs, the differential generated by FENIX scenario was calculated following the below steps:

I. The FENIX impact can be registered in three of the five routes (3, 4 and 5): i.e. the routes along with there are traffic lights;
II. The elimination of the stop & go of heavy vehicles at the traffic lights would avoid 48 seconds of emissions per vehicle (corresponding to the waiting time at the traffic light with the engine running);
III. These emissions are calculated as a **hypothetical additional journey** of heavy vehicles at the average speed considered (assuming that the emission of a vehicle is the same when it is stationary and when it is in motion).

It is clear that this assumption involves approximations, however for the purposes of this work it is believed that any differences due to the different state of the vehicle (stationary or in motion) do not lead to substantial variations in the final result of the estimate.

On the basis of what was just described, the distances of the 3 routes that include at least a traffic light have been updated and artificially extended, obtaining the data shown in the **Errore. L'origine riferimento non è stata trovata.**, where the FENIX impact is highlighted as a reduction of a hypothetical overall distance between 6% and 14%, thanks to shorter travel times, corrispondenting to around 700 km per day.

Route	Traffic lights	NO FENIX STOP&GO (s)	FENIX STOP&GO (s)	NO FENIX TIME_WORST (s)	FENIX TIME_BEST (s)	NO FENIX DISTANCE_WORST (m)	FENIX DISTANCE_BEST (m)	DELTA %
1	0	0	0	180	180	1,000	1,000	0%
2	0	0	0	499	499	2,770	2,770	0%
3	1	48	0	768	720	4,267	4,000	-6%
4	1	48	0	390	342	2,167	1,900	-12%
5	1	48	0	354	306	1,967	1,700	-14%

Table 8: Difference of distances without or with FENIX

These reductions, extended to the assumed 300 days of activity and traffic, would make it possible to total a saving 211,000 km in a year, as shown in the **Errore. L'origine riferimento non è stata trovata.**.

Route	Delta (%)	Delta (m/day)	Delta (m/year)
1	n.a.	n.a.	n.a.
2	n.a.	n.a.	n.a.
3	- 6 %	- 206,400	- 61,920,000
4	- 12 %	- 384,267	- 115,280,000
5	- 14 %	-112,533	- 33,760,00
Total		**- 703,200**	**- 210,960,000**

Table 9: Difference on an annual basis between the two scenarios

In the FENIX scenario the values of the daily emissions of the different macro pollutants are shown in the Table 10.

		Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS
	Nr. Vehicles	g	mg	mg	mg	mg	mg	g	mg	mg	mg	mg	mg
EURO 0	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 1	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 2	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 3	0	-	-	-	-	-	-	-	-	-	-	-	-
EURO 4	1252	482,393	3,017	9,655,822	88,580	10,421	1,797,663	1,428,258	39,765	7,953	216,926	338,142	498,025
EURO 5	1577	669,270	4,146	12,363,706	130,261	15,203	3,937,189	1,981,551	172,414	38,007	326,861	487,182	704,513
EURO 6	2677	1,152,390	7,037	2,217,398	155,411	25,804	894,348	3,411,426	271,530	52,781	363,604	636,893	1,006,362
	5,506	**2,304,054**	**14,200**	**24,236,926**	**374,253**	**51,428**	**6,629,200**	**6,821,235**	**483,709**	**98,741**	**907,391**	**1,462,217**	**2,208,900**

Table 10: Emissions in the FENIX scenario

The calculated values show a reduction compared to the current scenario for all the macro pollutants:

- 2,304 kg of fuel (diesel);
- 24.2 kg of NO_X
- 6.6 kg of CO
- 6.8 tons of CO_2

See the detailed calculation in the Table 21 (BOX 4).

3.6.3. Delta between the two scenarios

Table 11 summarizes the estimated emissions in the two scenarios and the delta between the current scenario and the FENIX scenario.

	Unit of measure in KG/YEAR												
	Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS	Total km
Current	731,558.77	4.51	7,695.33	118.83	16.33	2,104.81	2,165,806.46	153.58	31.35	288.10	464.27	701.35	3,829,860.00
With Fenix	691,216.11	4.26	7,271.08	112.28	15.43	1,988.76	2,046,370.56	145.11	29.62	272.22	438.67	662.67	3,618,660.00
DELTA	- 40,342.66	- 0.25	- 424.26	- 6.55	- 0.90	- 116.05	- 119,435.90	- 8.47	- 1.73	- 15.89	- 25.60	- 38.68	- 211,200.00

Table 11: Comparison of the pollutant emissions in the two scenarios

The values in the table show that the simple optimization of vehicular traffic flows, generated by a more integrated exchange of data between the two bodies could guarantee, in the short urban stretch between the port entrances and the motorway exits (toll gates), could produce an annual savin of:

- More than 40.3 tons of fuel (diesel);
- More than 420 kg of NO_X;
- Almost 120 kg of CO;
- About 120 tons of CO_2 corresponding to the load of five trucks (24 tons).

Therefore FENIX would allow annual emissions savings of CO_2 equal to five completely full trucks in the Genoa case study.

3.7. Genoa case study final considerations

The calculated emission savings may in fact appear decidedly limited (approximately 5.5%), however, it should be considered that the same is to be related to a series of extremely limited routes that develop in an urban context that identifies small distances: the motorway toll gates are rather close to the port gates and therefore the city route is rather limited.

In this analysis, neither the motorway routes nor the routes inside the port were considered.

Furthermore, it would be possible to monetize the distances saved according to the logic proposed by the European Commission in the "*Handbook on the external costs of transport*"[8] in relation to the impacts of heavy vehicles (Heavy Good Vehicles - HGV) calculated per Vehicle/km, as shown in the table of Table 12.

The data highlight all the types of negative externalities parameterized on the number of vehicles and the number of kilometers travelled, monetized according to the unit of measure of the European currency (€): these are costs that are incurred not only by road haulage companies but which affect the entire community

Externality		
Accident costs	15.50	€Cent/Vkm
Air pollution costs	9.38	€Cent/Vkm
Climate changes costs	6.48	€Cent/Vkm
Noise costs	5.70	€Cent/Vkm
Congestion costs - Delay	34.10	€Cent/Vkm
Congestion costs - Deadweight loss	6.00	€Cent/Vkm
Habitat damage costs	2.40	€Cent/Vkm

Table 12: Externalities per v/km
(Source EC Europa EU)

By applying these estimates to the values identified for the current status, in the absence of optimization by FENIX, in terms of daily valuations, the economic values shown in the Table 13 would be obtained.

[8] European Commission, Handbook on the external costs of transport, Version 2019 – 1.1

			Accident costs	Air pollution costs	Climate changes costs	Noise costs	Congestion costs - Delay	Congestion costs - Deadweight loss	Habitat damage costs
		€cent/Vkm	**15.5**	**9.4**	**6.5**	**5.7**	**34.1**	**6.0**	**2.4**
	ROUTES	**V/km**							
CURRENT STATUS	1	1376	213.3	129.1	89.2	78.4	469.2	82.6	33.0
	2	4127	639.7	387.1	267.4	235.3	1,407.4	247.6	99.1
	3	3307	512.5	310.2	214.3	188.5	1,127.6	198.4	79.4
	4	3124	484.3	293.1	202.5	178.1	1,065.4	187.5	75.0
	5	832	128.9	78.0	53.9	47.4	283.7	49.9	20.0
	€/ GG		**1,978.8**	**1,197.5**	**827.2**	**727.7**	**4,353.3**	**766.0**	**306.4**

Table 13: Externalities in the current scenario

Using the same calculation in the case of implementation of FENIX services, however, the economic values shown in the following table would be obtained.

			Accident costs	Air pollution costs	Climate changes costs	Noise costs	Congestion costs - Delay	Congestion costs - Deadweight loss	Habitat damage costs
	ROUTES	**V/km**							
STATUS FENIX	1	1376	213.3	129.1	89.2	78.4	469.2	82.6	33.0
	2	4127	639.7	387.1	267.4	235.3	1,407.4	247.6	99.1
	3	3100	480.5	290.8	200.9	176.7	1,057.1	186.0	74.4
	4	2740	424.7	257.0	177.5	156.2	934.3	164.4	65.8
	5	719	111.5	67.5	46.6	41.0	245.2	43.1	17.3
	€/ GG		**1,869.6**	**1,131.4**	**781.6**	**687.5**	**4,113.2**	**723.7**	**289.5**

Table 14: Externalities in the FENIX scenario

In the Table 14, routes 1 and 2 do not have any optimizations because there are no traffic lights and therefore there are no saving of emissions compared to the corresponding values in Table 13.

In this sense, the value of the environmental externalities deriving from the differential generated by the traffic optimization possible with FENIX (Figure 11) equals a lower cost of €170,000/year, mainly associated with traffic congestion costs and costs generated by accidents, to which additional 8,000/9,000 € in value of CO_2 avoided based on the most recent market values (i.e. 116 tons at 70/80 €).

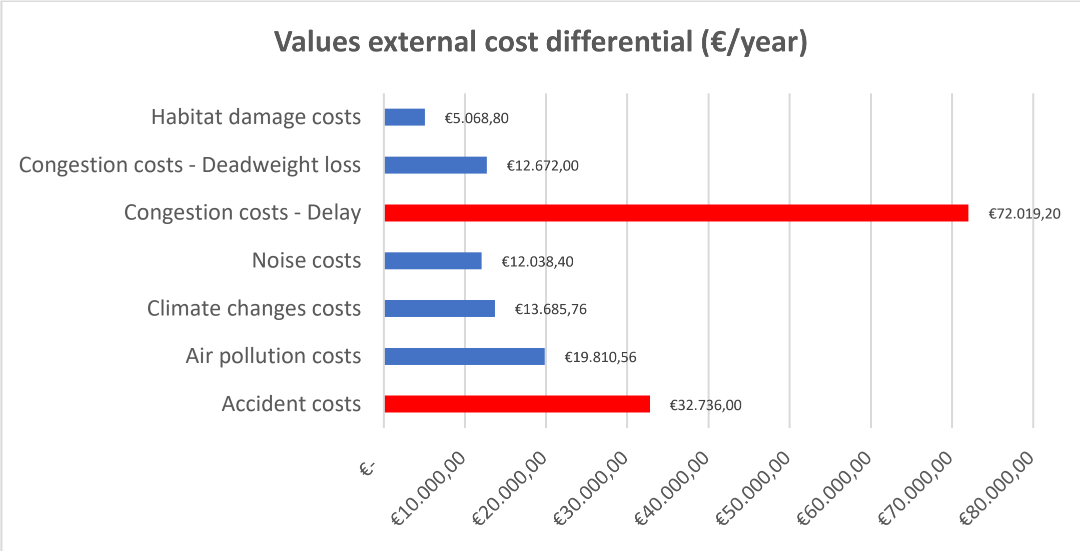

Figure 11: Values external cost differential
(Source: elaboration on EC Europa EU data)

BOX 1 – Visualization of the paths considered

Section 1 analyzed (Genoa Prà toll gate -> Prà gate) has a overall length of 1,000 m and it is estimated that 1,375 heavy vehicles travel through it every day (Figure 12).

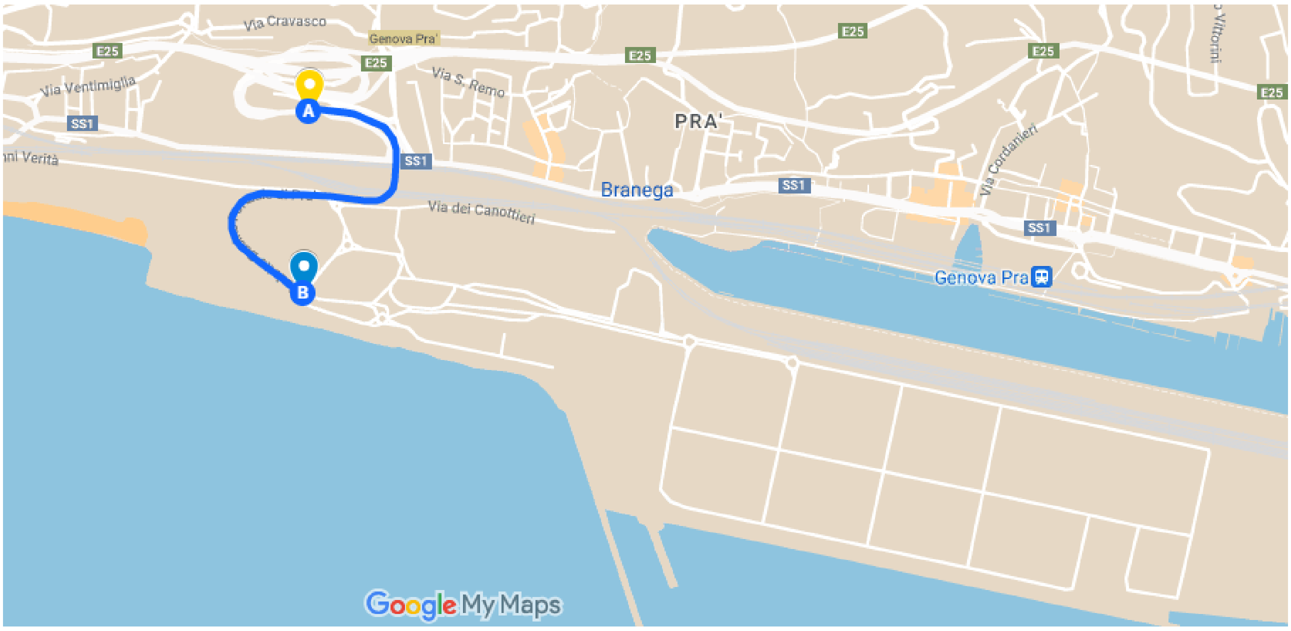

Figure 12: Route 1
(Source: elaboration on Google data)

Section 2 analyzed (Genoa Airport toll gate -> Ponente gate) has a overall length of 2,770 m and it is estimated that 1,488 heavy vehicles travel through it every day (Figure 13).

Figure 13: Route 2
(Source: elaboration on Google data)

Section 3 analyzed (Genoa Airport toll gate -> Etiopia gate) has a overall length of 4,000 m and it is estimated that 774 heavy vehicles travel through it every day (Figure 14).

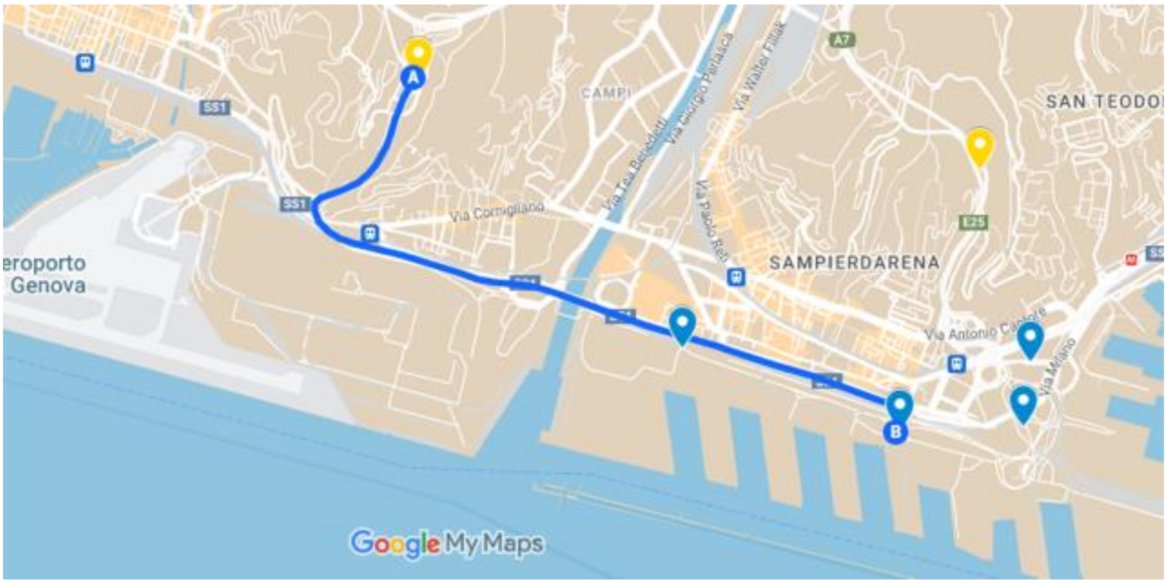

Figure 14: Route 3
(Source: elaboration on Google data)

Section 4 analyzed (Genoa Ovest toll gate -> San Benigno gate) has a overall length of 1,900 m and it is estimated that 1,441 heavy vehicles travel through it every day (Figure 15).

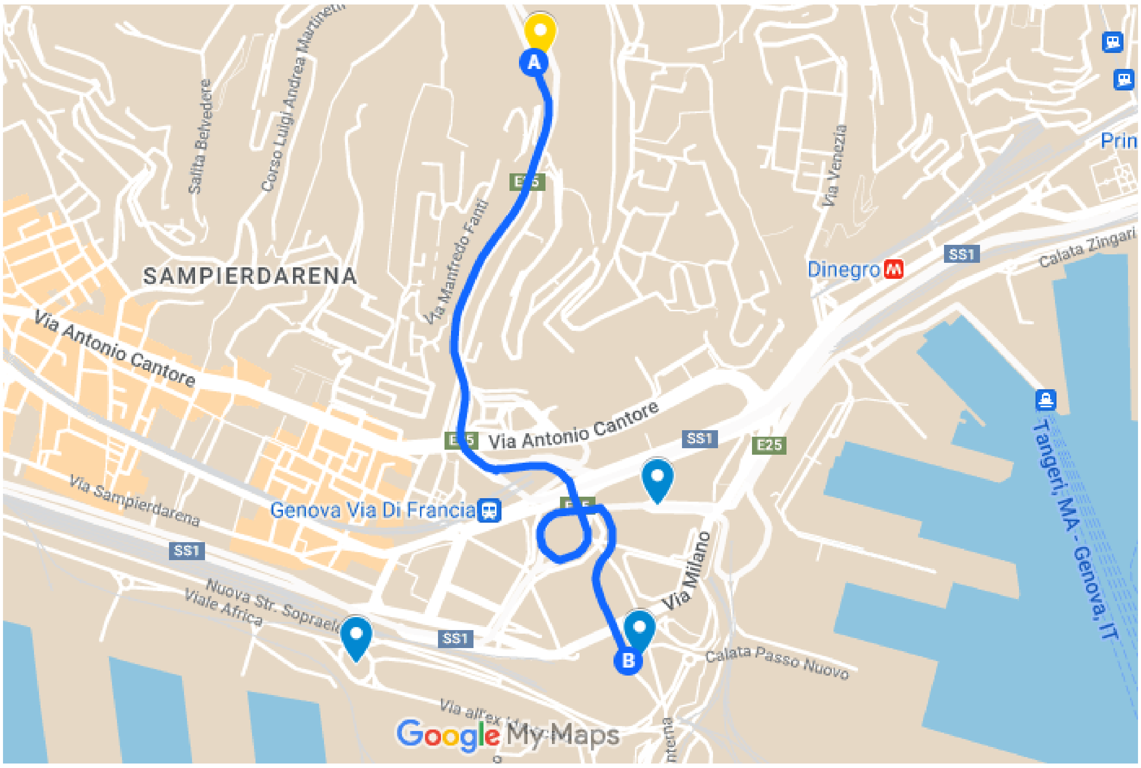

Figure 15: Route 4
(Source: elaboration on Google data)

Finally, Section 5 analyzed (Genoa Ovest toll gate -> Albertazzi/Passo Nuovo gate) has a overall length of 1,700 m and it is estimated that 442 heavy vehicles travel through it every day (Figure 16).

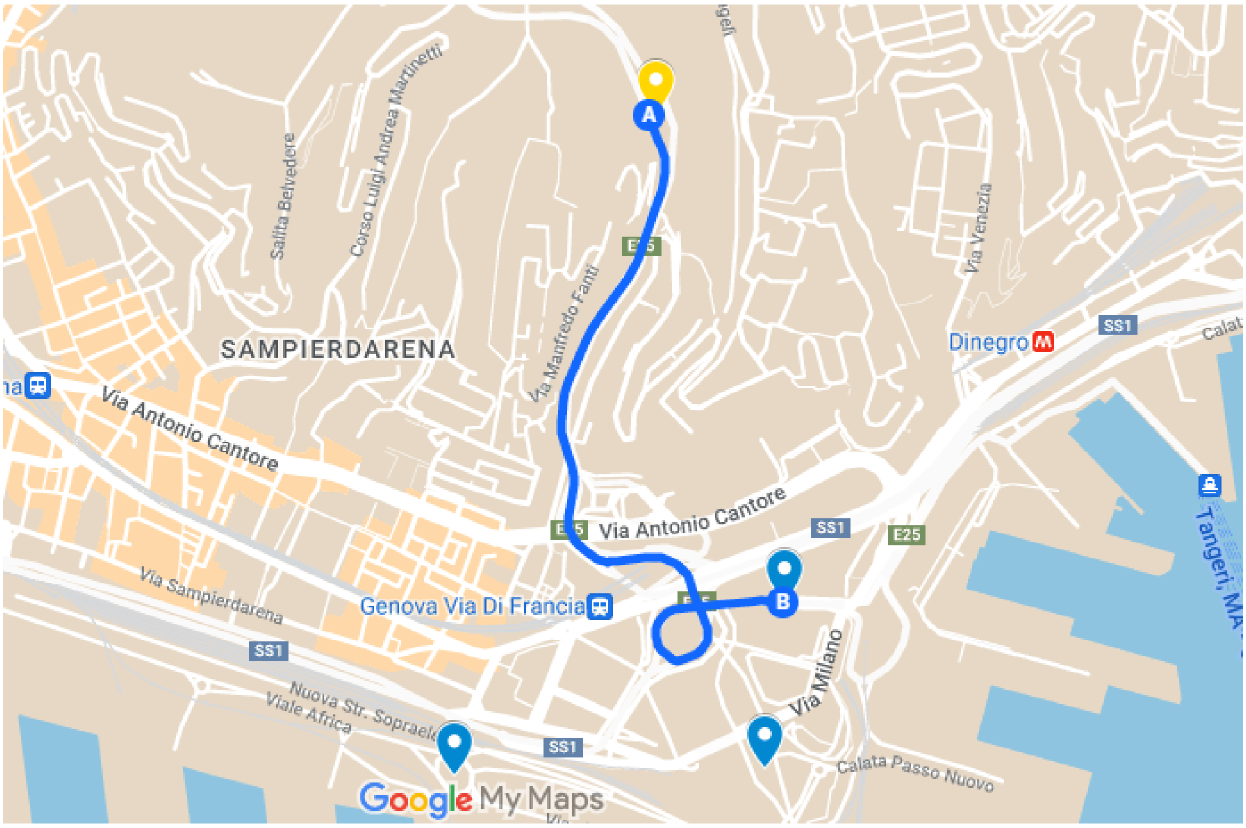

Figure 16: Route 5
(Source: elaboration on Google data)

BOX 2 – Heavy vehicles data

In this Annex the methodology and the calculation of the values used in paragraph 3.5 are reported.

Fuel used: diesel

Since a precise analysis of the types of heavy vehicles that deliver goods to the port is not available, an estimate derived from the current qualitative composition of the heavy vehicle fleet circulating in Italy has been used.

At this stage, it was analysed which fuel is most used by heavy vehicles circulating in Italy (Table 15). For this purpose, the most reliable source in this regard was consulted, the ACI - Automobile Club of Italy source. In this sense, the year 2021[9] was taken as a reference and the data derived from the ACI shown below.

Fuel	EURO 0	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	NC	ND	Total
Other	13	4	11	3	1	5	19	-	-	56
PETROL	48,741	19,979	30,402	26,115	25,451	11,968	31,679	-	988	195,323
PETROL LPG	4,627	1,852	2,049	2,546	17,611	6,710	21,168	-	32	56,595
PETROL CNG	1,623	559	1,155	2,672	18,935	24,508	27,217	-	24	76,693
ELECTRIC	-	-	-	-	-	-	-	9,209	-	9,209
DIESEL	588,228	216,525	448,642	665,194	646,610	505,087	843,269	-	2,167	3,915,722
HYBRID PETROL	3	-	-	1	1	15	6,979	-	-	6,999
HYBRID DIESEL	2	-	-	5	22	2	9,258	-	-	9,289
CNG	63	16	24	299	5,220	4,616	9,262	-	-	19,500
NOT DEFINED	419	29	5	17	1	-	-	-	185	656
Total	**643,719**	**238,964**	**482,288**	**696,852**	**713,852**	**552,911**	**948,851**	**9,209**	**3,396**	**4,290,042**
Diesel vehicles	**91.4%**	**90.6%**	**93.0%**	**95.5%**	**90.6%**	**91.4%**	**88.9%**	**0.0%**	**63.8%**	**91.3%**

Table 15: Composition of heavy vehicles per fuel used, 2021
(Source: ACI)

Diesel-powered vehicles represent more than 91% of the total: the estimates were made based on the prevailing fuel-powered mode (all the other types of fuel-powered vehicles will therefore not be considered in this analysis).

Load capacity

A further elaboration was then made to refine the effective number of heavy vehicles, i.e. those vehicles with a capacity exceeding 3.5 tons and more representative of the heavy traffic typical of port terminals. In fact, the Table 16 shows that only 13% of the circulating fleet of heavy vehicles surveyed belongs to categories that envisage capacities greater than 3.5 tons, equal to 511,226 units.

The analysis is therefore restricted to only these approximately half a million vehicles, excluding therefore those with a lower capacity because they are not representative of port traffic.

9 https://opv.aci.it/WEBDMCircolante/

What already described can be seen in the following table, which demonstrates how 87% of heavy vehicles have capacities below 3.5 tons. The analysis of this case study refers however, as already mentioned, only to the 13% on the right of the table.

Fuel	<= 2,5 t	2,6 - 3,5 t	3,6 - 7,5 t	7,6 - 12 t	12,1 - 16 t	16,1 - 32 t	> 32 t	N.I./ Not identified	Total Total
Petrol	181,889	10,474	1,558	716	258	373	30	25	195,323
Petrol-LPG	46,129	10,111	149	83	37	81	2	3	56,595
Petrol-CNG	85,601	9,892	394	25	19	260	1	1	96,193
Diesel	1,474,399	1,930,097	161,905	107,140	45,338	193,733	1,474	1,636	3,915,722
Hybrid	8,191	8,093	4	-	-	-	-	-	16,288
Electric	7,159	2,019	22	5	2	2	-	-	9,209
Others	26	19	2	2	-	7	-	-	56
Not identified	51	42	26	10	5	6	-	516	656
Total	1,803,445	1,970,747	164,060	107,981	45,659	194,462	1,507	2,181	4,290,042
HDV	87%		13%						
	3,404,496		511,226						

Table 16: Composition of heavy vehicles per loading capacity, 2021
(Source: ACI)

Lorries: fuel

Furthermore, in addition to heavy vehicles proper, lorries were also considered i.e. vehicles capable to load cargo in the unit itself (with no trailers). The lorries circulating in Italy in 2021, according to ACI are almost all (about 98%) diesel-powered vehicles (Table 17).

Region - Fuel	EURO 0	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	Non Contemplato	N.I. Not identified	Total Total
Petrol	100	7	5	34	-	2	1	-	5	154
Petrol-LPG	7	1	8	1	3	13	7	-	-	40
Petrol-CNG	2	-	-	-	-	46	3,300	-	-	3,348
Diesel	15,780	3,162	12,288	29,247	6,671	48,849	84,859	-	108	200,964
Hybrid	-	-	-	-	-	-	2	-	-	2
Electric	-	-	-	-	-	-	-	24	-	24
Others	2	-	-	-	-	1	36	-	-	39
not identified	30	-	2	27	1	6	433	-	16	515
TOTAL	15,921	3,170	12,303	29,309	6,675	48,917	88,638	24	129	205,086
Diesel	99%	100%	100%	100%	100%	100%	96%	0%	84%	98%

Table 17: Emission class distribution of the lorries registered in Italy, 2021
(Source: ACI)

Total numbers of heavy vehicles considered in the analysis

As mentioned before, only diesel vehicles were considered.

The lorries were therefore added to the heavy vehicles seen before (both in red in the tables), giving back an overall number of 712,190 vehicles.

General subdivision by emissions category

Therefore, on the basis of the values in the Table 16 and Table 17, a subdivision of the heavy vehicle fleet was defined according to shares belonging to the various emission categories as shown in the summary Table 18, which highlights that more than 56% of vehicles belongs to an emission class Euro 4 or higher. This subdivision was made on the basis of the percentages "interpolated" from the three tables seen previously, thus restricting the analysis only to diesel vehicles, with a capacity exceeding 3.5 tons, then adding the “lorries”.

Emissions class	**Vehicles**	
	%	**Number**
EURO 0	13%	92,577
EURO 1	4%	31,431
EURO 2	10%	70,861
EURO 3	16%	116,093
EURO 4	13%	91,091
EURO 5	16%	114,792
EURO 6	27%	195,345
TOTAL	**100%**	**712,190**

Table 18: Percentage of heavy vehicles by emissions category in Italy, 2021
(Source: ACI)

However, in consideration of the fact that the urban area of Genoa, as well as other important urban areas, has introduced a ban on the circulation of heavy vehicles up to the Euro 3 emission category[10], it has been assumed that all vehicles in transit respect this constraint for the port. Therefore, the new percentage distribution applied by the evaluation is declined as described in the Table 19.

Emissions class	**Vehicles**	
	%	**Number**
EURO 4	23%	91,091
EURO 5	29%	114,792
EURO 6	49%	195,345
TOTAL	**100%**	**401,228**

Table 19: Percentage of heavy vehicles by emission category higher than Euro 3, 2021
(Source: ACI)

[10] 151 0 0 - Direzione Ambiente, Ordinanza del Sindaco, n. ord-2019-311 data 25/09/2019, Oggetto: Limitazione della circolazione nell’ambito del territorio comunale per alcune tipologie di autoveicoli e motoveicoli al fine di prevenire e ridurre l’inquinamento atmosferico, a tutela della salute pubblica.

BOX 3 – Current scenario

				DAILY VALUES - CURRENT STATUS												
				Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS	
				g	mg	mg	mg	mg	mg	g	mg	mg	mg	mg	mg	KM
		Veihcles	Distance													
Route 1	EURO 4	313	1000	55,057	344	1,102,042	10,110	1,189	205,172	163,010	4,539	908	24,758	38,593	56,841	313
	EURO 5	394	1000	76,318	473	1,409,850	14,854	1,734	448,963	225,959	19,661	4,334	37,272	55,554	80,337	394
	EURO 6	670	1000	131,655	804	253,327	17,755	2,948	102,175	389,739	31,021	6,030	41,540	72,762	114,972	670
		1,377		**263,030**	**1,621**	**2,765,219**	**42,719**	**5,871**	**756,310**	**778,708**	**55,220**	**11,272**	**103,571**	**166,909**	**252,149**	**1,377**
		Veihcles	Distance													
Route 2	EURO 4	338	2770	164,688	1,030	3,296,478	30,241	3,558	613,718	487,604	13,576	2,715	74,058	115,441	170,025	936
	EURO 5	426	2770	228,570	1,416	4,222,466	44,487	5,192	1,344,633	676,741	58,883	12,980	111,630	166,383	240,606	1,180
	EURO 6	725	2770	394,621	2,410	759,319	53,219	8,836	306,258	1,168,199	92,982	18,074	124,512	218,096	344,616	2,008
		1,489		**787,879**	**4,856**	**8,278,263**	**127,947**	**17,586**	**2,264,609**	**2,332,545**	**165,441**	**33,770**	**310,200**	**499,920**	**755,247**	**4,125**
		Veihcles	Distance													
Route 3	EURO 4	176	4267	132,089	826	2,643,961	24,255	2,854	492,237	391,086	10,889	2,178	59,399	92,590	136,369	751
	EURO 5	222	4267	183,473	1,137	3,389,366	35,709	4,168	1,079,334	543,219	47,265	10,419	89,605	133,555	193,134	947
	EURO 6	377	4267	316,077	1,930	608,186	42,626	7,078	245,301	935,684	74,475	14,477	99,729	174,687	276,024	1,609
		775		**631,639**	**3,893**	**6,641,513**	**102,591**	**14,099**	**1,816,873**	**1,869,989**	**132,629**	**27,074**	**248,733**	**400,832**	**605,528**	**3,307**
		Veihcles	Distance													
Route 4	EURO 4	328	2167	125,006	782	2,502,186	22,955	2,701	465,842	370,115	10,305	2,061	56,214	87,625	129,057	711
	EURO 5	413	2167	173,329	1,074	3,201,982	33,735	3,937	1,019,663	513,187	44,652	9,843	84,651	126,172	182,457	895
	EURO 6	702	2167	298,877	1,825	575,090	40,307	6,692	231,953	884,766	70,422	13,689	94,302	165,181	261,004	1,521
		1,443		**597,212**	**3,681**	**6,279,258**	**96,996**	**13,330**	**1,717,457**	**1,768,068**	**125,379**	**25,593**	**235,167**	**378,977**	**572,517**	**3,127**
		Veihcles	Distance													
Route 5	EURO 4	96	1967	33,210	208	664,746	6,098	717	123,758	98,327	2,738	548	14,934	23,279	34,286	189
	EURO 5	121	1967	46,094	286	851,516	8,971	1,047	271,163	136,474	11,875	2,618	22,512	33,553	48,521	238
	EURO 6	206	1967	79,609	486	153,181	10,736	1,783	61,783	235,666	18,758	3,646	25,118	43,997	69,521	405
		423		**158,913**	**979**	**1,669,443**	**25,806**	**3,547**	**456,704**	**470,467**	**33,370**	**6,811**	**62,564**	**100,830**	**152,328**	**832**

Table 20: Estimated daily emissions for each route in the current scenario

BOX 4 – FENIX scenario

DAILY VALUES - STATUS WITH FENIX

Route		Vehicles	Distance	Specific consumption (g)	SO2 (mg)	NOx (mg)	COV (mg)	CH4 (mg)	CO (mg)	CO2 (g)	N2O (mg)	NH3 (mg)	PM2.5 (mg)	PM10 (mg)	PTS (mg)	KM
Route 1	EURO 4	313	1000	55,057	344	1,102,042	10,110	1,189	205,172	163,010	4,539	908	24,758	38,593	56,841	313
	EURO 5	394	1000	76,318	473	1,409,850	14,854	1,734	448,963	225,959	19,661	4,334	37,272	55,554	80,337	394
	EURO 6	670	1000	131,655	804	253,327	17,755	2,948	102,175	389,739	31,021	6,030	41,540	72,762	114,972	670
		1,377		**263,030**	**1,621**	**2,765,219**	**42,719**	**5,871**	**756,310**	**778,708**	**55,220**	**11,272**	**103,571**	**166,909**	**252,149**	**1,377**
Route 2	EURO 4	338	2770	164,688	1,030	3,296,478	30,241	3,558	613,718	487,604	13,576	2,715	74,058	115,441	170,025	936
	EURO 5	426	2770	228,570	1,416	4,222,466	44,487	5,192	1,344,633	676,741	58,883	12,980	111,630	166,383	240,606	1,180
	EURO 6	725	2770	394,621	2,410	759,319	53,219	8,836	306,258	1,168,199	92,982	18,074	124,512	218,096	344,616	2,008
		1,489		**787,879**	**4,856**	**8,278,263**	**127,947**	**17,586**	**2,264,609**	**2,332,545**	**165,441**	**33,770**	**310,200**	**499,920**	**755,247**	**4,125**
Route 3	EURO 4	176	4000	123,834	774	2,478,714	22,739	2,675	461,472	366,643	10,208	2,042	55,686	86,803	127,846	704
	EURO 5	222	4000	172,006	1,066	3,177,530	33,478	3,907	1,011,876	509,268	44,311	9,768	84,005	125,208	181,063	888
	EURO 6	377	4000	296,322	1,810	570,175	39,962	6,635	229,970	877,204	69,820	13,572	93,496	163,769	258,773	1,508
		775		**592,161**	**3,650**	**6,226,419**	**96,179**	**13,218**	**1,703,318**	**1,753,115**	**124,340**	**25,382**	**233,187**	**375,780**	**567,682**	**3,100**
Route 4	EURO 4	328	1900	109,621	686	2,194,225	20,129	2,368	408,508	324,563	9,036	1,807	49,295	76,841	113,173	623
	EURO 5	413	1900	151,996	942	2,807,892	29,583	3,453	894,166	450,025	39,157	8,632	74,233	110,643	160,000	785
	EURO 6	702	1900	262,092	1,601	504,310	35,346	5,869	203,405	775,871	61,755	12,004	82,696	144,851	228,880	1,334
		1,443		**523,709**	**3,228**	**5,506,427**	**85,058**	**11,690**	**1,506,078**	**1,550,459**	**109,948**	**22,443**	**206,223**	**332,334**	**502,054**	**2,742**
Route 5	EURO 4	96	1700	28,707	180	574,611	5,271	620	106,978	84,995	2,366	473	12,909	20,123	29,637	163
	EURO 5	121	1700	39,844	247	736,056	7,755	905	234,395	117,969	10,264	2,263	19,459	29,004	41,942	206
	EURO 6	206	1700	68,814	420	132,411	9,280	1,541	53,406	203,711	16,214	3,152	21,712	38,032	60,094	350
		423		**137,365**	**847**	**1,443,078**	**22,307**	**3,066**	**394,778**	**406,675**	**28,845**	**5,888**	**54,081**	**87,158**	**131,674**	**719**

Table 21: Estimated daily emissions for each route in the FENIX scenario

4. BENCHMARK ANALYSIS ON RHINE-ALPINE CORRIDOR

4.1. Introduction

The activity presented in this chapter focuses on the transferability of the study to other realities like the Ligurian case study along the Rhine-Alpine corridor. A benchmark analysis was set up to identify cities and urban centres that have similar characteristics to Genoa for which the same study methodology could be applied in a hypothesis of extension of the FENIX project.

It will be focused on all the inland terminals and the ports, maritime and inland (that here are all going to be called with the broad expression "freight centres") of the Corridor and then selected those which, for the reasons that will be seen later, are more similar to the port of the Ligurian city and for which it will therefore be possible to extend the methodology applied in the previous chapter.

The similarity with the port of Genoa is not intended in terms of cargo handled but in terms of urban typology. In fact, the analogy with the Ligurian case study concerns the **interference between commercial and urban traffic**. For this reason, one of the parameters that have been identified concerns precisely the proximity between the freight terminal and the historic centre (just as happens in Genoa). The Figure 17 shows the location of the freight centres along the Rhine-Alpine corridor.

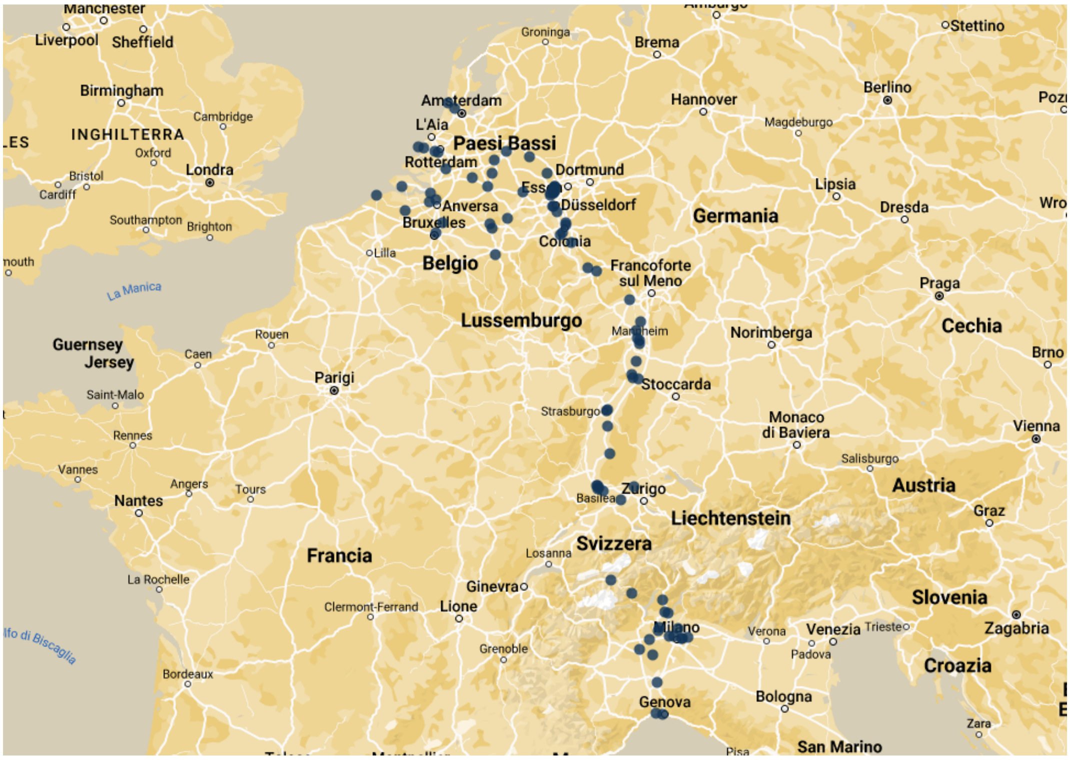

Figure 17: Location of the inland terminals and the ports of the Rhine-Alpine Corridor
(Source: EGTC - Rhine-Alpine corridor)

4.2. Selection of the freight centres

Given the number of freight centres along the corridor, it was deemed necessary to adopt a methodology for selecting the most relevant: therefore it was decided to focus on the twenty-five (25) freight centres that the European Union has identified as "core".

The next step was the identification of freight centres similar to the Genoa port case study among the twenty-five previously selected: two parameters were considered. The first one is the number of inhabitants of the city, in order to immediately understand whether it is a small town or a large urban agglomeration. The other is the distance as the crow flies between the historic centre and the freight terminals[11] (distance D). The data collected are shown in the Table 22.

Freight centre	Nation	Population (nr.)	Distance D (km)
Genoa	Italy	583,601	1.4
Novara	Italy	104,284	2.76
Milano	Italy	1,352,000	6.01
Mulhouse Ottmarsheim	France	111,273	14.9
Strasbourg	France	280,966	2.73
Karlsruhe	Germany	312,060	5.92
Mannheim/Ludwigshafen	Germany	309,370	3.43
Frankfurt-Main	Germany	763,380	2.29
Mainz	Germany	218,578	3.54
Koblenz	Germany	114,052	3.64
Koeln	Germany	1,083,498	2.77
Duesseldorf/Neuss	Germany	619,294	2.61
Duisburg	Germany	495,885	2.1
Liège Meuse	Belgium	197,355	4.83
Liège Canal Albert	Belgium	197,355	11.8
Brussels	Belgium	2,708,766	2.38
Gent	Belgium	262,219	6.15
Zeebrugge	Belgium	274,435	14.5
Antwerp	Belgium	523,248	7.23
Nijmegen	The Netherlands	166,492	3.11
Vlissingen	The Netherlands	44,608	1.52
Moerdijk	The Netherlands	36,556	3.3
Rotterdam	The Netherlands	623,652	4.28
Utrecht	The Netherlands	358,454	3.95
Amsterdam	The Netherlands	821,752	10.4

Table 22: The "core" freight centres of the Rhine-Alpine corridor and their characteristics

[11] To calculate distance D, first of all the historic centre of the reference city was identified i.e. the oldest area of the city. As for the freight terminal, the container terminal nearest to the historic centre was selected (if there is no container terminal in the freight terminal, another terminal was used). Therefore, distance D is the distance between the historic centre and the nearest container terminal (of the selected freight terminal).

Five freight centres were selected to which the methodology used for Genoa could be extended based on the following criteria:

- Freight centres that are too far from the city centre have been discarded: limited or no interference between commercial and private traffic;
- Selection of a freight centre for each country along the Rhine-Alpine corridor, i.e., Italy, France, Germany, Belgium and The Netherlands (except Switzerland);
- Cities with a number of inhabitants of the same order of magnitude as that of Genoa.

. The following centres have therefore been identified:

- Novara, Italy;
- Strasbourg, France;
- Duisburg, Germany;
- Antwerp, Belgium;
- Rotterdam, The Netherlands.

The cities of Antwerp and Rotterdam have a relatively greater distance freight-city centre than the other Belgian and Dutch cities, were still selected for the number of inhabitants closest to that of Genoa.

For the purposes of this assessment, the city of Milan is too large and the distance D too high to make a comparison with the context of proximity between the historic centre and the terminals, typical of the Genoese case. Instead, Novara was selected because, despite being a smaller city than Genoa, the Novara terminal is relatively close to the city centre.

4.3. Identification of the area of the analysis for each of the selected freight centre

Once the "freight centres" of interest have been identified, it remains to define which areas of them are relevant for the purposes of this assessment. As seen above, the "macro" criterion that was followed for the choice of urban areas was that of the potential mix between heavy traffic of commercial origin and light traffic of vehicles belonging to private citizens (smaller distance D).

In the following, considering the terminal of the identified urban area, a more detailed analysis ("micro" perspective) will be carried out to identify the gate or a group of gates in which an interference between commercial traffic and private traffic can actually be found.

4.3.1. Rotterdam

The city of Rotterdam has, as is known, the most important commercial port in Europe. The terminals of this port are many: only the container terminals of the port are fourteen (14). They are distributed along the delta of the Maas and the Scheur, in an approximately West-East direction.

The sections into which the big port of Rotterdam is divided are approximately four (4): the Maasvlakte, or the newer part of the port of Rotterdam which rises at of the encounter between the Scheur and the open sea; the Europoort; the Botlek harbour basin; the Eem/Walhaven harbour basin.

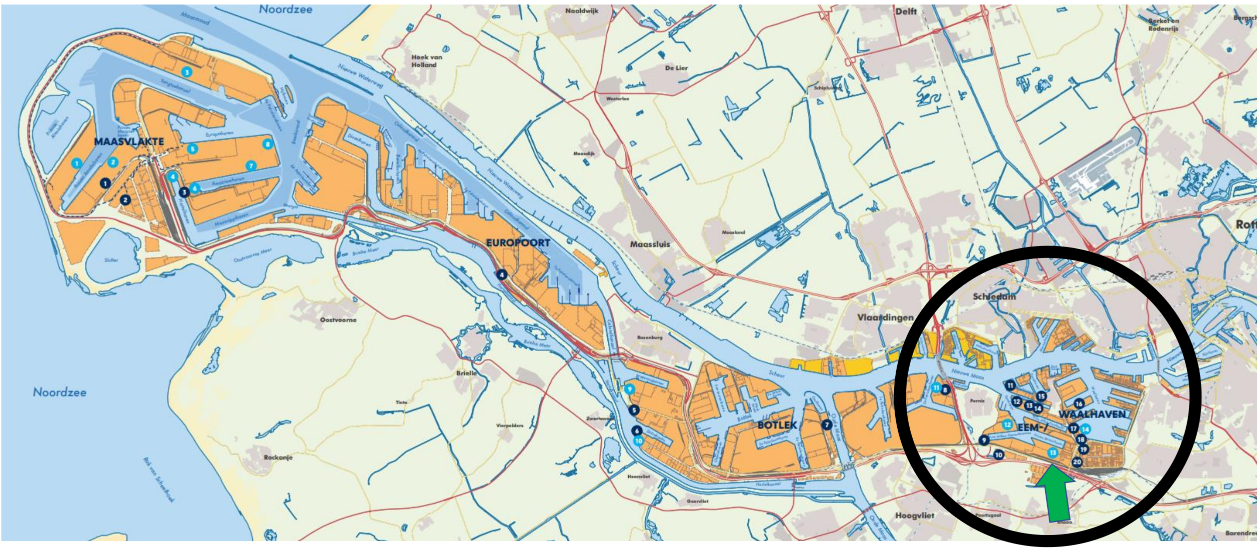

Figure 18: Selected area of the Rotterdam freight centre
(Source: elaboration on Port of Rotterdam data)

For the purposes of this work, mentioned several times, the westernmost port basins, Maasvlakte, Europoort and Botlek are not relevant, as they arise far from the city centre and therefore, mainly, it can be said that in these areas there are no major interferences between commercial traffic and urban traffic. The easternmost area, the Eem/Walhaven port basin, is more suitable as it is more in contact with the urban area, as can also be seen from the image in Figure 18. It was therefore decided to focus on this specific area.

Access to the port area of Waalhaven takes place through the gate on Reeweg road (Figure 19). In this area and from this gate it is possible to access several terminals, including the Rotterdam Shortsea Terminal (Ro-Ro and container terminal). The website of the managing body of this Terminal reports that in a year the trucks that arrive at the terminal are 320,000[12]; considering a number of working days equal to 300, it can be said that the daily trucks transiting through this gate are, at least, 1,066.

[12] https://rstshortsea.nl/terminal/

Figure 19: Access gate to the freight centre of Rotterdam: Eem/Walhaven

4.3.2. Antwerp

Antwerp's freight centre is located, as is known, along the banks of the Scheldt, and is the second largest European port after Rotterdam in terms of size. The largest port operator is PSA Antwerp which operates three container terminals and one dry bulk terminal. Two other container terminals are operated by DP World and Sea Invest respectively.

Antwerp's five terminals have very distinct locations. Two of them are located on the right bank of the river, but at a great distance from the city centre or, in general, from inhabited centres: they are located on peninsulas, with no contact with urban centres. Two other container terminals are located along the left bank, also in this case far from inhabited centres. The only area that appears closer to urban settlements is the one identified in Figure 20, which rises a short distance from the residential area of Stabroek and which was therefore considered in our analysis.

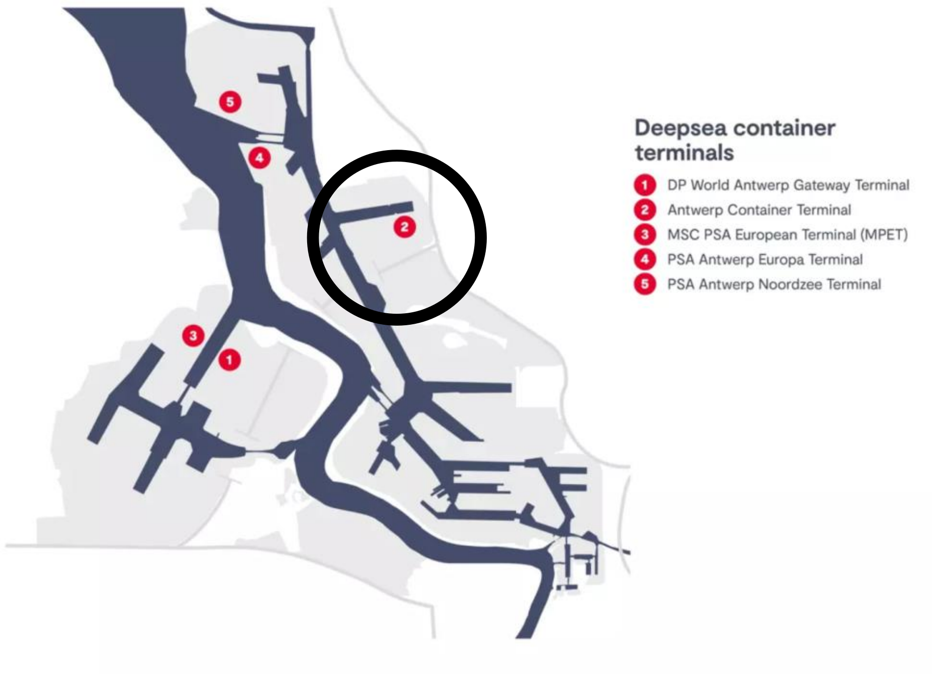

Figure 20: Selected area of the Antwerp freight centre
(Source: elaboration on Port of Antwerp Bruges data)

Access to this area of the port of Antwerp is possible through a gate located in Antwerpsebaan street (Figure 21): through this gate it is possible to reach various terminals, including the Antwerp Container Terminal.

Figure 21: Access gate to the freight centre of Antwerp

The desk analysis did not allow to find statistics that report the number of trucks that pass through this gate every day. It is therefore necessary to proceed with an estimate using deep-sea container traffic as an approximation of the entire port traffic. The total number of containers handled in the Port of Antwerp in 2021 was around 12 million TEU. The number of containers handled by the three PSA terminals was approximately 11 million TEU[13]. As a result, the total number of containers handled by the other two terminals is around 1 million TEU. No statistics have been found relating to the terminal in question, that of Sea Invest, but it is known that as regards the DP World terminal, the number of daily trucks that are handled by the terminal is 3,000[14]. Given the similarity of the two terminals in layout and overall handling figures, this number is also believed to be likely also for the Antwerp Container Terminal.

4.3.3. Duisburg

Duisburg is an important trimodal hub, i.e., a centre in which goods are moved both by rail, inland waterways and by road. The freight centre of Duisburg develops longitudinally along the Ruhr and Rhine rivers. For the purposes of this analysis, the freight yards further away from the city centre do not appear to be relevant. It was therefore decided to focus attention on the area close to the settlements of Duisburg and Ruhrort, those further north, indicated in the map in Figure 22. It is in this area that the accesses to the terminal structures have the greatest interference with the private urban road system.

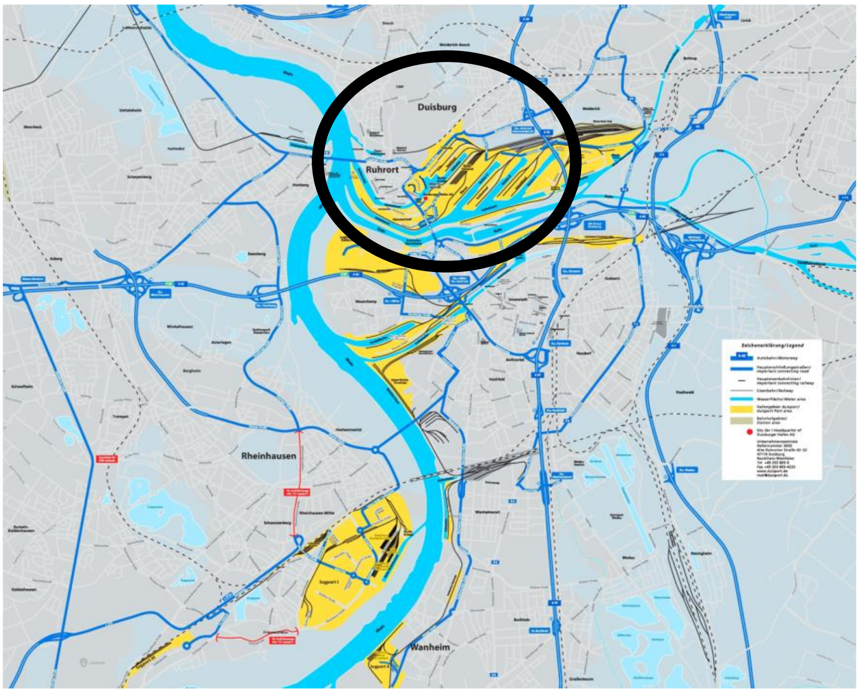

Figure 22: Selected area of the Duisburg freight centre
(Source: elaboration on Duisport data)

Access to this area of the freight centre of Duisburg takes place through a gate located in the Stahlinsel street (Figure 23) from which it is possible to reach several terminals, including the DuCeTe – Duisburg Container Terminal. Knowing the terminal handling statistics, it is possible to estimate the number of trucks entering

[13] https://www.psa-antwerp.be/en
[14] https://www.dpworld.com/en/antwerp/news/news-events/dp-world-is-the-first-terminal-in-the-world-to-use-a-kinetic-wireless-network

the terminal per day. The total TEU handled by the Duisburg River port is around 850,000[15]. As a trimodal terminal, some of these TEUs will go by rail and others by road.

To estimate the number of containers forwarded by rail, we referred to the Eurostat data "Modal split of freight transport"[16], relating to each individual country of the European Union: for Germany, the percentage of freight transport by rail is 17.6%. Therefore, by applying the complement of 100 of this percentage to the total TEUs handled, it follows that the TEUs shipped by road are 700,400 in a year which correspond to 2,335 containers/trucks per day - assuming the equivalence between TEU and truck (1 TEU = 1 truck).

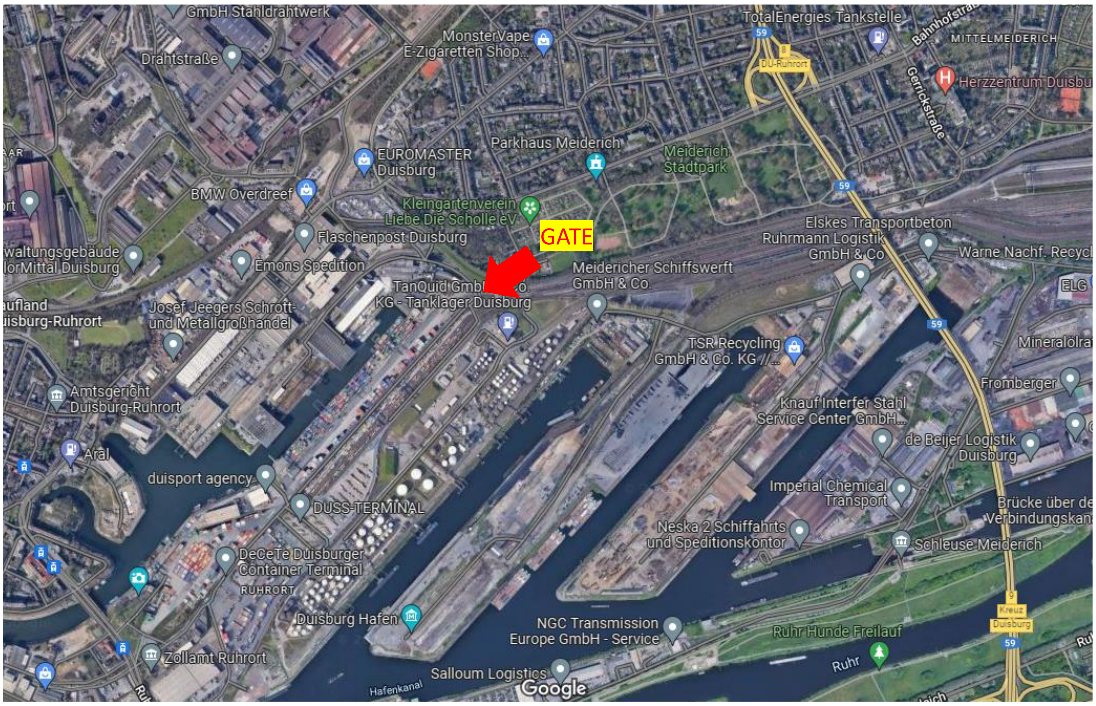

Figure 23: Access gate to the freight centre of Duisburg

4.3.4. Strasbourg

The Strasbourg freight centre develops mainly along the banks of the Rhine River. As can be seen from the image in Figure 24, the freight centre has a significant development in an approximately North - South direction.

For the purposes of this work, it was decided to focus only on the Northern area, i.e., the one in which the freight terminals are located closest to the city centre. In this area there are trimodal terminals, including container terminals.

[15] https://www.uirr.com/news/mediacentre/1291.html
[16] Eurostat, Modal split of freight transport, online data code: TRAN_HV_FRMOD

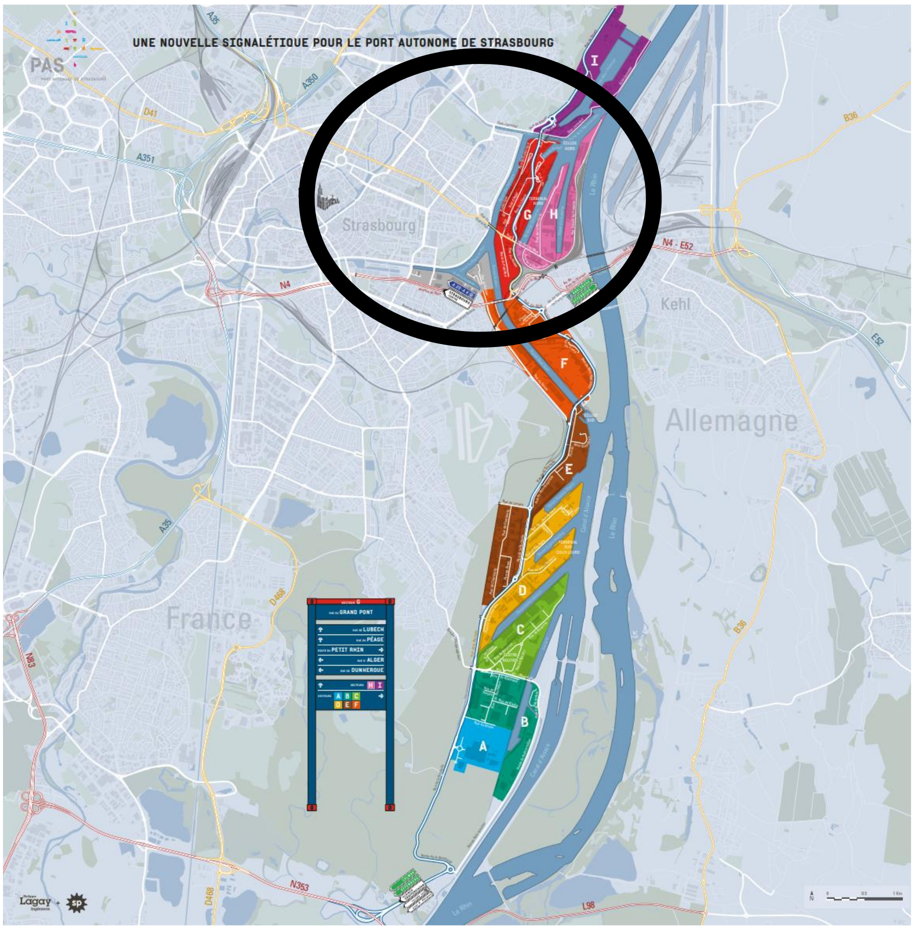

Figure 24: Selected area of the Strasbourg freight centre
(Source : elaboration on PAS data)

Access to this area of the Strasbourg freight centre takes place through a gate positioned along the street Rue Du Port du Rhin (Figure 25): from which it is possible to reach several terminals, including the Strasbourg Terminal Nord, that is the container terminal.

Starting from the number of containers handled in the river port of Strasbourg, it is possible to estimate the number of trucks that arrive/depart from the terminal every day. In 2021, 373,984 containers were handled[17]. Also in this case, reference is made to a trimodal terminal. Besides inland waterways, the other two modes are rail and road. The Eurostat value relating to the "Modal split of freight transport" for France is used, which for rail is 9.9%[18]. It is applied this value to the total number of TEUs, to estimate how many TEUs are being shipped by rail. The other part is, consequently, forwarded by road. It is therefore estimated that 336,960 TEUs are sent by road, which are equivalent to 1,123 trucks per day - assuming the equivalence between TEU and truck (1 TEU = 1 truck).

[17] https://www.strasbourg.port.fr/pas-group/annual-figures/?lang=en
[18] Eurostat, Modal split of freight transport, online data code: TRAN_HV_FRMOD

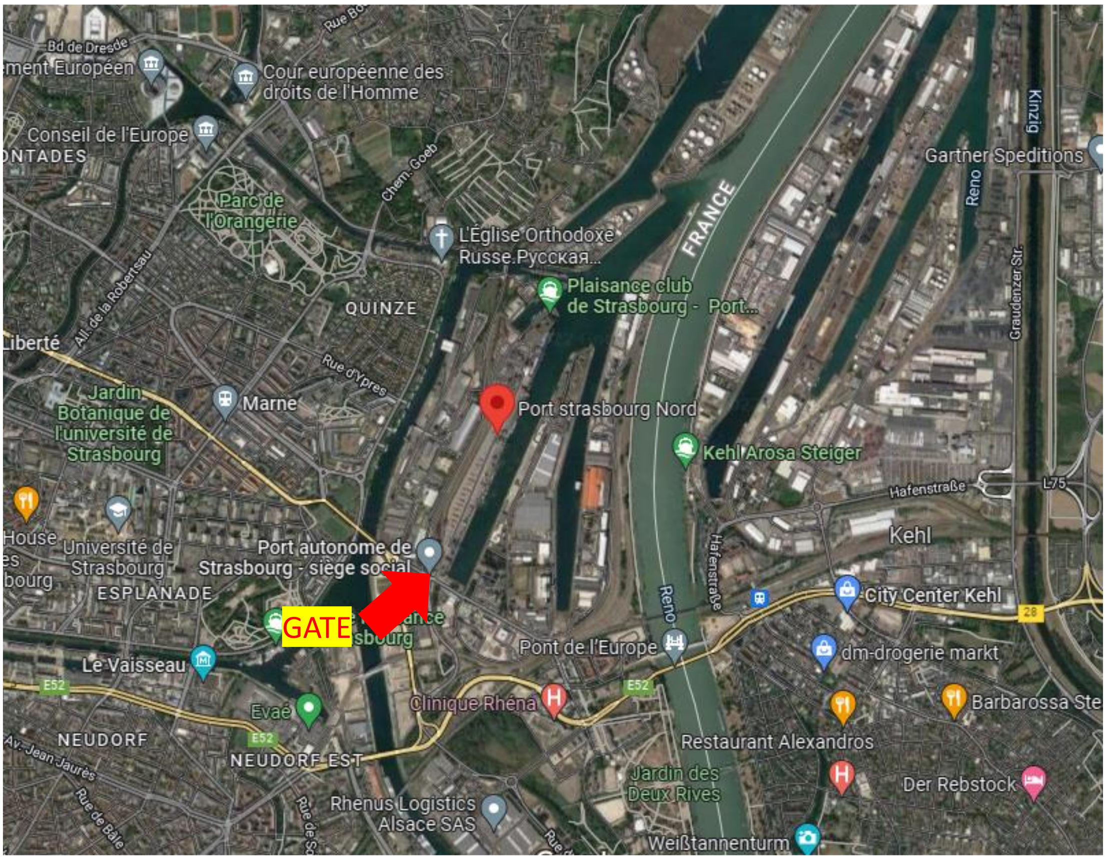

Figure 25: Access gate to the freight centre of Strasbourg

4.3.5. Novara

Novara is an important railway junction in North-western Italy. There are two freight terminals in Novara: the Centro Interportuale Merci, CIM, located north-east of the urban area, and the Boschetto railway station, located immediately east of the city centre.

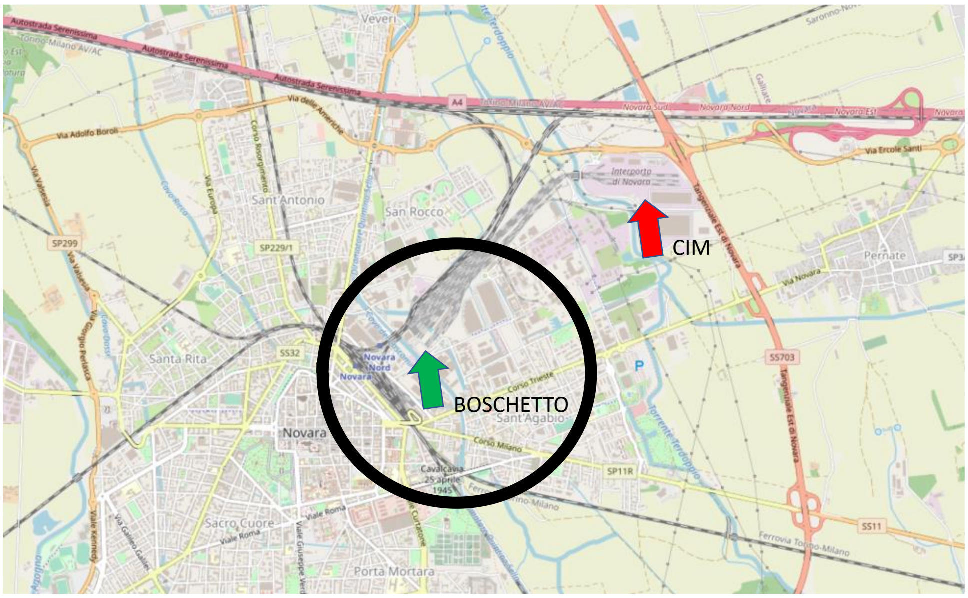

Figure 26: Selected area of the Novara freight centre
(Source: elaboration on Google data)

Access to the CIM terminal takes directly from the motorway exit (toll gate) and there is no interference between commercial traffic and city traffic. Therefore, this area is not of interest for this analysis.

The situation is different as regards the Boschetto terminal, closer to the city centre, where there may be interference between the two types of traffic (Figure 26). Attention will therefore be focused on this specific area and on the accesses located in the mixed area.

Access to this area of the Novara freight centre takes place through a gate positioned along the street Via Giovanni Bovio (Figure 27) from which it is possible to reach the Novara Boschetto intermodal terminal.

Figure 27: Access gate to the freight centre of Novara Boschetto

To estimate the number of trucks that enter/exit in/from this terminal every day, the total number of intermodal units handled in a year, corresponding to around 40,000, provided by the terminal manager can be used. Considering that it is a bimodal terminal, the units handled by the railway terminal necessarily arrive by road. Therefore, making as in the other cases, an equivalence between the intermodal units and the number of trucks which, considering an annual number of working days equal to 300, can be estimated 133 vehicles that enter/exit in/from this terminal every day.

4.4. Heavy vehicles characterization: age and Euro category

As analysed in the case study of Genoa, it is now possible to proceed with the quantification of the benefits obtainable thanks to FENIX for the additional five freight centres identified. Therefore, for each gate shown in the previous chapter, the routes that the trucks must follow in order to reach this gate starting from the nearest motorway exit (toll gate) have been identified.

As for Genoa, it has been verified whether there are traffic lights in these routes. The basic idea is always the following: if the municipality (of each of the five identified centres) has in advance the number of trucks expected arriving at a given gate and route, it can implement a “green wave” in the traffic lights belonging to that direction, such as to allow the fluidity of the traffic and therefore save time of emissions of these trucks.

It assumed that the municipal administration is connected to the FENIX network to which the freight centre infrastructure manager is also connected. If it is a port, as in the cases of Antwerp and Rotterdam, the system connected to FENIX may be the PCS - Port Community System. If, on the other hand, it is another internal infrastructure, as in the cases of Duisburg, Strasbourg and Novara, the connected system will be the management IT system of the single infrastructure.

This connection between the two bodies, obtained thanks to FENIX, allows the exchange between the infrastructure and the municipality of data on incoming trucks and the consequent regulation of traffic lights. The scheme is therefore similar of the one of Figure 4.

As for the case study of the port of Genoa (chapter 3), the urban routes leading from the nearest motorway toll gate to the freight centre gate identified in the previous chapter were identified and the presence of traffic lights along the route was verified.

Two scenarios have therefore been identified: the "without FENIX" scenario (actual scenario), the scenario in which heavy vehicles are blocked in their path by these traffic lights. The "with FENIX" scenario (FENIX scenario), the scenario in which heavy vehicles find a “green wave” at traffic lights, thanks to the dialogue possible with FENIX.

Each route "without FENIX" requires a stop at least one of the identified traffic lights. It has been assumed that heavy vehicles heading for the gate, stop at only one of the traffic lights on the route. In fact, if there are several traffic lights, it is assumed that the vehicle has found the green light in the other traffic lights. This is because a minimal and “conservative” estimate of the benefits has been realized: it is clear that, if the vehicle stopped at more than one traffic light, the benefits could be even greater.

The emission period in which the heavy vehicle is stopped at the traffic light has been transformed into a further hypothetical distance travelled by the vehicle at its average speed, similarly to what was done in the in par 3.5.

As far as the parameters “average speed of vehicles in urban areas”, “average stop time at a red light”, “type of fuel used by heavy vehicles” and “average emissions per km travelled” are concerned, the values reported in chapter 3 (see par 3.5) were used since, although referring to the Italian context, they are in any case also considered applicable to the other European countries taken into consideration.

Instead, for the composition of the vehicle fleet by type of emission class, data relating to the age of heavy vehicles in the European countries in question were used (data from Eurostat source). Those data serve to be able to assign the different emission classes to the vehicles transiting through the identified gates.

Similarly to what was done in Genoa, it was assumed that all the vehicles passing through the gates of the freight centres considered were registered in the country of the freight centre: this is obviously a simplification, but it is believed that it has no substantial impact on the final result.

In the table 23, the distribution per age (from the year of the registration) and per emission classes (Euro categories) of the heavy vehicles registered in a country are shown.

For Novara (Italy), the percentages reported in chapter 3 will be used (see par. 3.5).

	Less than 2 years	**From 2 to 5 years**	**From 5 to 10 years**	**More than 10 years**	**Total**	**Euro 6**	**Euro 5**	**Euro 4 or less**	**Total**
The Netherlands	30%	33%	24%	13%	100%	62%	24%	14%	100%
Belgium	23%	34%	29%	14%	100%	57%	29%	14%	100%
Germany	28%	40%	24%	8%	100%	68%	24%	8%	100%
France	24%	36%	28%	12%	100%	60%	28%	12%	100%

Table 23: Age and emissions class of the heavy vehicles (lorries and trucks) in NL, BE, DE and FR, 2020
(Source: Elaboration on Eurostat data)

4.5. Urban road routes identification

4.5.1. Rotterdam- Eem/Walhaven

To reach the gate identified in the previous chapter, the 1,066 daily heavy vehicles must travel the route shown in Figure 28. This route, from the motorway exit (tool gate) identified with the letter A to the gate identified with the letter B, has a length of 8.1 km and there are two traffic lights inside.

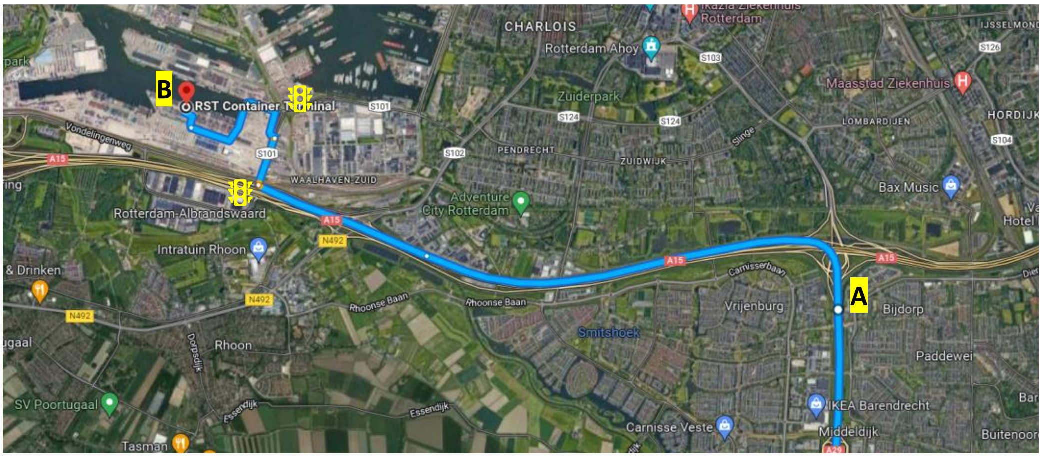

Figure 28: Rotterdam freight centre - Eem/Walhaven: route motorway toll gate - gate

4.5.2. Antwerp - Antwerp container terminal

To reach the gate identified for the Antwerp freight centre, the daily 3,000 heavy vehicles must travel, starting from the nearest motorway exit (toll gate), along the route shown in Figure 29 which has a length of 2 km and along which there is a traffic light.

Figure 29: Antwerp freight centre - Antwerp container terminal: route motorway toll gate - gate

4.5.3. Duisburg - DuCeTe

To reach the gate identified for the centre of Duisburg, the heavy must travel the route shown in Figure 30. This route is 2.67 km long and there are two traffic lights inside.

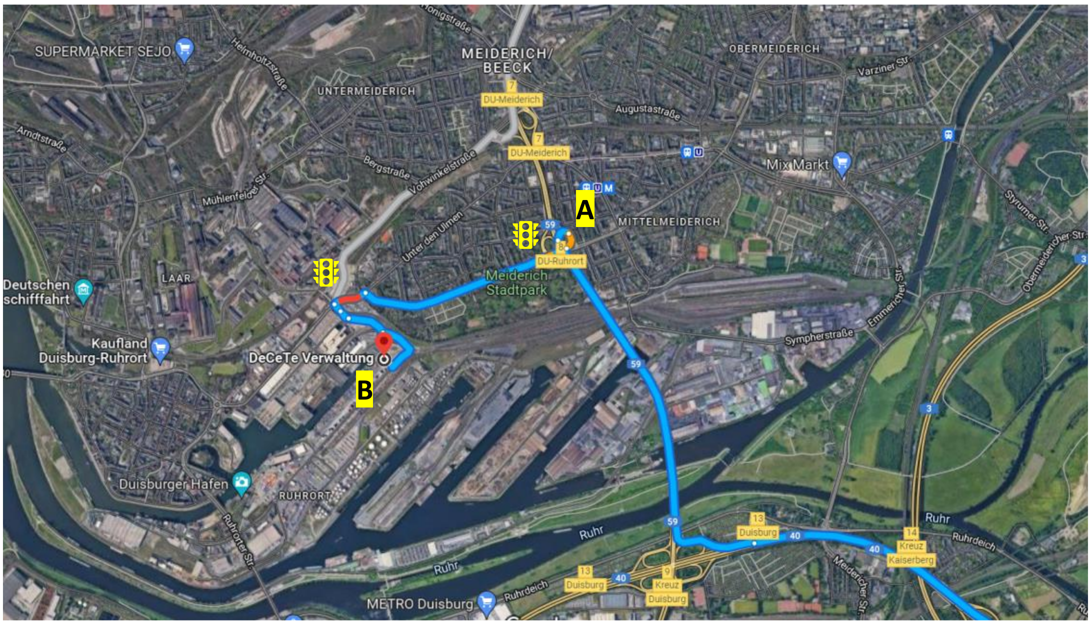

Figure 30: Duisburg freight centre - DuCeTe: route motorway toll gate - gate

4.5.4. Strasbourg - Strasbourg Terminal Nord

To reach the selected gate for the centre of Strasbourg, the daily 1,123 heavy vehicles must travel the route shown in Figure 31 which is 5.07 km long and has 10 traffic lights.

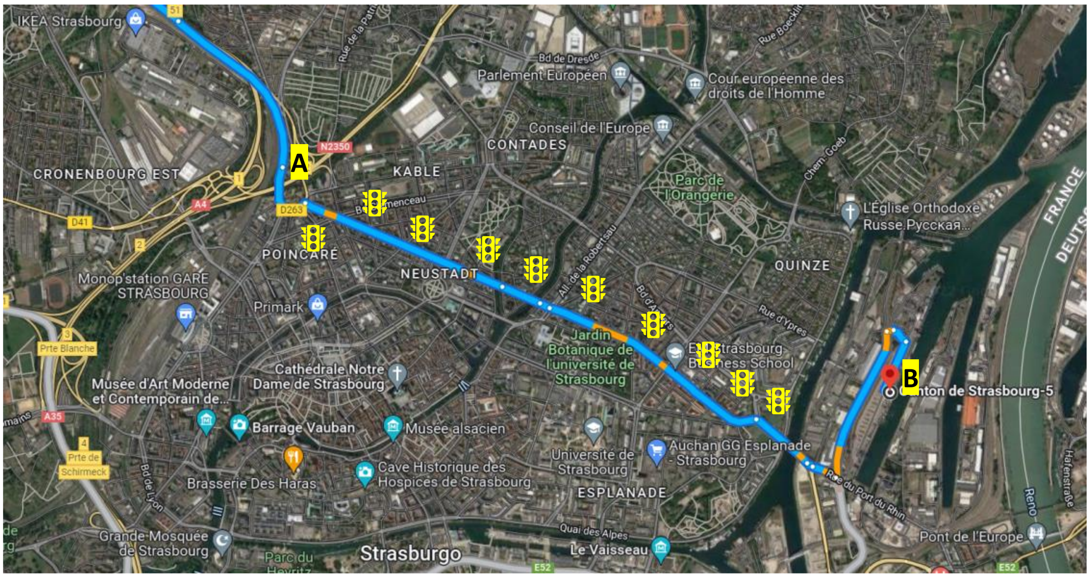

Figure 31: Strasbourg freight centre - Strasbourg Terminal Nord: route motorway toll gate - gate

4.5.5. Novara - Boschetto

Finally, to reach the gate reported for the Novara freight centre, the 133 heavy vehicles, estimated in the previous chapter to be in transit daily, must travel along the road shown in Figure 32 which has a length of 5.07 km and along which there is a traffic light, at the crossroads between via Emilio Wild and Corso Trieste.

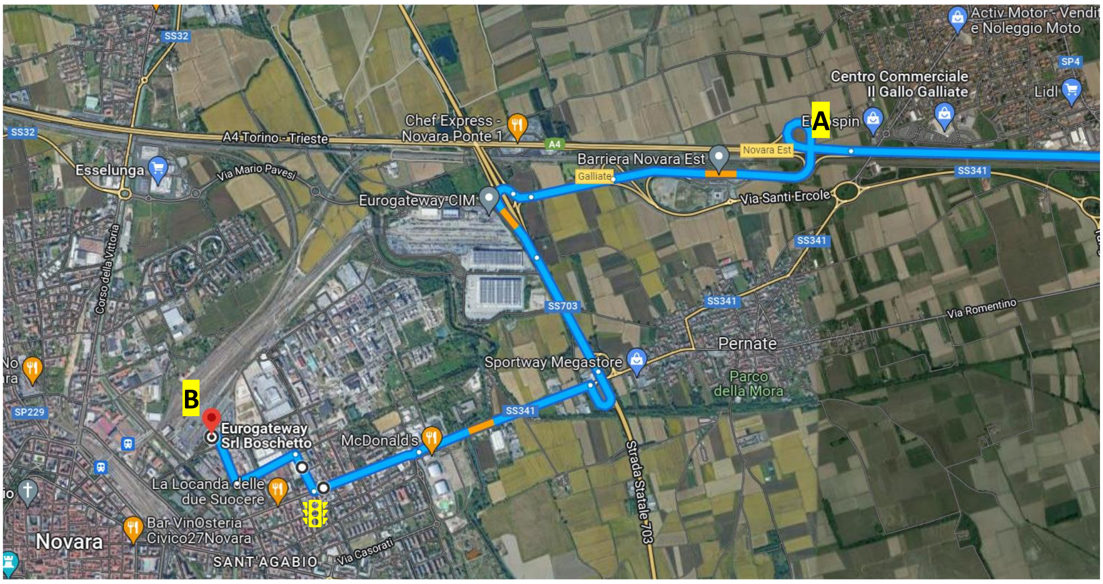

Figure 32: Novara freight centre – Boschetto: route motorway toll gate - gate

4.6. Emissions calculation in the two scenarios: current and with FENIX

4.6.1. Current scenario

The Table 24 shows the daily emission values referred to the current scenario. As can be seen, for each freight centre identified, the number of vehicles estimated to transit through the reference gates, the subdivision of the vehicles into emission classes, according to the values identified in paragraph 7.2, and the distance to be travelled are reported (at which has been added, in the case of the current status, the additional hypothetical distance, due to the stop at the traffic light).

4.6.2. FENIX scenario

The Table 25, on the other hand, shows the emissions calculated in the event that the data relating to the hours of entry and exit of trucks from the gates of a given terminal were exchanged, thanks to the FENIX network, between the terminal and the municipal administration.

Also in this case, the previously identified number of vehicles passing through the gates, the subdivision of vehicles by emission class and the distance travelled (which in this case corresponds to the real one, as there are no stops at traffic lights) have been reported.

				DAILY VALUES - CURRENT STATUS											
				Specific consumption	**SO2**	**NOx**	**COV**	**CH4**	**CO**	**CO2**	**N2O**	**NH3**	**PM2.5**	**PM10**	**PTS**
				g	**mg**	**mg**	**mg**	**mg**	**mg**	**g**	**mg**	**mg**	**mg**	**mg**	**mg**
		Veihcles	Distance												
Rotterdam	EURO 4	144	8,367	212,079	1,326	4,245,080	38,943	4,582	790,324	627,918	17,482	3,496	95,369	148,660	218,952
	EURO 5	256	8,367	415,129	2,572	7,668,850	80,797	9,430	2,442,125	1,229,099	106,943	23,575	202,742	302,185	436,989
	EURO 6	666	8,367	1,094,581	6,684	2,106,163	147,615	24,510	849,484	3,240,294	257,909	50,133	345,364	604,944	955,878
		1,066		**1,721,789**	**10,582**	**14,020,094**	**267,356**	**38,521**	**4,081,932**	**5,097,312**	**382,335**	**77,205**	**643,476**	**1,055,789**	**1,611,819**
		Veihcles	Distance												
Antwerp	EURO 4	422	2,267	168,325	1,053	3,369,276	30,909	3,636	627,272	498,372	13,876	2,775	75,694	117,990	173,780
	EURO 5	881	2,267	386,903	2,397	7,147,411	75,303	8,789	2,276,074	1,145,527	99,672	21,972	188,957	281,638	407,276
	EURO 6	1,697	2,267	755,863	4,616	1,454,412	101,936	16,925	586,611	2,237,586	178,099	34,620	238,491	417,744	660,082
		3,000		**1,311,091**	**8,066**	**11,971,099**	**208,148**	**29,350**	**3,489,957**	**3,881,485**	**291,646**	**59,367**	**503,142**	**817,372**	**1,241,138**
		Veihcles	Distance												
Duisburg	EURO 4	178	2,937	92,085	576	1,843,223	16,909	1,989	343,160	272,643	7,591	1,518	41,410	64,549	95,069
	EURO 5	565	2,937	321,439	1,991	5,938,079	62,562	7,302	1,890,965	951,706	82,808	18,254	156,986	233,985	338,366
	EURO 6	1,592	2,937	918,621	5,610	1,767,586	123,885	20,570	712,925	2,719,399	216,449	42,074	289,845	507,696	802,216
		2,335		**1,332,146**	**8,177**	**9,548,888**	**203,357**	**29,861**	**2,947,050**	**3,943,748**	**306,847**	**61,847**	**488,240**	**806,230**	**1,235,651**
		Veihcles	Distance												
Strasbourg	EURO 4	130	5,337	122,056	763	2,443,135	22,413	2,637	454,848	361,380	10,061	2,012	54,887	85,557	126,011
	EURO 5	314	5,337	324,545	2,011	5,995,451	63,166	7,372	1,909,235	960,901	83,608	18,431	158,503	236,246	341,635
	EURO 6	679	5,337	712,127	4,349	1,370,255	96,037	15,946	552,668	2,108,112	167,794	32,616	224,691	393,572	621,888
		1,123		**1,158,727**	**7,123**	**9,808,840**	**181,617**	**25,955**	**2,916,751**	**3,430,393**	**261,463**	**53,059**	**438,081**	**715,375**	**1,089,534**
		Veihcles	Distance												
Novara	EURO 4	31	5,337	28,717	180	574,818	5,273	620	107,016	85,025	2,367	473	12,914	20,130	29,648
	EURO 5	39	5,337	39,873	247	736,586	7,760	906	234,564	118,054	10,272	2,264	19,473	29,025	41,972
	EURO 6	64	5,337	66,950	409	128,824	9,029	1,499	51,959	198,193	15,775	3,066	21,124	37,002	58,467
		133		**135,540**	**835**	**1,440,228**	**22,063**	**3,025**	**393,539**	**401,272**	**28,414**	**5,804**	**53,511**	**86,156**	**130,087**

Table 24: Daily emissions along the Rhine-Alpine corridor freight centres - current scenario

				DAILY VALUES - STATUS WITH FENIX											
				Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS
				g	mg	mg	mg	mg	mg	g	mg	mg	mg	mg	mg
		Vehicles	Distance												
Rotterdam	EURO 4	144	8,100	205,312	1,284	4,109,615	37,701	4,435	765,103	607,881	16,924	3,385	92,326	143,916	211,965
	EURO 5	256	8,100	401,882	2,490	7,424,129	78,219	9,129	2,364,194	1,189,877	103,531	22,822	196,273	292,542	423,044
	EURO 6	666	8,100	1,059,652	6,471	2,038,953	142,905	23,728	822,376	3,136,893	249,679	48,534	334,343	585,640	925,375
		1,066		**1,666,845**	**10,245**	**13,572,698**	**258,824**	**37,292**	**3,951,673**	**4,934,651**	**370,134**	**74,741**	**622,942**	**1,022,098**	**1,560,384**
		Vehicles	Distance												
Antwerp	EURO 4	422	2,000	148,500	929	2,972,453	27,269	3,208	553,394	439,676	12,241	2,448	66,779	104,094	153,312
	EURO 5	881	2,000	341,334	2,115	6,305,612	66,434	7,754	2,008,005	1,010,611	87,933	19,384	166,702	248,468	359,309
	EURO 6	1,697	2,000	666,840	4,072	1,283,116	89,930	14,932	517,522	1,974,050	157,123	30,542	210,402	368,544	582,340
		3,000		**1,156,675**	**7,116**	**10,561,181**	**183,633**	**25,893**	**3,078,921**	**3,424,336**	**257,297**	**52,375**	**443,883**	**721,105**	**1,094,961**
		Vehicles	Distance												
Duisburg	EURO 4	178	2,670	83,714	524	1,675,657	15,372	1,808	311,964	247,858	6,901	1,380	37,645	58,681	86,427
	EURO 5	565	2,670	292,217	1,810	5,398,253	56,875	6,638	1,719,059	865,187	75,280	16,595	142,714	212,714	307,605
	EURO 6	1,592	2,670	835,110	5,100	1,606,896	112,623	18,700	648,113	2,472,181	196,771	38,249	263,495	461,542	729,287
		2,335		**1,211,041**	**7,434**	**8,680,807**	**184,870**	**27,146**	**2,679,136**	**3,585,226**	**278,952**	**56,224**	**443,855**	**732,936**	**1,123,319**
		Vehicles	Distance												
Strasbourg	EURO 4	130	5,070	115,950	725	2,320,909	21,292	2,505	432,093	343,301	9,558	1,912	52,141	81,277	119,707
	EURO 5	314	5,070	308,308	1,910	5,695,509	60,006	7,003	1,813,720	912,829	79,425	17,508	150,573	224,427	324,544
	EURO 6	679	5,070	676,500	4,131	1,301,703	91,233	15,148	525,019	2,002,647	159,399	30,985	213,450	373,883	590,776
		1,123		**1,100,759**	**6,766**	**9,318,122**	**172,531**	**24,656**	**2,770,832**	**3,258,777**	**248,382**	**50,405**	**416,165**	**679,586**	**1,035,027**
		Vehicles	Distance												
Novara	EURO 4	31	5,070	27,281	171	546,061	5,009	589	101,662	80,772	2,249	450	12,268	19,123	28,165
	EURO 5	39	5,070	37,878	235	699,736	7,372	860	222,829	112,148	9,758	2,151	18,499	27,573	39,873
	EURO 6	64	5,070	63,601	388	122,379	8,577	1,424	49,359	188,278	14,986	2,913	20,067	35,150	55,542
		133		**128,759**	**794**	**1,368,176**	**20,959**	**2,874**	**373,851**	**381,198**	**26,993**	**5,514**	**50,834**	**81,846**	**123,579**

Table 25: Daily emissions along the Rhine-Alpine corridor freight centres - FENIX scenario

4.6.3. Comparison between the two scenarios

Table 26 shows the annual savings in terms of fuel (diesel) and emissions possible thanks to the exchange of data through a FENIX connector between an intermodal terminal and the local administration which has the task of issuing provisions for the regulation of mobility. The values refer to the total of the five "freight terminals" along the Rhine-Alpine Corridor taken into consideration.

	Unit of measure in KG/YEAR											
	Specific consumption	SO2	NOx	COV	CH4	CO	CO2	N2O	NH3	PM2.5	PM10	PTS
Current	1.697.788,03	10,44	14.036,74	264,76	38,01	4.148,77	5.026.263,22	381,21	77,18	637,94	1.044,28	1.592,47
With Fenix	1.579.223,79	9,71	13.050,30	246,24	35,36	3.856,32	4.675.256,27	354,53	71,78	593,30	971,27	1.481,18
DELTA	- 118.564,24	- 0,73	- 986,45	- 18,52	- 2,66	- 292,44	- 351.006,95	- 26,68	- 5,41	- 44,63	- 73,01	- 111,29

Table 26: Annual savings: fuel (diesel) and emissions

According to the values in the table, the simple optimization of vehicular traffic flows, generated by a more integrated exchange of data between the local administrations and the logistics sector, could guarantee, only considering the short urban road path between the gates of the freight centres and the nearest motorway exits (toll gate) an annual saving of :

- more than 118 tons of fuel (diesel);
- more than 986 kg of NOX;
- more than about 292 kg of CO;
- about 351 tons of CO_2 corresponding to fifteen fully loaded trucks (24 tons).

By adding to these values those estimated for Genoa, we obtain the **possible annual savings at the level of the Rhine-Alpine corridor** (considering only the optimization of the flows of heavy vehicles in the urban sections where there is a traffic light) **equal to:**

- **more than 158 tons of fuel (diesel);**
- **more than 1,406 kg of NOX;**
- **more than 412 kg of CO;**
- **about 471 tons of CO_2 corresponding to the load of twenty trucks** (24 tons).

5. CONCLUSIONS

Thanks to the exchange of data between the freight centres and the municipal administrations through the FENIX network, it is therefore possible to save approximately 471 tons of CO_2 per year along the Rhine-Alpine Corridor only considering the six identified freight centres (more precisely considering only the gates of these freight centres near a city with therefore a possible interference between the traffic of heavy vehicles entering or leaving the gates and the urban traffic).

A "conservative" approach was followed in this study: in fact, the selected nodes along the Rhine-Alpine corridor are part of the “core” TEN-T network and the paths identified are rather short (from the freight centre gate to the entrance/exit of the nearest motorway).

Therefore, the savings could be even greater by applying the analysis to all the terminals of the corridor and extending the calculation to longer road sections.

However, the results of this study are encouraging.

Although the main purpose of the FENIX Project is to facilitate the exchange of data between the actors of the transport and logistics sector, it also responds to the "green" objectives of the European Union, such as the reduction of the environmental impact.

The report is focus on only one of the potential applications that the interaction between the information systems of the logistics players and those of the public administrations in the FENIX network could made possible: in fact, the fluidification of heavy traffic through the regulation of traffic lights, on the basis of reliable data and available in a short time, is just one of the areas where a local authority could benefit from the knowledge of the logistics and transport process.

As the UC10 of the ITA2 pilot site has shown, the Bodies in charge for the planning and regulation of the infrastructures and of the transport mobility at local/regional/national level are interested to have information (real-time and also non-real-time) on origin/destination vehicle flows, use of infrastructure, localization of logistic settlements, etc. in order to identify the better actions and interventions to meet the needs of a sustainable and eco-friendly mobility of businesses and citizens.

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