Interreg CENTRAL EUROPE

Co-funded by the European Union

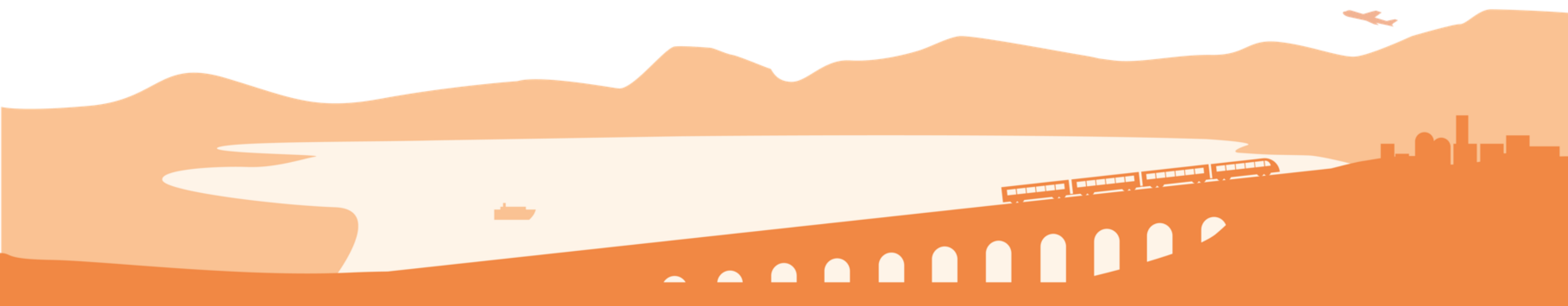
Rail4Regions

# Assessment of external effects of the local freight transport system

D.1.3.1

Final Version

01 2024



# Assessment of external effects of the local freight transport system

## Excecutive summary

The present document provides a summary of the outcomes from Deliverable 1.3.1 related to Activity 1.3 within Work Package 1 (WP1) of the Rail4Regions project. The primary goal of this deliverable is to underscore the competitiveness of rail freight transport as compared to the road freight transportation system. It aligns with the broader goal of WP1 to promote improved coordination among policies and responsible decision-makers for rail transport planning, spatial planning, and regional development.

The outputs from earlier deliverables, specifically D.1.1.4, which focuses on the overview of bottlenecks hindering rail freight transport, and D.1.2.4, which offers a summary of attitudes and expectations of stakeholders towards rail freight transport, are derived from various case studies addressed by the project. When combined with Deliverable 1.3.1, these collectively constitute the primary outputs of WP1.

The assessment of external effects of the local freight transport system involves a comprehensive comparative analysis between rail and road freight transportation. This analysis employs both qualitative and quantitative approaches to evaluate the positive and negative impacts of each mode of transportation.

The qualitative assessment underlines the strengths and weaknesses of each system, together with the benefits of one over the other from environmental, social, economic, and political aspects.

The quantitative assessment, based on 24 case studies elaborated by 5 partners, illustrates the financial savings in monetary terms resulting from a modal shift from road to rail. This analysis considers 3 future scenarios differing in the type of train fuel employed.

# Contents

# A. Overall introduction

The evaluation of external impacts on the local freight transport system involved a comprehensive analysis of both rail and road transportation, employing a combination of qualitative and quantitative methodologies.

This comparative analysis between rail and road freight transportation aims to highlight the positive and negative aspects of each, providing crucial insights for decision-makers. This clarification is necessary to enhance their understanding of the distinct characteristics of each mode, facilitating optimized logistics planning.

The qualitative assessment compares the two modes of transportation using a descriptive approach highlighting the elements where rail wins over road freight transport system and outlining the specific positive and negative aspects of each of them. This analysis gives a general view of all the aspects related to each mode being the strengths and weaknesses of both rail and road transportation, as well as the environmental, social, and economic externalities associated with each system. To conduct this analysis collaborative discussion groups were organized during the kick-off meeting in Varaždin. The outcomes of these brainstorming sessions were subsequently strengthened and solidified through insights derived from recent studies.

The quantitative assessment provides a financial perspective implemented through case studies provided by project partners, illustrating how a future scenario with rail as the central mode results in reduced external transportation costs. The analysis involves estimating the variation in external costs, considering factors such as noise, air pollution, climate change, accidents, and congestion as transport externalities.

These case studies serve as valuable examples, providing a concrete basis for assessing the financial implications associated with the identified externalities within the context of the local freight transport system, assuming a future scenario where the majority of the trip is supported by rail.

Both analyses engaged active and extensive participation from our partners, through face-to-face and online meetings, capitalizing their diverse professional backgrounds as transport operators and policymakers. Their rich experience, particularly gained during stakeholder meetings, was invaluable. These sessions played a crucial role in fine-tuning the content and approach of the assessment analysis.

# B. Methodology

The assessment of external effects of the local freight transport system utilized a comprehensive comparative methodology, incorporating both qualitative and quantitative dimensions to examine rail and road transport systems. The aim was to highlight the advantages of one system over the other. The qualitative assessment offered a descriptive overview of the positive and negative characteristics, as well as the external impacts of each system in a comparative manner. Conversely, the quantitative assessment relied on the case studies presented by project partners to estimate the external cost impacts of both rail and road systems.

In the qualitative assessment, the strengths and weaknesses of road and rail freight transport systems were considered, along with the positive and negative impacts they generate externally. When evaluating the strengths and weaknesses of each system, factors such as distance, volume of goods, infrastructure, and logistical requirements were carefully considered. External impacts were analysed in terms of environmental, social, economic, and political aspects, highlighting the benefits of rail transport compared to road and delineating the positive and negative aspects unique to each system.

The qualitative assessment involved a data collection session that included group discussions and online research. During the kick-off meeting, three groups discussed strengths and weaknesses as well as environmental, social, economic, and political externalities. The outcomes were recorded and presented by university partners. Results were further verified, reorganized, and integrated through online research, leading to a comparative analysis highlighting the pros and cons of each transport system.

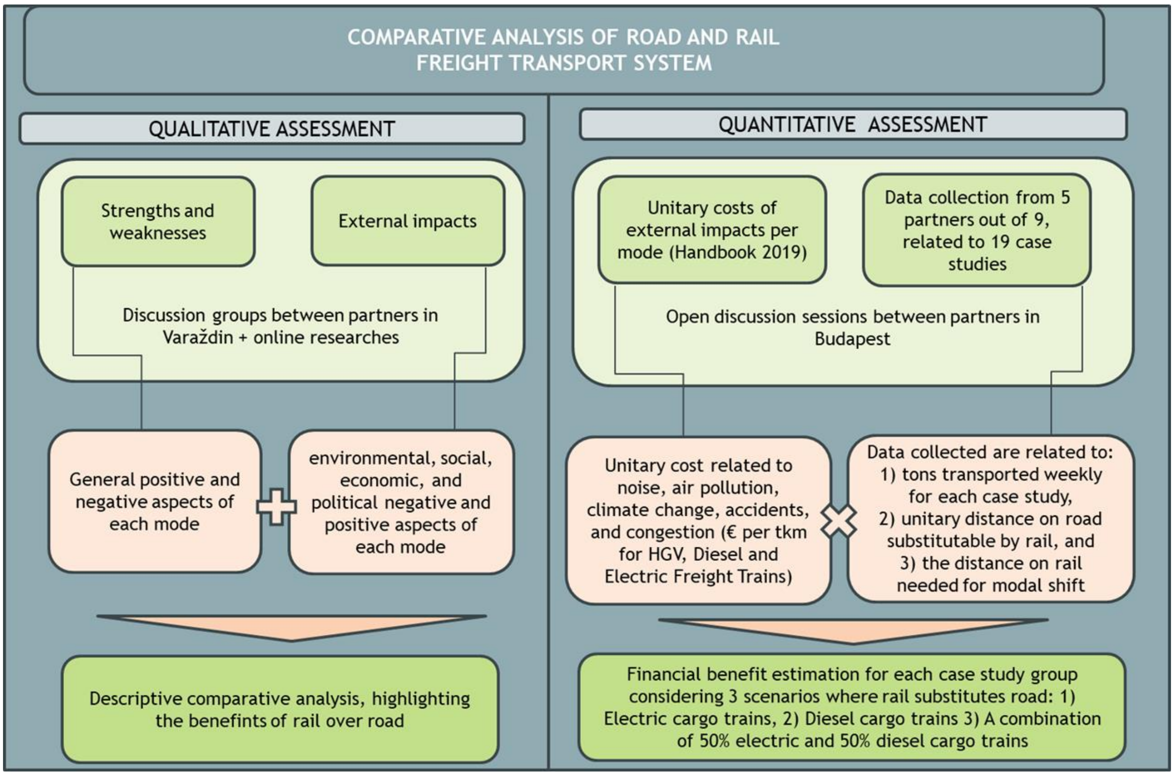
The quantitative assessment focused on determining the financial impact of externalities associated with noise, air pollution, climate change, accidents, and congestion from both rail and road freight transport systems. The primary goal was to calculate external cost savings attributed to the shift from road to rail as the primary mode of freight transportation. The comparison considered the segment where trucks are replaced by trains, assuming equivalent costs for the first and last mile, both of which are managed by trucks in all scenarios.

The quantitative method developed by the Task Leader relied on two main inputs: unitary transportation costs for each mode and type of externality, expressed in '€ per tkm' (euros per ton-kilometer), as reported by the European Commission's Handbook on the External Costs of Transport (2019); and data from each case study regarding origin, destination, tons transported weekly, unitary distance on road substitutable by rail, and the distance on rail needed for modal shift. The collected data were processed to calculate total tonne-kilometers on road that could be saved and those on rail that are needed, multiplied by the unitary cost, resulting in the total cost of each transportation mode and the calculation of total cost variation from road to rail.

The quantitative estimation method and the required data were shared and consolidated during an open session in the second face-to-face meeting in Budapest. A survey conducted by the Task Leader confirmed data availability from 5 out of 9 partners, leading to the creation of two templates (detailed and aggregated) based on the level of detail obtainable by each partner.

This quantitative estimation analysis is conducted for three future scenarios depending on the type of train employed:

- Electric cargo trains
- Diesel cargo trains
- A combination of 50% electric and 50% diesel cargo trains


COMPARATIVE ANALYSIS OF ROAD AND RAIL FREIGHT TRANSPORT SYSTEM
QUALITATIVE ASSESSMENT
Strengths and weaknesses
External impacts
Discussion groups between partners in Varaždin + online researches
General positive and negative aspects of each mode
environmental, social, economic, and political negative and positive aspects of each mode
Descriptive comparative analysis, highlighting the benefints of rail over road
QUANTITATIVE ASSESSMENT
Unitary costs of external impacts per mode (Handbook 2019)
Data collection from 5 partners out of 9, related to 19 case studies
Open discussion sessions between partners in Budapest
Unitary cost related to noise, air pollution, climate change, accidents, and congestion (€ per tkm for HGV, Diesel and Electric Freight Trains)
Data collected are related to: 1) tons transported weekly for each case study, 2) unitary distance on road substitutable by rail, and 3) the distance on rail needed for modal shift
Financial benefit estimation for each case study group considering 3 scenarios where rail substitutes road: 1) Electric cargo trains, 2) Diesel cargo trains 3) A combination of 50% electric and 50% diesel cargo trains

# C. Qualitative assessment

## Strengths and weaknesses of rail and road frieght transportation

Exploring the features of freight transportation, the analysis investigates the strengths and weaknesses of both rail and road logistics, revealing the key factors associated with each mode of transportation.

Road and rail freight transportation each have their own strengths and weaknesses, and the suitability of one over the other often depends on specific factors such as distance, volume of goods, infrastructure, and logistical requirements. Here's an overview of the strengths and weaknesses of road and rail freight transportation (1).

| STRENGTHS OF RAIL FREIGHT TRANSPORTATION |
|---|
| Higher carrying capacity of cargo train compared to trucks |
| Lower cost of transportation of rail compared to road transport for large volumes of goods transported over long distances (2) |
| More efficiency of rail compared to road transport in transporting large volumes of goods over long distances |
| More time reliability (a more predictable timetable) as trains typically operate on fixed schedules, and are not affected by road congestion or traffic delays |
| Regularity of transportation regardless of the season, time of day or weather |
| Less number of drivers per ton of cargo is required for rail transport compared to road transport |
| Universality of use for transportation of various goods in rail system |
| **WEAKNESSES OF RAIL FREIGHT TRANSPORTATION** |
| Limited and inflexible network of rail system |
| Limited connectivity or accessibility of rail system |
| Stable and consistent demand is necessary for investing in a rail-based logistics system |
| Requires specialized and high-cost staff, such as train drivers and technical staff |
| High technical requirements |
| Many permissions are required from government authorities, which can slow down transportation processes |
| Necessitates a sophisticated organizational structure |
| A large proportion of cost of transportation is related to fixed costs (up to 70%), which limits the possibilities of a flexible tariff policy |
| Complicated international transport due to fragmentation of rules and technologies in rail systems (interoperability issues) |
| Trans-EU corridors focus primarily on cross-border transport and less on regional lines |

| |
|---|
| Lack of financing mechanisms for the effective development of the railway infrastructure |
| Is not popular |

| STRENGTHS OF ROAD FREIGHT TRANSPORTATION |
|---|
| Higher flexibility comparing to rail system |
| Higher connectivity (point-to-point service delivery) comparing to rail system |
| Higher speed delivery over short distances comparing to rail system |
| More suitable for time-sensitive or short-distance shipments, and last-mile deliveries comparing to rail system |
| More competitive than rail system due to numerous offers by transport operators and more ease of entry for them |
| Higher frequency than rail system providing more options for shippers and allowing for dynamic scheduling |
| Higher freight protection through little handling and few transhipments in contrast to rail transport system |
| Lower investment costs are needed comparing to rail system |
| Lower skill requirements for truck drivers comparing to cargo train drivers |
| Lower level of organization needed comparing to rail-based logistics system |
| More scalable than rail system thanks to the ability to adapt, expand, or handle increased demand effectively without significant obstacles |
| Lower fees of road system as opposed to rail (3) |
| Integrated and harmonized market |
| High popularity |
| **WEAKNESSES OF ROAD FREIGHT TRANSPORTATION** |
| Less efficient than rail system for large-volume, long-distance transportation due to limited cargo capacity |
| High cost of transportation for medium and long distances |
| High number of drivers needed |
| Vulnerability to external factors such as traffic congestion and weather conditions, especially in countries with severe climatic conditions |
| Highly dependent on fuel prices, that can impact operational costs |
| Less security than rail transport system due to vulnerability to theft on parking lots and hijacking |

# External effects of rail and road frieght transportation

Rail and road freight transportation have various external impacts that extend beyond the direct operation of these modes of transport. Understanding these external impacts is crucial for policymakers, businesses, transport operators and communities to make informed decisions about freight transportation modes.

Here are some external impacts associated with both rail and road freight transportation relating to environmental, social, economic, and political aspects.

## Environmental impacts

Concerning the environmental external costs, the comparison between the two modes of transportation primarily revolves around the following aspects: emissions, noise and vibration, energy efficiency and land use. Subsequently, the specific environmental aspects of each mode are outlined.

### Environmental benefits of rail transport compared to road

- **Emissions**: in contrast to road transport systems, rail transportation produces fewer greenhouse gas emissions and lower levels of pollutants, including nitrogen oxides and particulate matter. Notably, the road freight transport system has a significant impact on air quality, particularly in urban areas, releasing carbon and various air pollutants.

- **Noise**[1]**:** in comparison to road transport systems, the rail transport system typically generates less noise, particularly when utilizing electric or modern diesel-electric locomotives. Conversely, the road freight transport system significantly contributes to noise pollution, especially in residential areas (4).

- **Energy efficiency:** the rail transport system exhibits higher energy efficiency per ton-mile than its road counterpart, particularly over long distances with substantial cargo volumes. On the other hand, the road freight transport system necessitates higher energy consumption than rail, particularly when dealing with extensive transportation distances and substantial volumes of freight.

- **Land use**: the rail transport system has a more compact land footprint compared to an extensive road network. Unlike the rail system, the road infrastructure requires a larger land footprint, encompassing both the road network and the necessary parking facilities.

### Particular environmental considerations related to rail transport

- Although rail system is more energy-efficient than road system, it still requires energy often derived from non-renewable sources.

- Raw materials extraction for rail infrastructure construction, such as metals and aggregates, can contribute to environmental degradation and habitat destruction.

[1] Noise pollution can impact ecosystems and wildlife. Excessive noise can disrupt natural habitats, interfere with communication and mating behaviours of animals, and potentially lead to changes in animal populations. In this sense, noise is an environmental externality when it disturbs the balance of natural ecosystems.

- Diesel-powered locomotives, while more fuel-efficient, still emit pollutants such as nitrogen oxides and particulate matter.
- The construction and maintenance of rail infrastructure may involve changes in land use, potentially leading to deforestation and can contribute to soil erosion and sedimentation, affecting water quality in nearby water bodies.
- Poorly designed rail infrastructure may have a negative impact on the visual appeal and environmental aesthetics of the surrounding area.
- In case of accidents, chemical spills have the potential to extensively contaminate soil, water, and air.

### Particular environmental impacts related to road transport

- The consistent and heavy loads transported by trucks contribute to the deterioration and damage of roads.
- The presence of roads and parking lots can impact drainage and contribute to flooding, as their surfaces impede water absorption into the ground.

In summary, the road freight transport system demonstrates a higher environmental impact per ton-mile than its rail counterpart when compared to the rail system.

## Social impacts

In the context of social external costs, the comparison between the two modes of transportation primarily centres on the following aspects: safety, congestion, health and noise. Subsequently, the specific social aspects of each mode are outlined.

### Social benefits of rail transport compared to road

- **Safety:** the rail transport system excels in safety when compared to roads, as evidenced by lower accident rates and fatalities.
- **Congestion:** road congestion, which often results in delays and increased transportation costs, is alleviated by promoting a modal shift from road to rail.
- **Health**: the rail transport system generates lower levels of air pollution compared to the road transport system, potentially resulting in fewer respiratory issues and an overall enhancement of well-being for communities along rail routes. In contrast, the release of pollutants by heavy vehicles on roads can harm air quality, posing health risks for nearby residents (5).
- **Noise**[2]: in general, road transport systems are often associated with higher levels of noise disturbance for society, mainly due to the proximity of roads to residential areas. Extensive road networks allow free and continuous movement throughout the city. In addition, the existing buildings are often located very

[2] On the social side, noise pollution affects people's well-being, health, and quality of life. Continuous exposure to high levels of noise can lead to stress, sleep disturbances, hearing impairment, and other health issues. It can also disrupt daily activities, communication, and overall enjoyment of the environment. Thus, noise is a social externality when it impacts individuals and communities within society.

close to existing roads. On the other hand, railways are typically located away from densely populated areas and train noise is characterized by periodicity, being intermittent.
It should be noted that freight transport is mostly carried out at night, more people are exposed to railway noise at night-time (>50 dB) than during the entire day (>60 dB), which is due to the higher volume of railway vehicles associated with freight transport occurring at night (6).

### Particular social considerations related to rail transport

- A developed rail transport system fosters enhanced access to employment opportunities across various sectors (rail operations, maintenance, and support services) and improves connectivity for residents (✓).
- Elevated rail lines or barriers may create physical barriers, potentially dividing communities. However, at-grade rail lines with proper crossings and integration into the urban fabric can have a more positive impact (✗).

### Particular social considerations related to road transport

- The road freight transport system provides numerous job opportunities (✓).
- Roads, especially in urban areas, can lead to community division if they act as barriers, separating neighbourhoods or disrupting the cohesion of communities. Highways, in particular, are known for their potential to fragment communities and create physical divides. However, well-designed urban roads with proper crossings and pedestrian infrastructure may have a less divisive impact (✗).
- The prolonged durations spent on the road for days are detrimental to the well-being of drivers given the challenges they encounter, including limited resting places, inadequate hygiene facilities, and the prolonged separation from home and parents (✗).
- Road maintenance costs are borne by society, as taxpayers fund road repairs and maintenance, impacting public budgets (✗).
- The presence of heavy road freight traffic may negatively affect local businesses (✗).

## Economic impacts

In terms of economic external costs, the noteworthy aspects associated with rail and road transportation are highlighted as follows:

### Economic impacts of rail transport

- A rail transport system, being more energy-efficient than road transport system, mitigates environmental remediation expenses, leading to lower healthcare costs related to air pollution (✓).
- An efficiently optimized rail freight transport system, encouraging trade, can positively impact a country's competitiveness in the global markets (✓).
- Building and maintaining rail infrastructure requires high investment (✗). However, it subsequently reduces maintenance and infrastructure costs for roadways in case of a modal shift from road to rail (✓).

- The rail-based logistics system holds the potential for job creation, income generation, and the stimulation of local economies, as well as industrial and commercial development along rail routes (✓).

### Economic impacts of road transport

- Road freight transportation facilitates the movement of goods, contributing to economic growth by supporting industries, businesses, and trade activities (✓).
- In general, roads tend to require more frequent maintenance compared to rail infrastructure. Roads are constantly exposed to a variety of stressors, including heavy vehicular traffic, weather conditions, and environmental factors (✗).
- Well-connected road networks can stimulate regional development by connecting remote areas to economic centres (✓).

## Political impacts

In the realm of political external costs, the key facets linked to rail and road transportation are listed as follows:

### Political impacts of rail transport

- The development of environmental policies supporting the rail transport system is essential, as rail is widely acknowledged as a crucial element in sustainable transportation systems (✓).
- Within a rail-based transport system, regional development and economic equity can be fostered through the creation of new job opportunities, and increased trade between regions and nations (✓).
- Essential revisions in intermodal transportation planning are required to establish a rail-based logistics system (✓).
- Building and maintaining rail infrastructure requires long-time investment, time-consuming planning and significant regulatory requirements (✗).
- The rail-based logistics system requires substantial bureaucratic challenges (✗).
- Promoting a rail-based logistics system introduces challenges in land use and zoning policies, as the presence of rail yards and terminals may give rise to concerns related to land use planning, environmental considerations, and community development (✗).

### Political impacts of road transport

- The road freight industry creates employment opportunities for a diverse range of workers, including drivers, logistics professionals, maintenance personnel, and administrative staff (✓).
- The wear and tear caused by heavy road traffic necessitate constant maintenance and repairs. Politicians may face challenges in funding these infrastructure needs, leading to debates about budget and public resources allocations (✗).

- Roads can become congested, leading to delays, frustration, and increased travel times for individuals. This can contribute to public dissatisfaction, and politicians may face pressure to address congestion-related issues (×).
- The emissions from vehicles on roads can contribute to air pollution. Politicians may face criticism for inadequate environmental regulations or insufficient efforts to promote cleaner transportation alternatives (×).
- Road accidents and fatalities pose significant safety concerns. Politicians may be held accountable for road safety issues, and public pressure may lead to calls for stricter regulations, improved enforcement, and increased investments in safety measures (×).
- The road transport system heavily relies on fossil fuels, contributing to political debates on energy independence, climate change, and the need for sustainable transportation policies (×).
- Tolls may be subject to political debates, especially concerning their impact on businesses, consumers, and regional economic development (×).

Leveraging the advantages of both transport systems, a combined road-rail freight transport system could enhance the modal share of rail freight by capitalizing on positive aspects of each system like the flexibility of road transport for short distances and the energy efficiency and low carbon footprint of rail transport.

# D. Quantitative assessment

In the quantitative assessment analysis, the project focused on determining the financial impact of externalities associated with noise, air pollution, climate change, accidents, and congestion arising from the rail and road freight transport system. The primary objective was to calculate the external cost savings attributed to the shift from road to rail as the primary mode of freight transportation.

This analytical process involved conducting case studies to collect substantial and pertinent data from the project partners. So that, the methodology for estimating externalities and the necessary data for the analysis were shared and extensively discussed during an open session at the Budapest meeting with project partners.

The group discussion resulted in three key outcomes:

- Confirmation of the methodology for quantitative cost estimation analysis.
- Consolidation of the data required to conduct the quantitative cost estimation analysis.
- Implementation of a survey among partners to assess data availability for estimation, resulting in confirmation from 5 out of 9 partners regarding their ability to obtain the necessary data.
- Understanding the level of detailed information available from partners, leading to the development of two templates for data collection (detailed and aggregated data collection templates).

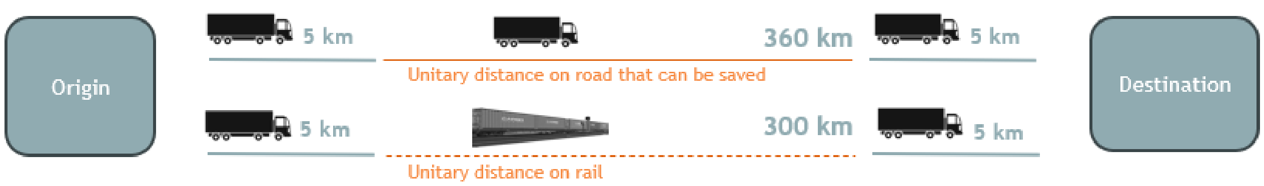
In conclusion, despite the unavailability of data for certain case studies among some partners, the participants collectively opted to proceed with the quantitative assessment. This decision underscores the significance of the results from the evaluation analysis, providing valuable financial insights into the cost savings associated with rail transport in future scenarios.

## Data collection

To facilitate a quantitative assessment of externalities associated with both rail and road transportation, two templates were distributed among partners considering the level of detailed data available by partners.

Specifically, partners were required to prepare the following information for each case study, considering a future intermodal scenario where rail plays a central role in the journey, complemented by trucks handling the first and last mile:

- Good name,
- Origin of trip,
- Destination of trip,
- Total tons transported in a week,
- The unitary distance on road that can be saved for each trip,
- Unitary distance on rail that is needed for each trip to shift from road to rail.




For one partner (Kordis from Czech Republic) with accessible case study data for the quantitative estimation analysis, the collection of precise information concerning specific origins and destinations posed a challenge. Consequently, they were instructed to compute estimated unitary distances for each type of goods on both road and rail, as outlined below:

- Good name,
- The medium tons transported in a week,
- The estimated medium unitary distance on road that can be saved for each trip;
- The estimated medium unitary distance on rail that is needed for each trip to shift from road to rail.

The table below serves as the template designed for partners with **detailed** information available for case studies.

| Good name | Origin | Destination | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) |
|---|---|---|---|---|---|
| | | | | | |

This template, on the other hand, is specifically tailored for partners with **aggregated** information available for case studies.

| Good name | Tons transported in a week (medium) | Medium distance on road that can be saved (km) | Medium distance on rail that is needed (km) |
|---|---|---|---|
| | | | |

The table below lists the names of goods for which the necessary data was provided by the respective partners.

| Partner (country) | Case studies | Number of case studies | Template used |
|---|---|---|---|
| TMIL (Germay) | Glass bottles, Gravel and timber | 3 | Detailed |
| University North (Croatia) | food products, raw materials, pharmaceutical products, goods related to the wood industry, goods related to the metal industry and grain | 5 | Detailed |
| Varaždin County (Croatia) | metal products, wood products, stone, containers, grain, wood industry goods, gelatin, plastic mass | 8 | Detailed |
| Novara Province (Italy) | Consumer goods (cosmetics), Waste, Stone (feldspar powder), Stone (marble slabs and blocks) | 4 | Detailed |
| Kordis (Czech Republic) | Cement, Lime, Steel, Bricks | 4 | Aggregated |

# Methodology of quantitative estimation

The quantitative estimation analysis involves calculating the external cost savings associated with a future scenario in which rail serves as the primary mode of freight transportation, and the first and last mile of the travel is complemented by means of trucks. This means that the major travel distance made by heavy vehicles would be substituted by cargo trains.

This estimation is made by assessing the external costs arising from both rail and road-based freight transport systems, considering three prospective future scenarios:

- Employing electric cargo trains
- Utilizing diesel cargo trains
- Implementing a combination of 50% electric and 50% diesel cargo trains

The present analysis is based on two main sets of data. Firstly, for all case studies provided by each partner, the estimation incorporates the elaboration of data collected to determine the values associated with the 'total ton-kilometers saved on roads' and the 'total ton-kilometers required on rail' in case of modal shift occurring within a given week in future scenarios.

The following tables present two examples of data collected and processed for each template type (detailed and aggregated). The remaining data collected from partners is documented in the attached files.

| Detailed data collected by TMIL | | | | | | Data elaborated | |
|---|---|---|---|---|---|---|---|
| **Good name** | Origin | Destination | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) | tn*km on road (per week) | tn*km on rail (per week) |
| **Glass bottles** | Steinbach am Wald | Nordhausen | 2000 | 198 | 204 | 396,000 | 408,000 |
| **Gracel** | Artern | Hamburg | 2000 | 344 | 483 | 688,000 | 966,000 |
| **Gravel** | Artern | Berlin | 2000 | 240 | 237 | 480,000 | 474,000 |
| **Timber** | Ohrdruf | Wilhelmshafen | 1600 | 468 | 450 | 748,800 | 720,000 |
| **Timber** | Ohrdruf | Arneburg | 1600 | 292 | 309 | 467,200 | 494,400 |
| **Timber** | Ohrdruf | St. Pölten (A) | 1600 | 624 | 620 | 998,400 | 992,000 |
| **Al case studies of TMIL** | | | | | | **3,778,400** | **4,054,400** |

| Aggregated data collected by KORDIS | | | | Data elaborated | |
|---|---|---|---|---|---|
| **Good name** | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) | tn*km on road | tn*km on rail |
| **Cement** | 822 | 180 | 160 | 147,960 | 131,520 |
| **Lime** | 9 | 60 | 75 | 540 | 675 |
| **Steel** | 419 | 240 | 250 | 100,560 | 104,750 |
| **Bricks** | 164 | 50 | 50 | 8,200 | 8,200 |
| **Al case studies of TMIL** | | | | **257,260** | **245,145** |

Here are the summarized final results of calculations pertaining to the 'total ton-kilometers saved on roads' and the 'total ton-kilometers required on rail' across all case studies conducted by each partner.

| | TMIL | University North | Varaždin County | Novara | KORDIS |
|---|---|---|---|---|---|
| **Tn*km on road** | **3,778,400** | **3,361,000** | **2,923,000** | **1,332,840** | **257,260** |
| **Tn*km on rail** | **4,054,400** | **3,709,000** | **3,666,000** | **1,766,150** | **245,145** |

In a second step, the estimation analysis considers the unitary values of each external costs (average costs) associated with each mode of transportation, as reported in the Handbook on the External Costs of Transport by the European Commission (7), expressed in '€ per tkm' (euros per ton-kilometer).

| Externalities | Mode | **€ per tkm** |
|---|---|---|
| Noise | HGV (Heavy Goods Vehicle) | 0.007 |
| | Freight train electric | 0.006 (8) |
| | Freight train diesel | 0.004 |
| Air pollution | HGV | 0.0076 |
| | Freight train electric | 0.00004 |
| | Freight train diesel | 0.0068 |
| Climate change | HGV | 0.0053 |
| | Freight train diesel | 0.0025 |
| Accidents | HGV | 0.013 |
| | Freight train diesel | 0.001 |
| Congestion | HGV | 0.008 |

Subsequently, these two sets of data are employed in the subsequent formulas to compute the total external cost, related to each externality, attributed to road and rail-based freight transportation systems, specifically in the segment where rail replaces the road transport system.

*Total external cost for road$_e$ (euro)= Unitary external cost of road$_e$ * total tkm saved on road*

*Total external cost for rail$_e$ (euro) = Unitary external cost of rail$_e$ * total tkm needed on rail*

| | | Total external costs of case studies (euro), grouped per partner | | | | |
|---|---|---|---|---|---|---|
| Externalities | Mode | TMIL | University North | Varaždin County | Novara | KORDIS |
| Noise | HGV | 26,448.80 | 23,527.00 | 20,461.00 | 9,329.88 | 1,800.82 |
| | Freight train electric | 24,326.40 | 22,254.00 | 21,996.00 | 10,596.90 | 1,470.87 |
| | Freight train diesel | 16,217.60 | 14,836.00 | 14,664.00 | 7,064.60 | 980.58 |
| Air pollution | HGV | 28,715.84 | 25,543.60 | 22,214.80 | 10,129.58 | 1,955.18 |
| | Freight train electric | 162.18 | 148.36 | 146.64 | 70.65 | 9.81 |
| | Freight train diesel | 27,569.92 | 25,221.20 | 24,928.80 | 12,009.82 | 1,666.99 |
| Climate change | HGV | 20,025.52 | 17,813.30 | 15,491.90 | 7,064.05 | 1,363.48 |
| | Freight train diesel | 10,136.00 | 9,272.50 | 9,165.00 | 4,415.38 | 612.86 |
| Accidents | HGV | 49,119.20 | 43,693.00 | 37,999.00 | 17,326.92 | 3,344.38 |
| | Freight train diesel | 4,054.40 | 3,709.00 | 3,666.00 | 1,766.15 | 245.15 |
| Congestion | HGV | 30,227.20 | 26,888.00 | 23,384.00 | 10,662.72 | 2,058.08 |

Finally, the total cost variations within a potential rail-based freight transport system for the group of case studies provided by each partner are computed using the following formula.

*External cost variation (euro) = Total external costs for rail - Total external costs for road*

## Estimation results

The table below reports the outcomes of computed external cost variations for each scenario, with respect to each externality, within the context of the group of case studies provided by each partner.

In general, the variations in external costs for future scenarios across all case study groups consistently exhibit negative values. This indicates that the adoption of a rail-based transport system results in a reduction of external costs associated with transportation. This trend is observed consistently across the majority of cases.

However, there are a few exceptions in specific case studies:

- In Varaždin, there is a modest increase in noise cost externality (+1,535 euro) and in air pollution cost externality (+2,714 euro), in the respective scenarios of electric train and diesel train.
- In Novara, there is a modest increase in noise cost externality (+1,267 euro) and air pollution cost externality (+1,880 euro), considering respectively the electric train and the diesel train scenario.

The contrasting trend in these cases is primarily attributed to the fact that the tonne-kilometers on rail significantly exceed those on the road (+25% and +33% increases in case of Varaždin and Novara case studies, respectively) when compared to other case studies in the group. Nevertheless, in these exceptional cases, the scenario involving a combination of 50% electric and 50% diesel trains leads to cost savings in external expenditures.

| | | External costs variation in a week (euro) related to case studies group | | | | |
|---|---|---|---|---|---|---|
| Externalities | Train type | TMIL | University North | Varaždin County | Novara | KORDIS |
| Noise | electric | - 2,122.40 | - 1,273.00 | +1,535.00 | + 1,267.02 | - 329.95 |
| | diesel | - 10,231.20 | - 8,691.00 | - 5,797.00 | - 2,265.28 | - 820.24 |
| | 50% electric 50% diesel | - 6,176.80 | - 4,982.00 | - 2,131.00 | - 499.13 | - 575.10 |
| Air pollution | electric | - 28,553.66 | - 25,395.24 | - 22,068.16 | - 10,058.94 | - 1,945.37 |
| | diesel | - 1,145.92 | - 322.40 | +2,714.00 | +1,880.24 | - 288.19 |
| | 50% electric 50% diesel | - 14,849.79 | - 12,858.82 | - 9,677.08 | - 4,089.35 | - 1,116.78 |
| Climate change | electric | - 20,025.52 | - 17,813.30 | - 15,491.90 | - 7,064.05 | - 1,363.48 |
| | diesel | - 9,889.52 | - 8,540.80 | - 6,326.90 | - 2,648.68 | - 750.62 |
| | | - 14,957.52 | - 13,177.05 | - 10,909.40 | - 4,856.36 | - 1,057.05 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 50% electric 50% diesel | | | | | |
| Accidents | electric | - 49,119.20 | - 43,693.00 | - 37,999.00 | - 17,326.92 | - 3,344.38 |
| | diesel | - 45,064.80 | - 39,984.00 | - 34,333.00 | - 15,560.77 | - 3,099.24 |
| | 50% electric 50% diesel | - 47,092.00 | - 41,838.50 | - 36,166.00 | - 16,443.85 | -3,221.81 |
| Congestion | electric | - 30,227.20 | - 26,888.00 | - 23,384.00 | - 10,662.72 | - 2,058.08 |
| | diesel | - 30,227.20 | - 26,888.00 | - 23,384.00 | - 10,662.72 | - 2,058.08 |
| | 50% electric 50% diesel | - 30,227.20 | - 26,888.00 | - 23,384.00 | -1 0,662.72 | - 2,058.08 |

As illustrated in the table below, the overall external cost variations across each case study group indicate significant cost savings when shifting from road to rail as the primary mode of transportation.

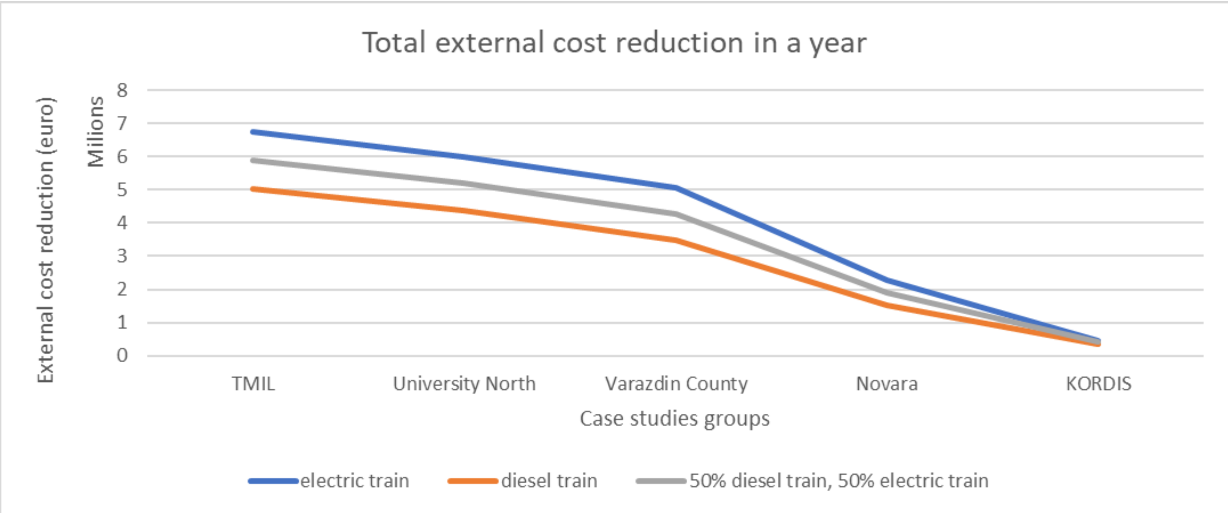
The more substantial the volume shifted to rail, the greater the resulting monetary savings, leading to a reduction in external costs. This is evidenced by the TMIL and Kordis case studies, which exhibit annual savings of nearly €6.7 million and €0.5 million, corresponding to 10,800 and 1,414 tons of goods, respectively.

| Total external costs variation (weekly and annualy) and total tons transported | | | | | | |
|---|---|---|---|---|---|---|
| Indicators | scenario | TMIL | University North | Varaždin County | Novara | KORDIS |
| Total tons in a week (tn) | All | 10,800 | 10,900 | 10,000 | 3,360 | 1,414 |
| Total cost reduction in a week (euro) | Electric train | 130,048 | 115,063 | 97,408 | 43,846 | 9,041 |
| | Diesel train | 96,559 | 84,426 | 67,127 | 29,257 | 7,016 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 50% diesel 50% electric train | 113,303 | 99,744 | 82,267 | 36,551 | 8,029 |
| **Total cost reduction in a year [3](euro)** | Electric train | 6,762,495 | 5,983,252 | 5,065,219 | 2,279,972 | 470,145 |
| | Diesel train | 5,021,049 | 4,390,162 | 3,490,599 | 1,521,375 | 364,851 |
| | 50% diesel 50% electric train | 5,891,772 | 5,186,707 | 4,277,909 | 1,900,673 | 417,498 |

When comparing the three scenarios, the total reduction in external costs is greater when employing electric cargo trains compared to diesel trains (€6.7 million and €5.9 million annually saved, respectively, in the case of employing electric and diesel trains, as evidenced by the TMIL case studies).

However, in the case of utilizing a combination of 50% electric and 50% diesel cargo trains, the total cost savings fall at an intermediate level between the two extreme scenarios (almost €5 million saved as evidenced by the TMIL case studies).




[3] 52 weeks in a year are considered to calculate the annual external cost savings.

# E. Most significant conclusions

The Rail4Regions project, within WP1, aims to improve coordination among policies and responsible decision-makers for rail transport planning, spatial planning, and regional development. In line with this broader aim, Deliverable 1.3.1 seeks to underscore the competitiveness of rail freight transport compared to the road freight transportation system. This is achieved through the assessment of external effects on the local freight transport system.

The assessment analysis entails a comprehensive comparative study between rail and road freight transportation, employing both qualitative and quantitative approaches to evaluate the positive and negative impacts of each mode of transportation.

The qualitative assessment highlights the strengths, weaknesses, and external impacts associated with environmental, social, economic, and political aspects related to both rail and road transport systems. This analysis was conducted through extensive face-to-face discussion groups involving project partners, and the outcomes were further validated and integrated through online research managed by collaborative group work coordinated by the Task Leader.

Evaluating the strengths and weaknesses of each system, three groups of conclusions can be summarized:

a. the rail freight transport system proves advantageous over road transport, considering the following aspects:
   - carrying capacity,
   - cost of transportation and efficiency in handling large volumes of goods over long distances,
   - time reliability, unaffected by road congestion or traffic delays,
   - regularity of transportation regardless of the season, time of day or weather,
   - number of drivers needed per ton of cargo,
   - security of goods, as the road system is more vulnerable to theft in parking lots and hijacking.

b. the road freight transport system proves to be more suitable considering the following aspects:
   - flexibility (extended infrastructure network) and connectivity (point-to-point service delivery),
   - speedy delivery over short distances (last-mile deliveries),
   - ease of entry for transport operators,
   - frequency,
   - investment costs,
   - fees of road system,
   - level of skill required by drivers,
   - market integration and popularity,
   - safety of goods (little handling and few transshipments).

c. the rail-based freight transport system presents challenges, necessitating:
   - a stable and consistent demand for investing in a rail-based logistics system,
   - a sophisticated organizational structure,
   - international policies to overcome the fragmentation of rules and technologies in rail systems (interoperability issues),
   - financing mechanisms for the effective development.

The comparative analysis regarding external impacts confirms that the rail freight system appears to be more sustainable in terms of:

- environmental impacts, producing lower levels of greenhouse gas emissions and pollutants, less noise, and requiring less energy and land use,
- social impacts, considering safety, congestion, and health in terms of air quality and noise disturbance.

In terms of economic external costs, a rail-based freight transport system leads to a reduction in expenses related to environmental remediation (lower healthcare costs due to decreased air pollution) and lessens maintenance and infrastructure costs for roadways. Additionally, it creates new job opportunities and fosters industrial and commercial development. On the other hand, road freight transportation facilitates the movement of goods, connecting remote areas to economic centres, and contributes to economic growth and regional development.

In terms of political external costs within the rail-based transport system, positive impacts are associated with the development of environmental and transport policies, regional development, and economic equity. Conversely, the negative political aspects of the rail system are linked to long-term investments, time-consuming planning, significant regulatory requirements, substantial bureaucratic challenges, and challenges related to land use and zoning policies (considering rail yards and terminals).

On the other hand, within the road freight transport system, while it creates employment opportunities for a diverse range of workers, it necessitates constant maintenance and repairs of roads due to heavy road traffic. It also leads to public dissatisfaction due to congestion, air pollution, road accidents, fatalities, and climate change. Moreover, road toll policies may be subject to political debates, especially concerning their impact on businesses, consumers, and regional economic development.

A combined road-rail freight transport system would help increase the modal share of rail freight, benefitting from the positive aspects of both transport system, like the flexibility of road transport over short distances as well as the energy efficiency and low carbon footprint of rail transport.

In the quantitative assessment, the project concentrated on evaluating the financial consequences of external factors such as noise, air pollution, climate change, accidents, and congestion stemming from both the rail and road freight transport systems. The main aim was to quantify the cost savings associated with the shift from road to rail as the primary mode of freight transportation.

The quantitative method developed by the Task Leader relied on two main inputs: unitary transportation costs for each mode and type of externality, expressed in '€ per tkm' (euros per ton-kilometer), as reported by the European Commission's Handbook on the External Costs of Transport (2019); and data from each case study regarding origin, destination, tons transported weekly, unitary distance on road substitutable by rail, and the distance on rail needed for modal shift. The collected data were processed to calculate total tonne-kilometers on road that could be saved and those on rail that are needed, multiplied by the unitary cost, resulting in the total cost of each transportation mode and the calculation of total cost variation from road to rail.

The quantitative methodology relied on two primary inputs: unitary transportation costs for each mode and type of externality, expressed in '€ per tkm' (euros per ton-kilometer), sourced from the European Commission's Handbook on the External Costs of Transport (2019); and case study data, including origin, destination, weekly tons transported, unitary road distance substitutable by rail, and the rail distance required for modal shift. The collected data underwent processing to calculate the total tonne-kilometers on the road that could be saved and those on rail that are needed. These values were then multiplied by the unitary cost, resulting in the total cost for each transportation mode and the computation of the total external cost variation from road to rail.

This quantitative estimation is based on 24 case studies conducted by 5 project partners. It is performed for three future scenarios depending on the type of train employed: electric cargo trains, diesel cargo trains and a combination of 50% electric and 50% diesel cargo trains. The comparison, between rail-based future scenarios and road-based scenario, considered the segment where trucks are replaced by trains, assuming equivalent costs for the first and last mile, both of which are managed by trucks in all scenarios.

Overall, the changes in external costs for future scenarios, observed across all case study groups and each factor of externality, consistently show negative values. This implies that transitioning to a rail-based transport system leads to a decrease in external costs related to transportation. This pattern remains consistent across the majority of case studies group.

The observed contrasting trend in a few cases, particularly concerning noise in the electric cargo trains scenario and air pollution in the diesel cargo trains scenario related to case studies in Varaždin county and Novara, can be primarily attributed to a significant increase in tonne-kilometers on rail compared to those on the road (+25% and +33% increases in the Varaždin and Novara case studies, respectively). This stands in contrast to the situation in other case studies within the group. Nevertheless, in these exceptional instances, the scenario involving a combination of 50% electric and 50% diesel trains results in cost savings in external expenditures.

Considering all externalities factors together, the total variations in external costs within each case study group highlight noteworthy savings when transitioning from road to rail as the primary mode of transportation. The greater the volume shifted to rail, the more significant the resulting financial savings, resulting in a decrease in external costs. This is exemplified by the TMIL and Kordis case studies, showcasing annual savings of approximately €6.7 million and €0.5 million, corresponding to 10,800 and 1,414 tons of goods, respectively.

When examining the three scenarios, the total decrease in external costs is more pronounced with the use of electric cargo trains than with diesel trains (€6.7 million and €5.9 million annually saved, respectively, as observed in the TMIL case studies).

However, in the scenario involving a combination of 50% electric and 50% diesel cargo trains, the total cost savings fall at an intermediate level between the two extreme scenarios (almost €5 million saved, as indicated by the TMIL case studies).

# F. Attached files

| Detailed data collected by University North | | | | | | Data elaborated | |
|---|---|---|---|---|---|---|---|
| **Good name** | Origin | Destination | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) | tn*km on road (per week) | tn*km on rail (per week) |
| **Food products** | Koprivnica | Port Rijeka | 1,200 | 260 | 320 | 312,000 | 384,000 |
| **Raw materials** | Koprivnica | Port Rijeka | 2,500 | 260 | 320 | 650,000 | 800,000 |
| **Pharmaceutical products** | Koprivnica | Port Rijeka | 1,200 | 260 | 320 | 312,000 | 384,000 |
| **Goods related to the wood industry** | Križevci | Port Koper | 2,500 | 309 | 289 | 772,500 | 722,500 |
| **Goods related to the metal industry** | Križevci | Port Koper | 2,500 | 309 | 289 | 772,500 | 722,500 |
| **Grain** | Đurđevac | Koprivnica - Port Rijeka | 1,000 | 271 | 348 | 271,000 | 348,000 |
| **Goods related to the wood industry** | Đurđevac | Koprivnica - Port Rijeka | 1,000 | 271 | 348 | 271,000 | 348,000 |
| **Al case studies of University North** | | | | | | **3,361,000** | **3,709,000** |

| Detailed data collected by Varaždin County | | | | | | Data elaborated | |
|---|---|---|---|---|---|---|---|
| **Good name** | Origin | Destination | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) | tn*km on road (per week) | tn*km on rail (per week) |
| **Metal products** | Ivanec | Rijeka | 500 | 226 | 385 | 113,000 | 192,500 |
| **Wood products** | Ivanec | Rijeka | 1,000 | 226 | 385 | 226,000 | 385,000 |
| **Stone** | Ivanec | Rijeka | 1,000 | 226 | 385 | 226,000 | 385,000 |
| **Containers** | Ivanec | Rijeka | 250 | 226 | 385 | 56,500 | 96,250 |
| **Containers** | Ivanec | Rijeka | 250 | 226 | 158 | 56,500 | 39,500 |
| **Grain** | Ludbreg | Split | 1,250 | 503 | 530 | 628,750 | 662,500 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Grain** | Ludbreg | Rijeka | 1,250 | 257 | 335 | 321,250 | 418,750 |
| **Wood industry goods** | Ludbreg | Split | 500 | 503 | 530 | 251,500 | 265,000 |
| **Wood industry goods** | Ludbreg | Rijeka | 500 | 257 | 335 | 128,500 | 167,500 |
| **Gelatin** | Ludbreg | Split | 125 | 503 | 530 | 62,875 | 66,250 |
| **Gelatin** | Ludbreg | Rijeka | 125 | 257 | 335 | 32,125 | 41,875 |
| **Gelatin** | Ludbreg | Koper | 125 | 311 | 295 | 38,875 | 36,875 |
| **Gelatin** | Ludbreg | Graz | 125 | 171 | 160 | 21,375 | 20,000 |
| **Plastic mass** | Ludbreg | Split | 125 | 503 | 530 | 62,875 | 66,250 |
| **Plastic mass** | Ludbreg | Rijeka | 125 | 257 | 335 | 32,125 | 41,875 |
| **Plastic mass** | Ludbreg | Koper | 125 | 311 | 295 | 38,875 | 36,875 |
| **Plastic mass** | Ludbreg | Graz | 125 | 171 | 160 | 21,375 | 20,000 |
| **Containers** | Varaždin | Rijeka | 1000 | 244 | 360 | 244,000 | 360,000 |
| **Containers** | Varaždin | Koper | 1000 | 290 | 295 | 290,000 | 295,000 |
| **Containers** | Varaždin | Graz | 500 | 141 | 138 | 70,500 | 69,000 |
| **Al case studies of Varaždin County** | | | | | | **2,923,000** | **3,666,000** |

| **Detailed data collected by Novara** | | | | | | **Data elaborated** | |
|---|---|---|---|---|---|---|---|
| **Good name** | Origin | Destination | Tons transported in a week (t) | Distance on road that can be saved for each trip (km) | Distance on rail that is needed for each trip (km) | tn*km on road (per week) | tn*km on rail (per week) |
| **Consumer goods (cosmetics)** | Novara district | Frosinone district | 250 | 700 | 716 | 175,000 | 179,000 |
| **Waste** | Alessandria district | Germany (Dresden) | 960 | 854 | 1,240 | 819,840 | 1,190,400 |
| **Stone (feldspar powder)** | VCO district | Sassuolo district | 1,000 | 200 | 230 | 200,000 | 230,000 |
| **Stone (marble slabs and blocks)** | VCO district | Genoa (Port of Prà) | 1,150 | 120 | 145 | 138,000 | 166,750 |
| **Al case studies of Novara** | | | | | | **1,332,840** | **1,766,150** |

# G. References

(1) Petr Kurenkov, Oksana Pokrovskaya, Mark Anastasov, Mikhail Sokolov and Alexander Bochkov, *Study of the current state of the transport infrastructure of road and rail transport of the Russian Federation*, IOP Conference Series Materials Science and Engineering, 2019, https://www.sciencedirect.com/science/article/abs/pii/S221053952200013X

(2) *Pros & Cons of Rail: Shipping Cost, Speed, Capacity and More*, Track Record, 2023, https://www.up.com/customers/track-record/tr082019-rail-pros-cons.htm

(3) *Road Transport vs Rail Transport – Head-to-head Comparison*, DHL Freight Connections, 2023, https://dhl-freight-connections.com/en/solutions/road-transport-vs-rail-transport-head-to-head-comparison/

(4) *Rail Infrastructure in Africa, Financing Policy Options*, African Development Bank, 2015, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Events/ATFforum/Rail_Infrastructure_in_Africa_-_Financing_Policy_Options_-_AfDB.pdf

(5) Lucia Rotaris, Stefano Tonelli, Luigi Capoani, *Combined transport: Cheaper and greener. A successful Italian case study*, Research in Transportation Business & Management, 2022, https://www.sciencedirect.com/science/article/abs/pii/S221053952200013X

(6) Marcin Wrótny and Janusz Bohatkiewicz, *Traffic Noise and Inhabitant Health—A Comparison of Road and Rail Noise*, Sustainability, 2021, https://www.mdpi.com/2071-1050/13/13/7340

(7) European Union, *Handbook on the external costs of transport*, 2019, https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1

(8) Matthew Terlich, *A Comparison of Diesel and Electric Locomotive Noise Emissions from Coal Terminal Rail Loop and Spur line*, 2013, https://documents.pub/document/a-comparison-of-diesel-and-electric-locomotive-noise-proceedings-of-acoustics.html?page=1