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Deliverable D 3.2

Case Studies Report

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Table of contents

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no. 826055 (TER4RAIL)

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1. Table of figures

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2. Executive Summary and Introduction

"Rail transport already plays a vital role in supporting Europe's society, developing its economy, and protecting its environment. It has the potential to contribute much more." With these words, ERRAC, the European Rail Research Advisory Council (https://errac.org), introduced its "2050 Vision" document. The present case studies report contributes to highlighting the above-mentioned potential, which is often not yet fully exploited. The report is part of the TER4RAIL project research. TER4RAIL (Transversal Explanatory Research Activities for Rail - www.ter4rail.eu) entails a CSA Coordination and Support Action to determine exploratory research activities among different actors that are beneficial for railways. Rail can concretely become the backbone of the transport system of the future. The success stories described in this document are just examples of the disruptive potential the rail sector has. The role of rail as a major driver in developing the strategic objective of smart, green and sustainable growth has been described by analysing three main "macro-areas". The first one is dedicated to the public transport sector. The cases studies of Vienna and Nantes have been analysed and extensively presented. The aim is to highlight both a capital city of approximately 1.9 million inhabitants and a medium sized city/area with 600.000 inhabitants. Vienna is a very interesting example of positive development of urban rail in Europe, with harmonic co-operation between both metro and Light Rail Transit (LRT). These two modes constitute the "engine" of the public transport in the city, accounting for 79.5% of the total ridership, 73.7% of the vehicles and 84.6% of the available seats. Numbers and statistics regarding the growth in network length, service expansion, investments in infrastructures, customer satisfaction are presented, highlighting their positive impact on the city and on the ridership. Currently, the public transport market share in Vienna is 38% and the number of annual Public Transport (PT) passes over the last 10 years has constantly increased (+133%) while the number of private vehicles' registrations remained stable. The transition towards the MaaS system, driven by digitalization, is also reported. Nantes Metropole, on the other hand, is the first French area that managed to reduce the market share of cars, due to a consistent and coordinated policy, continuously developing and encouraging the use of the LRT network since the tram reintroduction in 1985. Nantes was one of the first cities engaged in shared mobility and soft modes (such as walking and cycling), and it has a very effective Public Transport Authority (PTA) that covers all facets of mobility under the same umbrella. As a result of these efforts, the service was widely recognized as extremely accessible, fast, efficient and pleasant, and the ridership registered an increase of 54% over the last 10 years.

The second macro-area is dedicated to the High Speed Rail (HSR) expansion on the Madrid-Barcelona line in Spain, and the positive effects that this fast development has had on changing the "rules of the game", putting the rail system at the centre of the transport choices of millions of citizens and gaining increasingly high market share, especially in the competition with airlines (in 2012 HSR market share surpassed that of

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airlines for the first time, and has continued growing since). The Spanish case, hereby analysed can be also applied to other Countries, such as Italy, France and the BeNeLux region, where HSR became something similar to a "national (in some few cases cross-national) metro system" capable of moving millions of passengers in a few hours, bringing them to the heart of the cities. As an example, the total Paris-Barcelona travel time dropped from 12 hours in 1991 to about 6 nowadays. The HSR explosion is also analysed from the environmental point of view, highlighting the CO_2 emissions related to a Madrid-Barcelona trip by plane (92 kg/pax), car (74 kg) and train (13 kg), thus reaffirming the primary role the rail sector has in the fight against climate change.

The third macro-area is freight transport. In the first success story, the Marathon Train, the longest freight train in Europe (1,524m), is presented. The Marathon Train was the result of a European Commission co-funded project finished in 2012 and demonstrated in real operating conditions the benefits, in terms of capacity, time, cost-efficiency and energy saving, of a 1.5 km long freight train, with two radio-controlled locomotives (one in the front and one in the middle of the train). Two tests have been successively performed, on the 300km tracks between Lyon and Nimes, in France. As a result of the tests, the capacity increased by 50% while the operating costs decreased by 30%. An additional 10% energy saving was registered. Commercial speed was not affected by the length of the train. The M2O project, currently ongoing, is further exploiting the outcomes of the first project. The second freight story regards the TIGER project that can be considered the father of a modern way to organize the distribution of cargo in the main European ports. The project tested the concept of "Dry Port" in four European large port areas. Dry Ports will efficiently and effectively link the maritime flow to the overland modes, decreasing the movements inside the seaports through a rail link between the vessel and the Dry Port, located a short distance from the dock. This new distribution system, currently replicated in many ports, allows for a saving of 15-20% of operating costs, reduces the dwelling/transit time by more than one third and the movements inside the port, increasing the service performances by 85% while reducing congestion and accidents.

Please note that a shorter version of this report, with a summary of the success stories presented has been produced and is available on the project website www.ter4rail.eu.

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3. Abbreviations and acronyms

Abbreviation / Acronyms	Description
ATC	Automatic Train Control
AVE	Alta Velocidad Española
AVLO	Alta Velocidad Low cost
CER	Centre for European Railways
ERA	European Railway Agency
ETCS	European Train Control System
FAO	Fully Automated Operations
HSR	High Speed Railway
IM	Infrastructure Manager
M2O	Marathon2Operation
OSS	One Stop Shop
PTA	Public Transport Authority
PTO	Public Transport Operator
RU	Railway Undertaking
S2R JU	Shift2Rail Joint Undertaking
SPC	Single Point of Contact
STM	Specific Transmission Module
TEN-T	Trans European Network-Transport
TEU	Twenty foot Equivalent Unit
TSI	Technical Standards for Interoperability
WP	Work Package

4. Background

The present document constitutes the Deliverable D3.2 "Cases Studies Report" in the framework of the WP3, task 3.3 of TER4RAIL project S2R IPX-02-2018.

Please note that a "short version" of this document has been produced and shared by TER4RAIL project partners. It is available on TER4RAIL project website www.ter4rail.eu. It will also be disseminated by TER4RAIL project partners through multiple channels.

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5. Objective

The purpose of this report is to properly illustrate the strong role railways may have in the European society. For this purpose, a collection of case studies and success stories from Europe and beyond is developed in-depth, including a detailed examination of the following:

- Case(s) A - Two European metropolitan area(s) representing a high demand for public transport –rail transport included;
- Case(s) B - One European corridor area(s) representing high speed rail development and benefit for society and/or environment;
- Case(s) C – Two European rail freight success stories.

This analysis will include a collection of case studies and success stories regarding rail and its benefits to society aiming at evidencing:

- Case A – How can the rail public transport system (e.g. including tram, light rail and metro) become the backbone of a multimodal transport system in metropolitan areas?
- Case B – How can the rail mainlines (high speed lines) contribute to change the "rules of the game" in the transport sector and facilitate the smooth movement of millions of people?
- Case C – How can the railways contribute to the creation of a more efficient, reliable, safe and environment-friendly freight transport system in Europe?

This task results in a report, targeting the general European citizens with no specific rail background; it comprises an analysis of the role that rail transport may play in multimodal systems, thus offering a clear picture.

Success stories and valuable examples are produced and studied to constitute a model to be replicated all around Europe, fostering continuous learning from positive experiences. This Task is aligned with the WP4 guidelines, to properly contribute to the process of consensus building around rail as the backbone of European sustainable transport of the future and to the formulation of the right messages that will be sent to the citizens.

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6. European Metropolitan Area(s) success stories

6.1. Introduction

T wo European success stories have been selected and are presented in order to show how public transport, and in particular urban rail, can become the backbone of mobility in cities, promoting an easy, smooth, green and efficient way of moving millions of people every day. Vienna, a capital city in which about 2 million people live, and Nantes, a medium sized city with a strong public transport network are perfect examples of integration between collective transport (driven by metros and light rail) and private vehicles, delivering efficient and positively evaluated services to citizens. These two examples are presented and analysed in the following pages with numbers, graphs and charts provided by the public transport operators and authorities. Considerations on current expansion plans and future challenges and trends are also provided.

6.2. Vienna

Vienna is the Austrian capital and most densely populated city, with 1.9 million inhabitants in 415 square km (about 4,578 inhabitants per square km). The urbanisation trend is increasing in recent years, and the city will reach 2.2 million inhabitants in 2025. Urbanisation means "new mobility needs", which in order to be fully satisfied, require strong efforts, in terms of organisation and planning of services. Wiener Linien is the public transport operator (PTO) in Vienna. It is the largest PTO in Austria, employing more than 8,600 people, and operates 5 metro lines, 129 bus lines and 28 tram lines, with a total of 1,253, rail vehicles, 447 buses and 269 trailers per day, serving approximately 965 million passengers per year on its network. Vienna has the most extensive public transport network in Austria, at 263 km (670.3 km of track). In terms of fleet, 1,253 railcars and tramcars serve 2.65 million citizens every day (768 railcars, 485 tramcars), running for 213,000 km each day (equivalent to circling the world 5 times). Metro and LRT are the main "engines" of the Vienna public transport system. Combined, they account for 79.5% of the total ridership, 73.7% of the vehicles and 84.6% of the available seats. Total metro network length is 87.5 km (253.2 km of track). Average distance between stations is 761.9 m and average line length is 16.6 km. Ridership in 2019 was 463.1 million passengers. The first metro line was built in Vienna in 1969. With regards to LRT network, total length is 175.6 km (track length 417.1 km). Average line length is 7.9 km and average distance between stops is 396.2 m. Ridership in 2019 was 305.5 million passengers.

The graph here below shows the evolution of the passenger who decided to use the public transport in Vienna in the last 19 years (update 2019). In this period, an impressive +33% in ridership was experienced, from 724 million (yearly) passengers in 2000 to 961 million passengers in 2019. In the same amount of time, the total population in Vienna

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increased by 22% (from 1.6 to 1.9 million inhabitants)[1].

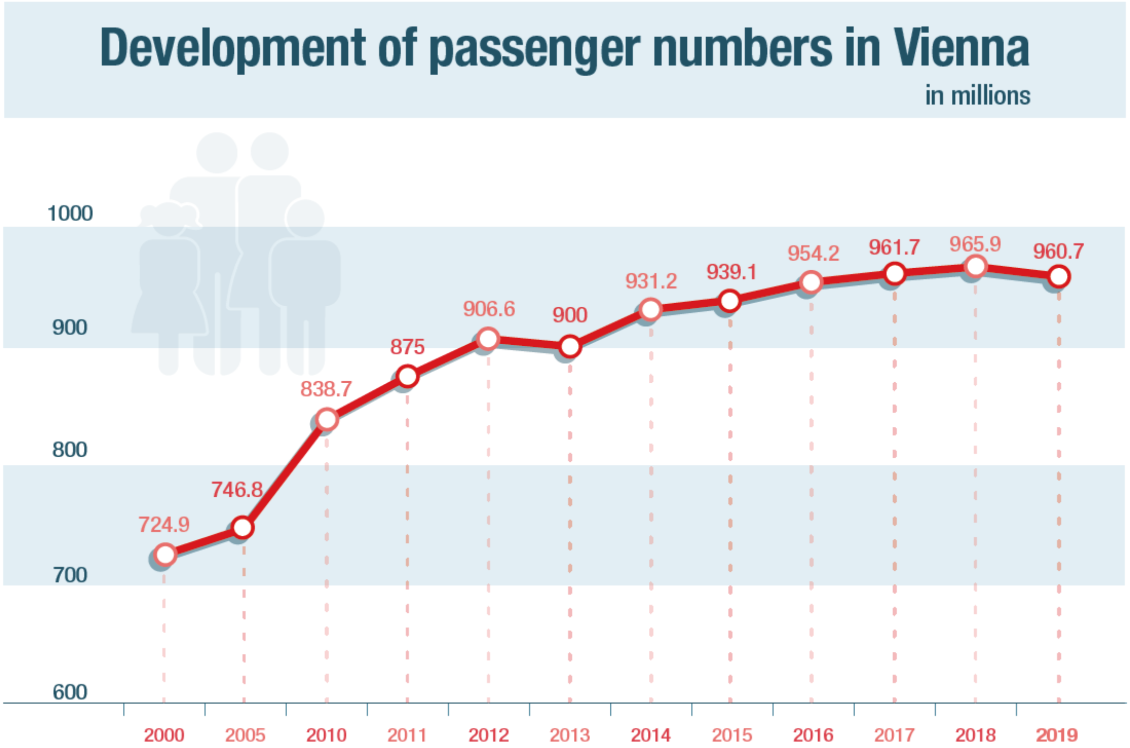

Figure 1: Development of passenger numbers in Vienna, 2000-2019 – Source: Wiener Linien

The success of the public transport in Vienna, is also measurable considering the total number of annual passes sold to the citizens. The situation of the last decade is represented in the figure below. In the period 2010-2019, there was an increase in the number of annual passes of +147%. 852,000 people in Vienna use every day an annual pass. In 2010 there were only 355,000. This increase was particularly driven by full fare passes, since the number of pensioner passes registered a minor increase. Annual passes constitute the 45% of the total tickets sold in Vienna in 2019, the biggest share. They are followed by youth ticket semester passes (17.8%), tickets sold at ticket desks (11.3%), monthly passes (10.2%), short term network tickets (7.8%), and weekly passes (3.8%).

[1] https://www.wien.gv.at/statistik/pdf/pop-proj-2018-sum.pdf

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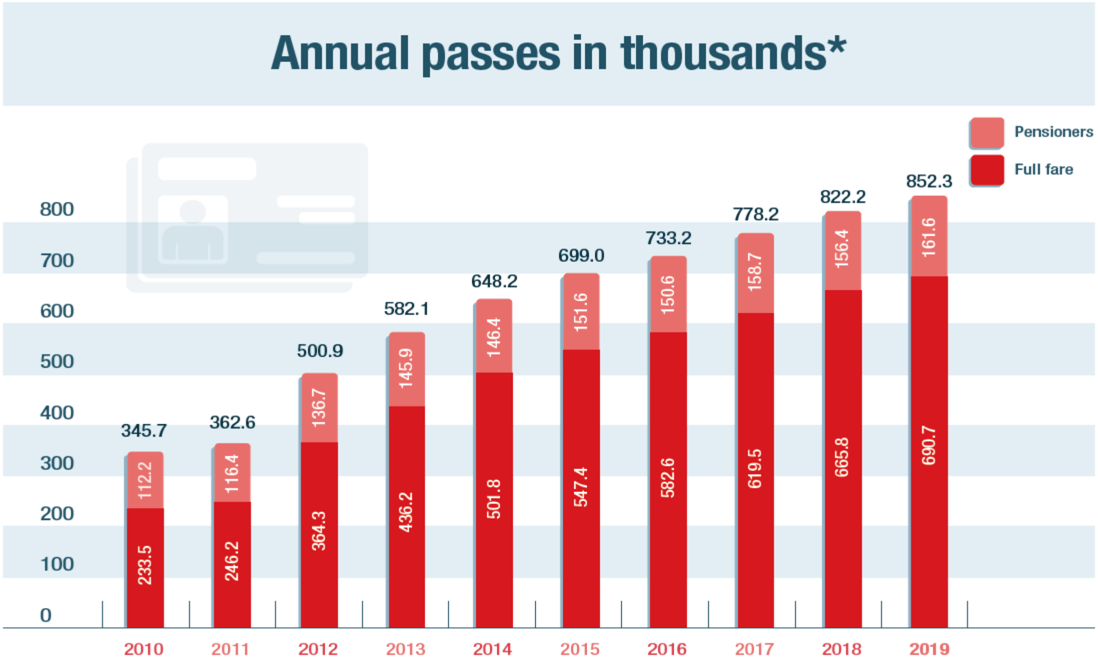

Figure 2: Annual passes (in thousands), 2010-2019 – Source: Wiener Linien

To measure the success of the public transport driven by urban rail (particularly metros) in Vienna, it is also interesting to evaluate the evolution of annual passes compared to the car usage (measured considering the total number of registered cars circulating in the city). This number, in the decade 2008-2019, have just witnessed a minor increase, ranging from 650 to 700,000 per year. The annual public transport passes sold, as shown in the previous picture, registered a massive increase. Citizens of Vienna clearly appreciated the service provided by the local PTO, and used it largely to move around the city for work or leisure purposes.

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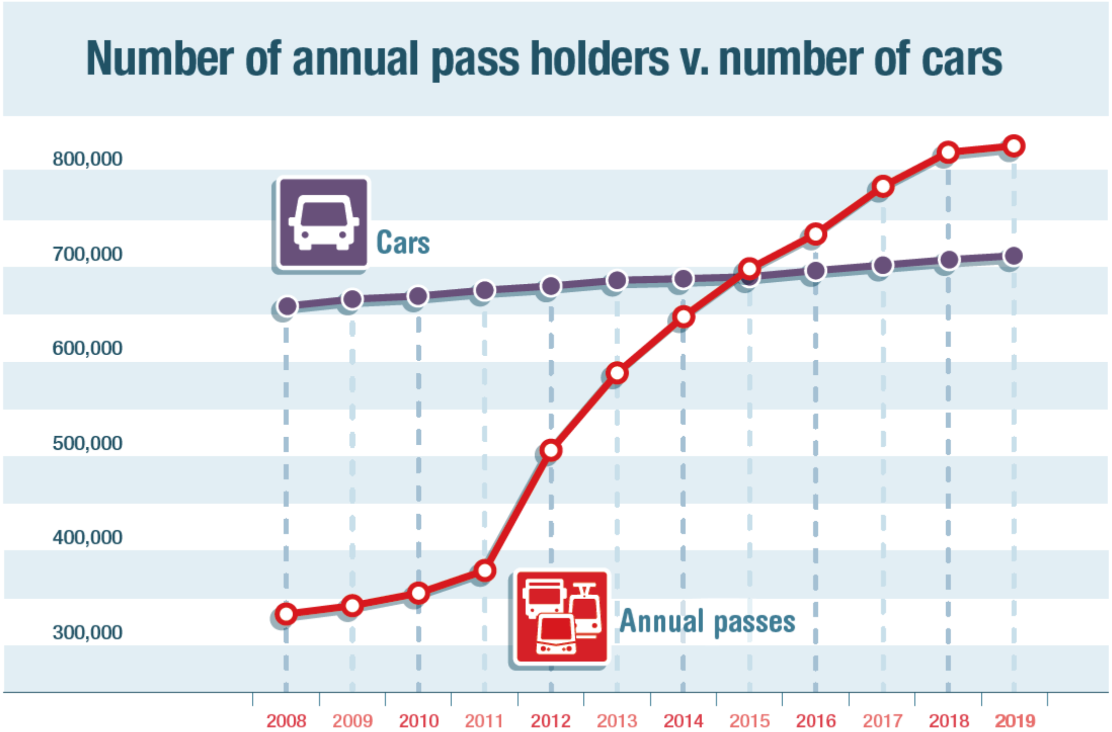

Figure 3: Annual PT pass holders vs registered cars circulating in Vienna, 2008-2019 – Source: Wiener Linien

The analysis of the modal split in Vienna, evaluated in different years, confirms the high level of customer satisfaction towards the public transport. Comparing 1993 to 2018, habits and behaviours of the Austrians have changed a lot: according to the numbers, they have decided to leave their cars behind (-11%) and this decrease was compensated by a more intense utilisation of public transport (+9%) and soft modes, like cycling (+4%). Analysing the public transport market share between 1993 and 2018 (but the same share is confirmed also in 2019), it is visible its "explosion", particularly boosted by the years 2010-2012, in which this share increased by 1/3. In general, in the considered period, public transport market share passed from 29% to 38%. Despite this is already a very positive evolution, in Vienna there is a huge potential to improve these numbers and make the car market share fall to 20%, leaving 80% to public transport combined with cycling and walking. This is a target set by the local PTO for 2025.

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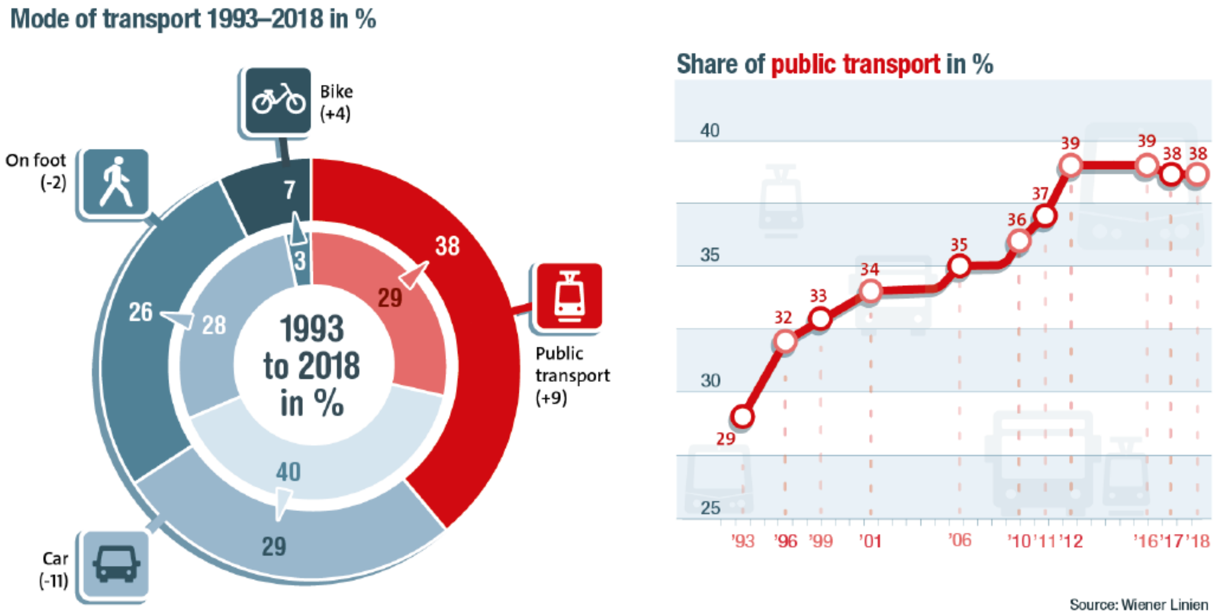

Figure 4: Mode of transport 1993-2018 in % and evolution of public transport share, 1993-2018 – Source: Wiener Linien

The massive increase of public transport utilisation starting in particular from the year 2010 is also understandable analysing the investments that Wiener Linien (supported by the City of Vienna and by the Federal Government) made in the last decade. The year 2010 was a year of important investments: 411 million euros, 62% of which was for underground infrastructure. Since 2010, an average of 335 million euros per year have been invested in improvement of the service and construction/extension of lines. In 2010, the 4th expansion phase of Vienna underground started. Line U2 was extended (4.3 km) in 2013 and additional 4.5 km of U1 line were opened in 2017. Construction/extension of U2 and U5 are currently ongoing, with works planned on tracks, stations, interchanges and improvement of accessibility and smooth connections with other modes. With regards to metro and light rail, 8,000 km of track lines are currently being modernised in the city. The 5th expansion phase of Vienna underground will start in 2022. By this date, U1, U2 and U5 will be further extended (+6.6 km) and fully automated operations will be implemented and operating on the new U5 line. Particularly important is the U2xU5 project, a modern, smooth and easily accessible junction between lines U2 and U5. The project was presented in 2014 and will be completed starting from 2025-2027. FAO will be fully implemented on the U5. Automation in metros ensures more safety, also thanks to the platform screen doors that only open once the train has pulled into the station. Delays caused by items on the tracks will also be eliminated. FAO also ensures flexibility, due to a better adaptation of schedules to peak times, and optimisation of speed and frequency according to the demand. It finally means savings and personalisation of service, since employees will be available on trains or in stations to help and support passengers. A new generation of

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vehicles will be operated in Vienna in the next years, semi-automated on U1 and U4, and fully automated on U5.

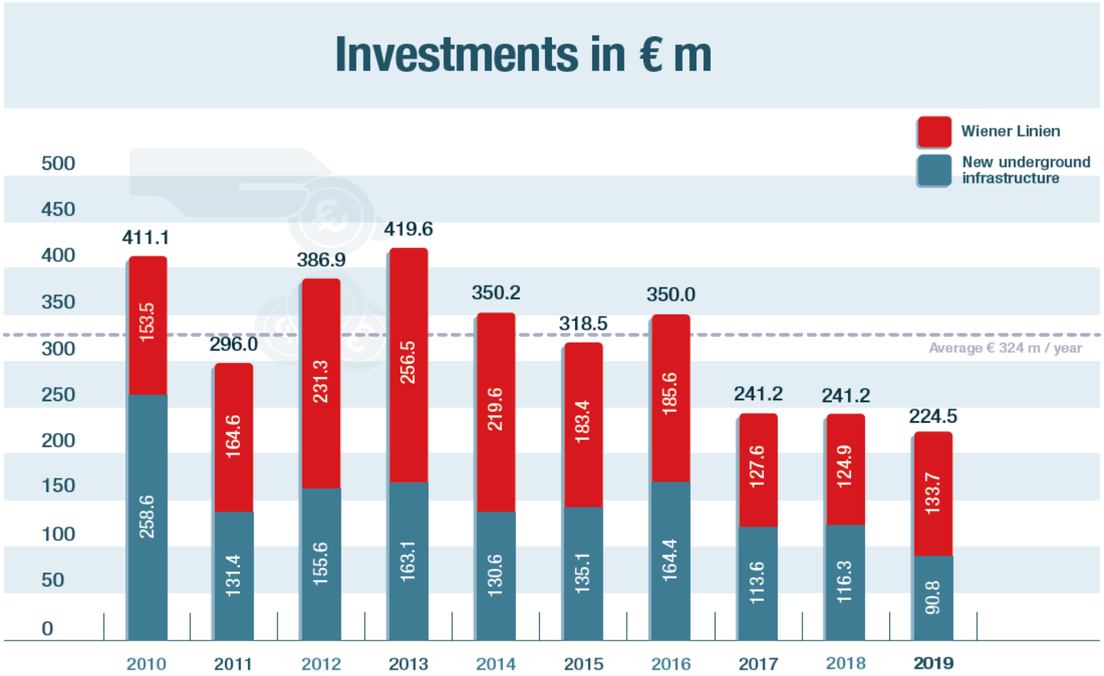

Figure 5: Investments in public transport (m euros), 2010-2019 – Source: Wiener Linien

Together with the investments, the fare revenues have also registered a strong increase in the same period, passing from the 411.4 million in 2010 to the 580.5 million euros in 2019 (a very slight decrease compared to 2018, due to the increase in yearly passes, which are cheaper than monthly passes).

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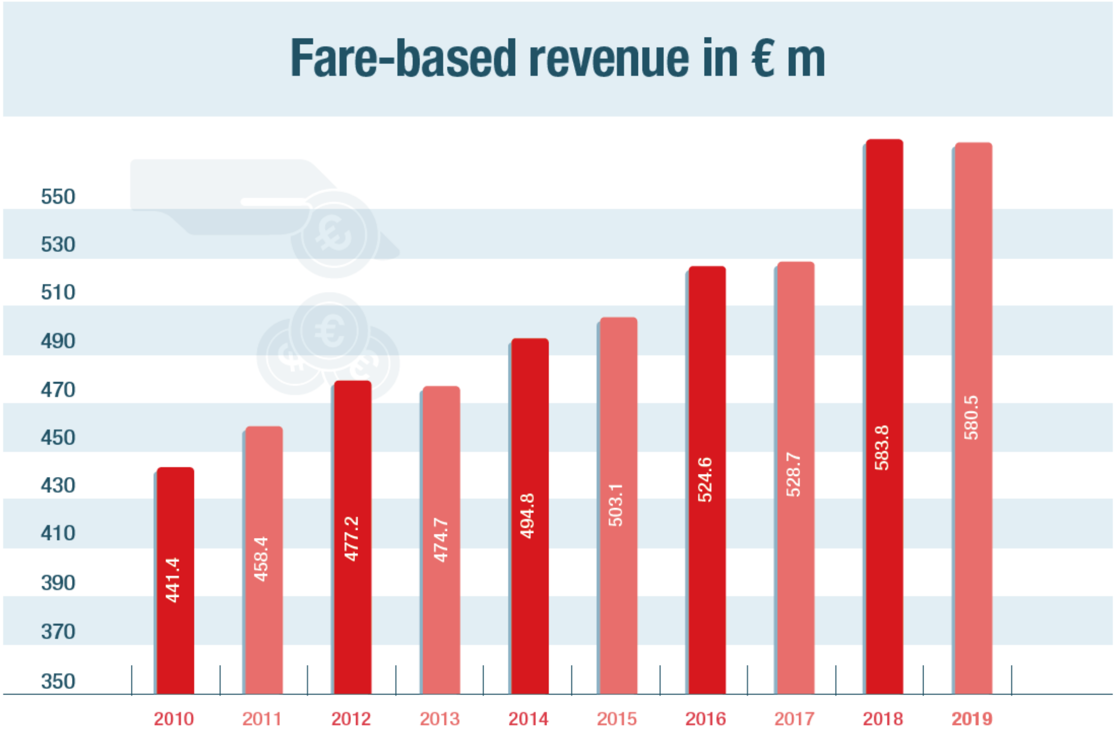

Figure 6: Fare-based revenues (in m euros), 2010-2019 – Source: Wiener Linien

Vienna citizens love public transport. Data collected from the annual surveys performed by Wiener Linien show that the levels of satisfaction of users increased significantly in the last decade. Passengers considering "very good" the service offered by the PTO were the 30% in 2010 and 54% in 2019. The percentage of people rating the service "bad" or "very bad" dropped from 5% to 1% over the same period. The service is appreciated by women slightly more than men. The quality of service, according to the surveys, is widely appreciated in all age ranges, particularly the 16-35 band. Only 5% of people in the age range 60-70 rated the services as "bad" or "relatively bad". In general, the perception of the service is extremely good both for men and women and practically in every age range, and this can better explain the reasons behind the very positive numbers (in terms of modal split, network utilization and annual passes) previously highlighted. Particularly appreciated by users is the accessibility of stations and LRT stops. All 109 metro stations are barrier-free and 95% of tram/bus stop are barrier-free. The citizens are involved in several phases of the decision making process. In fact, the so called ombudspersons act as a link between the construction site and the residents. The ombudspersons are always ready to listen to the concerns of the local residents, providing first-hand information and working to find solutions together. Each construction phase has its own contact persons who can be reached by local residents either at the construction office or by telephone. This involvement is extremely important since it increases the degree of acceptance of the possible disruptions due to long lasting works/building sites by the citizenship, and increases the commitment of

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the citizens together with their feeling to be active part of the city evolution.

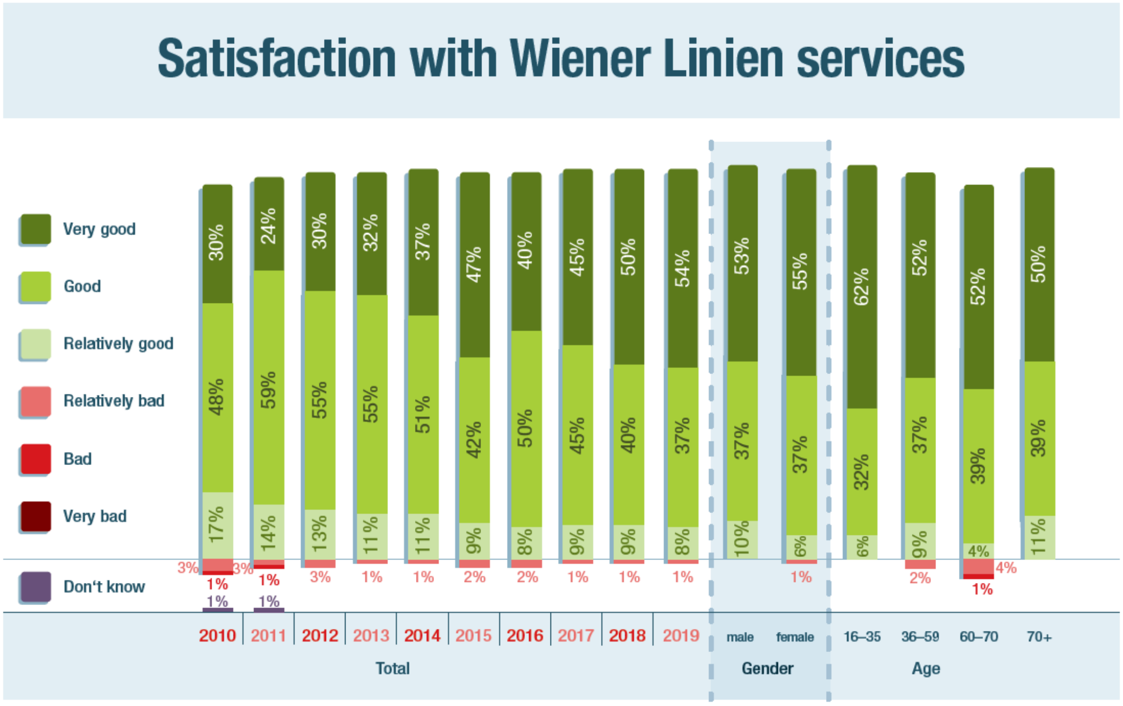

Figure 7: Satisfaction with Wiener Linien services, 2010-2019 – Source: Wiener Linien

As said at the beginning of this success story, the population of the Austrian capital is expected to grow in the coming years. In order to cope with this expected increase in the mobility needs of citizens and in order to keep a high level of user satisfaction, the public bodies and the local PTO are working together in order to prepare and keep offering a highly satisfactory service to the passengers. In this regard, new construction/extension/modernisation projects have been already discussed. One of the most important targets of Wiener Linien for the future is to increase e-mobility. The share of e-mobility in Vienna is currently around 50%, using e-buses and rail vehicles capable of saving 1,500 kg of CO_2 (combined, on average) annually. The aim is to increase this percentage by 2030. New interchanges will be built in the next future, in order to improve the service and the connections between lines and between urban and suburban/mainline networks. New services means not only new travel routes, less journey time, smoother and easier connections, but also new employees. The U2xU5 project by itself created 16,000 new jobs.

Finally, presenting the future plans, it is important to mention the progresses towards the full implementation of MaaS – Mobility as a Service, in Vienna. Cities face two major trends nowadays: urbanisation and a change in the mobility usage behaviour. Especially younger people are highly flexible in their modal choice. About 50% of the 14 to 29 year-olds prefer a joint use of mode instead of owning them. Digital technologies make it easy to access different services. However, there is one major problem: all providers use their

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own systems, which are often incompatible with each other. That makes it nearly impossible for the people, to keep track on all mobility services in cities. Wiener Linien and Upstream Mobility (a technical enabler) have recognized this ambiguity and developed WienMobil – an easy to use multimodal app, which enables users to access the broad variety of mobility services in Vienna. WienMobil combines public transport with taxis, parking, rental cars, car sharing and bike sharing. Users are able to find the best combination of modes for their individual journey. It is also possible to buy tickets for public transport and to book car sharing cars directly in the app. Users can organise everything in one app so there is no need to switch between the apps of different providers. It is a pay-as-you-go version of MaaS, not yet containing a flat-rate tariff. WienMobil always calculates routes based on all potential modes of transport. Booking a journey relying on various modes of transport can be taken care of conveniently using the app. Billing with the relevant mobility partners is executed directly with these partners on the base of the payment method stored in the app. Various filters help to quickly identify the best route for the user's specific requirements and preferences. The environmental impact of a selected route is also displayed.

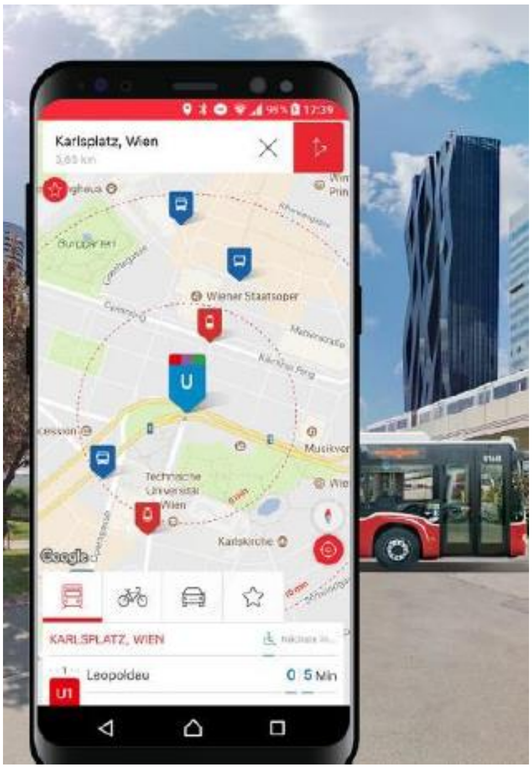

Figure 8: WienMobility app screenshot – Source: Wiener Linien

Public ownership guarantees the coherence with urban policy and the barrier-free and non-discriminating affordable access to mobility for everyone.

As Wiener Linien provides the public transport backbone to the city, the WienMobil app provides the citizens of Vienna with a multimodal planning and booking tool. To offer

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not only a digital but also a physical platform was the natural next step. The first WienMobil station was opened in 2018; five more were opened in 2019. These stations offer a physical platform for the additional mobility needs that cannot or do not want to be covered by public transport: E-bikes, cargo bikes, bike garages, E-charging for cars, hybrid rental cars.

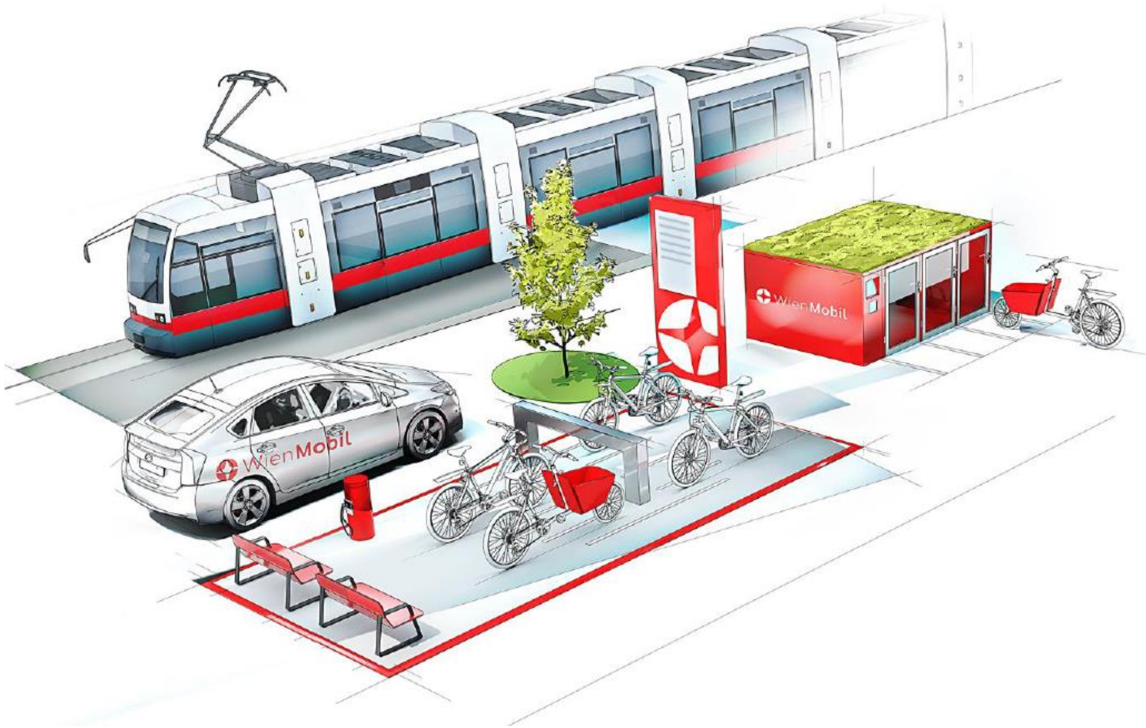

Figure 9: Example of WienMobility station – Source: Wiener Linien

What are the next steps for the deployment of MaaS in Vienna? Mobility flat rates for WienMobil are currently under development, together with the integration with other partners to the app for improving cooperation and enlarging the service to be delivered to the user. These developments will enrich the mobility offer currently deployed in the city, contributing to serve efficiently the needs of a growing public transport oriented population.

6.3 Nantes

Nantes Metropole is an intercommunal structure of 24 communes, created in 2001 having as its main urban agglomeration the city of Nantes. It is located in the Loire-Atlantique department, in the Pays de la Loire region, western France. The Greater Nantes administration is actively involved in 10 fields of competence: urban planning, transport & mobility, public space & roads, environment, water, economy, university & research, international, social development, waste management and energy. The total

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population of the entire area is 677,766 inhabitants[2] (2020), with a density of about 1,235 inhabitants per square km[3]. The city of Nantes is the focal point of a bigger area of 114 municipalities, not only densely populated but also in constant demographic expansion. The mobility needs of people living in the area are therefore increasing, particularly since the beginning of the new millennium. It is important to mention that the total number of jobs in both the Nantes Metropole and in the conurbation ring around Nantes Metropole area registered a tremendous increase starting from the year 1999, growing on average by 32% until 2011 and increasing ever since. In parallel, the average composition of households diminished on average by 8.5% (but the population grew). These numbers help us to understand the mobility challenges the area had to face in order to satisfy the mobility needs of a growing and differently organized population, both in the urban conglomeration and in the rural outskirts.

In order to face these challenges and to plan the organization of capacity properly in order to respond promptly to these new and evolving mobility needs, Nantes Metropole decided to focus on a light rail network, and in particular trams as the preferred engine of the public transport system. The former 110 km-long system, strongly damaged during the World War II and subsequently closed in 1958, was re-opened in 1985, after a forward looking decision (taken by the PTA) to abandon the idea of building a high-capacity motorway node in the city centre. Instead of building a new road infrastructure and to avoid all the negative consequences (in terms of pollution, noise, accidents, emissions and congestion), the political choice was focused on a ring-road to be built around the city, complemented by an efficient public transport network inside it. The first tram line was completed in 1985 and was called "Tram 1". The reasons why the urban rail was chosen as preferred mode are multiple. First of all, a bus network had limited capacity compared to trams that are capable to efficiently carry a higher number of passengers. Moreover, the trams were preferred to subways also for aesthetic reasons. In fact, they allow to discover the city in a different way and they constitute themselves integral part of the city landscape, contributing to the creation of a dynamic urban environment. The tram lines also constitute a physical and tangible link between different neighbourhoods, contributing to create a sense of unity among citizens. Before the opening of the first line, a private-public local company dedicated to the project was created. Its name was SEMITAN, which is still operating the lines. The whole project was funded by the local government and partially by the French State. The tram of Nantes was the first modern tram in France, and was planned not only by SEMITAN and the local/national authorities but even the citizens and users participated. This involvement has been one of the keys for the success of the project, as the engagement of the local population contributed in a relevant way to understanding their needs and priorities.

Since the Tram 1 line inauguration in 1985, other lines were built and extended through

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[2] UN World Urbanization Prospects.

[3] Institut National de la Statistique et des Etudes Economiques www.insee.fr

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the years, reaching the current situation of 43 km of tramway lines (3 lines with average section of 433m, 91 stations in total), with expansion projects planned for the future. In parallel, park & ride facilities have been planned and built around the key nodes of the network, in order to encourage people to leave their cars in the outskirts and move in the city using the public transport system (21 park & ride points, for a total of 6,000 spaces). Tan (tramway, busway, bus, navibus) ticket holders have been given free access to park & ride facilities and this contributed to the great success of the rail-oriented public transport in Nantes, accelerating the transition from private vehicle to mass transit as preferred mode. Frequency and headways have been progressively adjusted in order to meet the increasing demand. Communication and information system have also been improved in order to keep users constantly informed about the status of their rides. This resulted in an incredible success and tram is currently the preferred mode for about 300,000 people every day. 5 regional and suburban rail lines connect the city to the region and the national network, allowing seamless transportation of people leaving outside the Nantes urban conglomeration. The mobility offer in the area is completed by a system of navibus and ferries, 7 km of busways and chronobuses, 45 lines of buses and a line of Proxitan, an on demand mobility system.

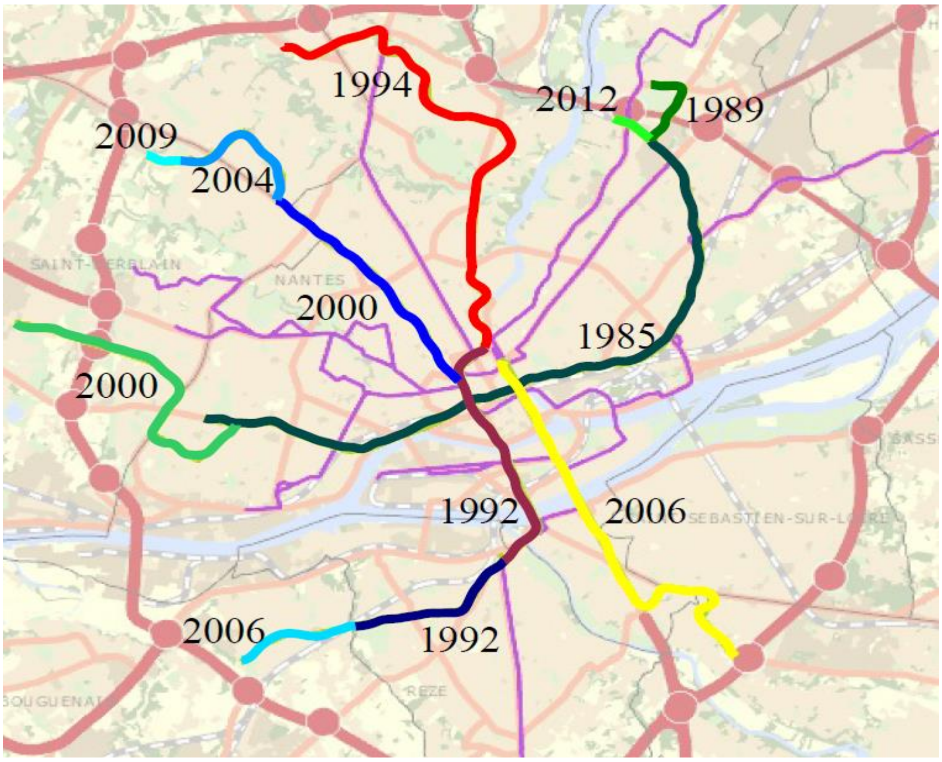

Figure 10: The steps from 1985 to actual network - Source: Nantes Metropole

From 1985, the development of urban rail in the city of Nantes contributed in a significant way to reshape the public spaces and to make the whole city much more liveable and also more attractive from the touristic point of view. In fact, starting from the nineties, the city started to experience an unprecedented increase in the number of

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tourists and visitors. This increase is also due to the Paris-Le Mans section of the new West High Speed Line which started operations in 1989, cutting travel time Paris-Nantes from 3 to 2 hours. Furthermore, the drastic reduction of travel time between Paris and Nates led the French State to relocate some services from Paris area to Nantes. New businesses were also attracted by the Nantes area quality of life and the shorter travel time from Paris.

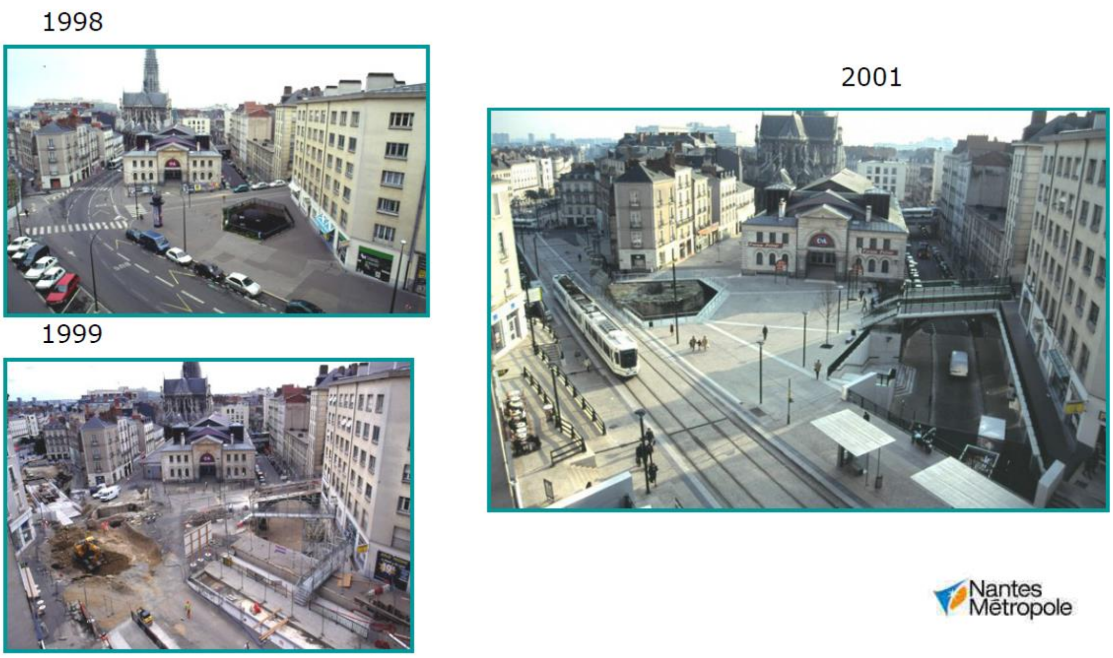

Figure 11: Pont Savetout in 1998, 1999 and 2001 - Source: Nantes Metropole.

Due to the intense efforts in terms of forward looking planning and investments made by the authorities and all the entities involved in the design, construction and operation of light rail lines in Nantes Metropole, the city and its outskirts could benefit of higher life quality standards, improved connections between areas, a better organization of spaces, including more green areas and pedestrian zones, and lower levels of pollution, GHG emissions and noise. In terms of GHG emissions per capita, there was an impressive 20% drop between 2003 and 2016. In terms of reduction of energy consumption, there was a 13% drop between 2003 and 2016. In 2013, Nantes has been the European Green Capital. Nantes has always been a proactive city in terms of renewable energy, with nearly 820 GWh produced by non-fossil energy sources (2018). The photovoltaic solar roof of the Pierre Quinon Stadium is one of the largest installations in Western France. The heating network, Centre Loire, after a promising start, will be widely extended (14,500 connected housing units, 70% renewable). The energy refurbishment of buildings has been given a new boost with the launch of the national "Living Better" programme. The achievement of its ambitions has earned Nantes particular recognition from European experts for its climate and energy policy. Nantes Metropole obtained the

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Cit'ergie label in 2015 (French equivalent of the European Energy Award) awarded by ADEME following an independent and rigorous audit of its Local Climate, Air and Energy Plan and associated public policies, a guarantee of the continuation of its efforts since its nomination as Green Capital[4].

In the recently adopted Roadmap for Energy Transition and Urban Travel Plan (2018), new actions to further develop sustainable mobility are planned:

- €1 billion invested by 2030 to support new uses and to develop a culture of intermodality (new tram lines and chronobus routes, e-busway, end of diesel buses, new river shuttles, car-sharing and shared vehicles, provision of electric bicycles, new cycle paths and construction of secure bicycle parking facilities such as the new SNCF station with 3,000 bicycle spaces, etc.);
- Urban logistics issues, particularly those related to freight transport, are likely to become central; it is a question of taking structuring measures to optimise as much as possible the "last mile" covered;
- The use of shared cars, bicycles and walking in the city centre will be encouraged by the systematic rollout of 30 km/h roads in the city centre, the creation of new cycle lanes, the establishment of a digital car-sharing platform with Breton and Loire communities, "car-sharing lines" and the testing of lanes reserved for car-poolers. The production of a master plan by 2030 will be launched, making it possible to define, in a prospective manner, a logic of continuous routes that the bicycle network can serve. The notion of "close metropolitan area" is also at the heart of Nantes Metropole's sustainable mobility project. The aim is to develop the diversity of urban functions within neighbourhoods, to increase the density of jobs, shops and housing. This will shorten the distance of travel, encourage alternative modes of travel and reduce fossil fuel consumption. This involves strengthening local services, developing teleworking with the creation of co-working spaces, third party sites and optimising the "last mile". The development of clean vehicle fleets (electric or natural gas) will be stepped up, both for public transport and for the fleet of Nantes Metropole and private urban service operators. To this end, power terminals continue to be rolled out in the car parks managed by Nantes Metropole. Nantes is contributing to the experimental development of hydrogen for mobility. It involves the installation of a hydrogen fuel production and distribution station in Saint-Herblain in the end of 2018 with the objective to encourage new public and private users to equip themselves

[4] www.ec.europa.eu

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with electric vehicles with range extenders, thanks to a hydrogen-powered fuel cells[5].

Citizens could live the public spaces in a completely different way, benefiting from all the positive externalities brought by an improved mobility, capable of promptly adapt to their needs. They also discovered not only the efficiency of trams in connecting easily different areas, but also the pleasure of using soft modes such as walking and cycling in order to reach the public transport stations and nodes. In this way, Nantes has been the first French city that managed to reduce the market share (modal split) of cars due to a consistent and coordinated policy carried out by the local authorities and the PTA, who continuously developed the LRT network since the tram reintroduction in 1985 and redesigned spaces in order to reduce parking areas providing a valuable alternative to private cars. The ambitious target of Nantes Metropole is to reach 72% of trips using alternative (to private cars) modes by 2030. Additionally, it should also be noted that the development of an efficient public transport network, driven by tramways, also impacted the real estate market contributing to make certain areas of the city much more attractive also under this point of view. Examples of the impressive impact the development of LRT systems had on the city are represented in the pictures "before and after" shown in these pages. Nantes was in 2019 the fifth most-expensive city for second-hand flats after Paris, Bordeaux, Nice and Lyon, according to Notaires de France. In particular, the price per square meter increased by approximately 10% between 2018 and 2020 and it will keep growing according to the current trends (affected by the development plans the city made in the past and will make in the future in order to become a "green" capital with an extremely high quality of life)[6].

[5] www.ec.europa.eu

[6] Notaires de France https://www.notaires.fr/fr

Figure 12: Place des Lauriers in 1998 and 2001 - Source: Nantes Metropole.

Figure 13: Place du Château de Rezé in 1988 and 1997 – Source : Nantes Metropole.

The Nantes tram network is used every year by 71 million passengers. Nantes is one of the European cities with the highest number of public transport trip per inhabitant (210). The network, operated by SEMITAN, has known a great success since its opening, as already discussed. But this success increased in the first 15 years of the new millennium, when the ridership grew by 54.6% (compared to 2001) and the total length grew by

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26.5%. And the growth of these numbers is continuing, considering the latest figures.

In order to keep offering to the citizens and the tourists the same levels of service quality, a particular attention is dedicated by the public transport authority to the constant maintenance and renewal of the rail infrastructure and the fleet, in order to minimize the risks of derailment, people falling and problems to the operations (1 minute lost = 2 more vehicles for the same capacity). Safety is also a priority, and for this reason vehicles are equipped with several security cameras.

New challenges are ahead, for the Nantes PTA and PTO in order to keep the service efficient meeting the increasing and evolving demand needs. First of all, it is important to improve the quality of the service, investing in new vehicles (energy efficient) with a longer average life and higher standards of safety. Infrastructure is key, and for this reason renewal and maintenance of tracks and stations is performed regularly. Communication to the customers is also an aspect particularly relevant for the PTA and PTO that developed systems capable of giving to the passenger real time information both at the station and via digital tools. If all these aspects are tackled promptly and efficiently, Nantes can keep recording the extraordinary results experienced since the re-opening of the tram lines in 1985. As a particularly interesting indicator of this exceptional success, it is important to mention that, according to Nantes Metropole's reports, in 1983 only 50% of residents supported the tramway. This percentage raised to 93% in 1995. Today. The tramway is considered the pride of the city, a true reference and a sort of icon. The residents love the LRT system and consider this to be "pleasant, fast, qualitative, functional and safe". It is an integral part of the city's heritage. Particularly appreciated, according to the figures, are the easy boarding/accessibility (even for PRM), the punctuality, the reliability and the comfort during the ride.

7. European High-speed success story

7.1. Introduction

High-speed services in Spain have completed 25 years in operation (1992-2017) avoiding during this time the emission of 13 million tons of CO_2. For example, lines such as Madrid-Valladolid or Madrid-Malaga have transported a large number of passengers and have avoided the emission of 200,000 and 800,000 tons of CO_2. There is one line to highlight, the Madrid-Barcelona line, since it is the one with the highest number of passengers in the Spanish High-Speed system, and has also very high saving rates in terms of CO_2 emissions and energy consumption: 4.2 million tonnes of CO_2 emissions have been avoided and energy savings of 19,000 GW/h were reached, equivalent to what is consumed by the population of the cities of Madrid and Barcelona in a year.

This document presents the evolution of the railway services between Madrid and Barcelona, going through the history, its infrastructure and services, the evolution of the number of passengers becoming the preferred mean of transport in this route, and its

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impact in the environment.

7.2. A walkthrough geography and history

The distance between Madrid and Barcelona, the biggest cities in Spain, has always conditioned transportation and travel times. Starting from Madrid, the most common route of cavalry, carriages and walkers since the 17th century headed northeast following the valley of the Henares River towards Guadalajara and Sigüenza. It crossed Ministra Mountains to reach the vicinity of Medinaceli, and Arcos de Jalón, and continued through the valley of the Henares River towards Calatayud and the Ebro River, reaching Zaragoza. At this point the route goes east, through Los Monegros desert and up to Lérida, where it heads slightly southeast to reach Camp de Tarragona and, from there, along the coast, finally reaching Barcelona.

Curiously, this is not the route followed by the Royal Diligence Company when it established a service between Barcelona and Madrid. They followed the route from Barcelona to Valencia along the coast and from there, turned west towards Madrid. With the opening of the first railway line in the peninsula, between Barcelona and Mataró (1848), the importance of communicating Madrid and Barcelona by this new mean of transport was soon acknowledged.

The Compañía de los Ferrocarriles de Madrid a Zaragoza y Alicante (MZA) was the first to start in 1857 the construction of a railway line between Madrid and Zaragoza following the natural route to the Ebro valley (through Guadalajara and Calatayud).

This line was built fast, except for the mountainous area that divides the waters between the central plateau and the Ebro River. Finally, in 1865 the traffic between Madrid and Zaragoza was completely opened.

However, the objective was to reach Barcelona and be an alternative to its competitor, Compañía del Norte, which had already built the line from Zaragoza to Barcelona going through Lleida and Manresa. Using this connection, MZA inaugurates a direct night train service between Madrid and Barcelona, paying a fee for the use of the infrastructure to the Compañía del Norte.

Finally, MZA managed to have its own connection from Zaragoza to Barcelona by merging with the Railway Company Compañía del Ferrocarril de Barcelona a Francia, which had built an alternative connection between both cities located south of the previous one, passing through Caspe, Mora la Nueva and Tarragona.

From there, with the evolution of technology and the increase of speed, the travel time from Madrid to Barcelona began to decrease, reaching less than 12 hours in the 1930s.

However, the Civil War truncated any improvement. During the process of infrastructure and rolling stock rebuilding, the duration of the trip increased to 15 hours.

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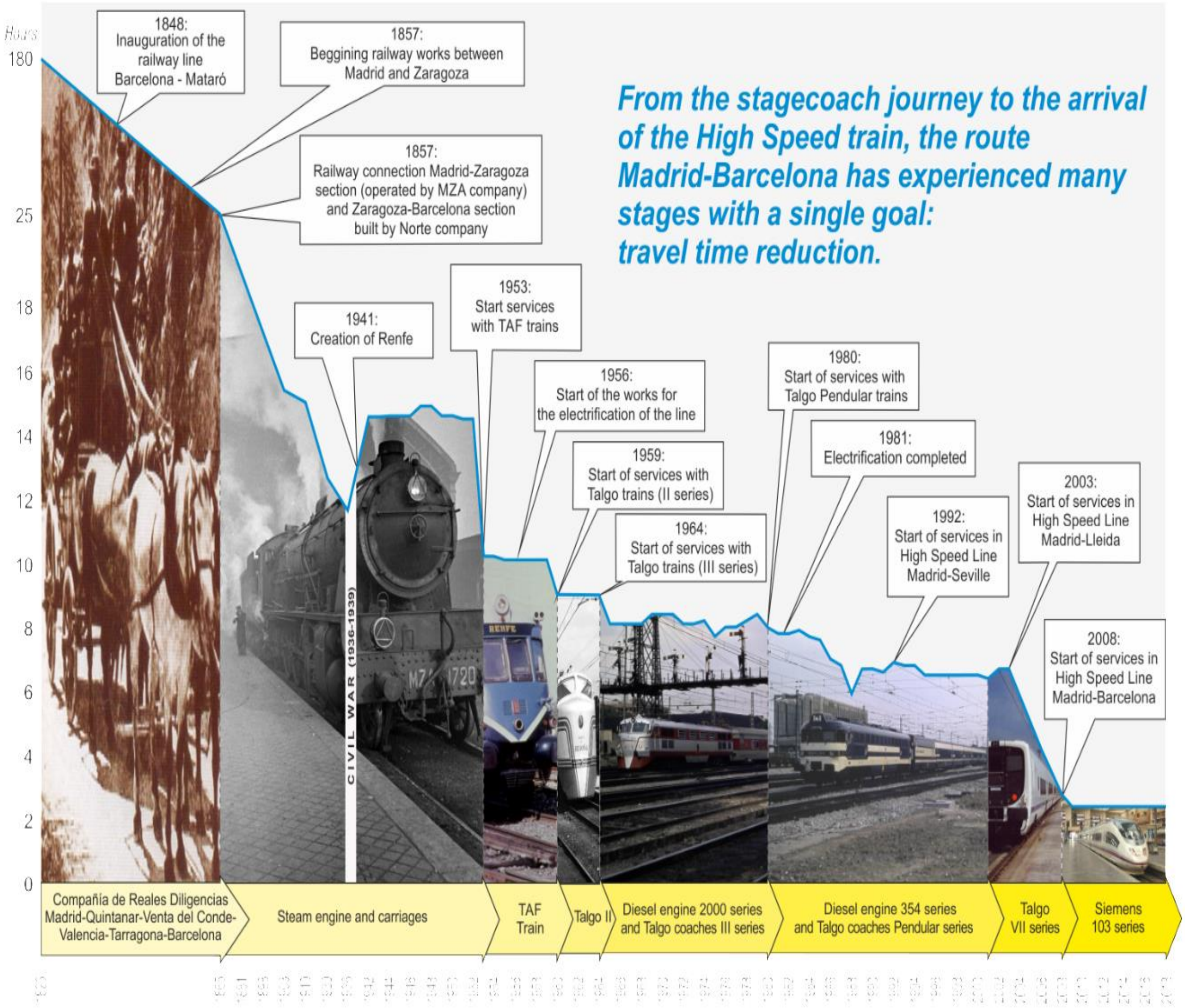

Figure 14: Main facts in the Madrid-Barcelona route history - Source: Spanish railway timetables guide and miscellaneous source

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Little by little, improvements were incorporated at the rolling stock (new trains capable of reaching higher speed), and on the infrastructure (double track, electrification and signalling), which enabled faster train services. With respect to other means of transport in those years, mainly bus and plane, rail had almost 90% of the passengers on the route between Madrid and Barcelona until the arrival of the "Air Shuttle"[7] in 1974.

From that year on, the plane became the undisputed leader in trips between both cities. The number of passengers travelling by train decreased, despite improvements in infrastructure in the late 1970s or the introduction of the Talgo Pendular (new rolling stock).

In 2008, the trend changed radically. With the launch of the High-Speed Rail services between Madrid and Barcelona the train began to gain market share from the airplane, and in 2012 the train surpassed the airplane as the preferred mean of transport between the two cities.

The gradual decrease in travel time and, therefore, an increase in the competitiveness of the train compared to the plane, must also be related to the demographic variable: Madrid and Barcelona experienced strong population growth, especially since the 50s. They continue being the two most important demographic agglomerations in Spain nowadays. To be more precise, the city of Madrid has more than 3.2 million inhabitants and the city of Barcelona more than 1.6 million. Considering the demographic volume of both cities plus their respective metropolitan areas, Madrid registers 6.1 million and Barcelona 5.1 million inhabitants (Observatorio del Ferrocarril en España 2018). This means connecting 11 million of potential users that are about 25% of the total Spanish population.

Spanish High-Speed lines are currently preparing for a new scenario: the entry of new rail operators. This issue will imply the rupture of the current monopoly of RENFE and therefore, a new revolution in the market, as it already happened in air transport. In this scenario, initially planned for December 2020 (although deadlines have been extended due to the COVID-19 crisis), there will be several companies circulating in the corridors that will open up to competition: RENFE, SNCF (under the Rielsfera brand) and the Air Nostrum-Trenitalia consortium. The Madrid-Barcelona line will be one of those through which more than one company can circulate, along with the Madrid-Valencia / Alicante and Madrid-Seville / Malaga lines.

[7] "Air Shuttle" or "Puente Aéreo" is a flight service established by Iberia to connect Madrid and Barcelona with an open ticket, which allows the passenger to choose any flight and provides total flexibility for the booking.

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7.3. High-Speed Rail Infrastructure in Spain

The High-Speed network in Spain sums up 3,300 kilometres by 2019[8]. Its construction began in 1992 with the opening of the Madrid-Seville line, and grew with the construction and operation of the lines from Madrid to Toledo, Malaga, Valencia and Alicante, Valladolid, León and Zamora. The Madrid-Barcelona line, with the extension to the French border, was opened in several stages: from Madrid to Lleida (2003), from Lleida to Tarragona (2006), from Tarragona to Barcelona (2008), from Figueres to the border (2010) and from Barcelona to Figueres (2013).

Figure 15: High-speed Rail network in Spain (2019) – Source: Modified from "Atlas High-Speed Rail In Spain". Spanish Railways Foundation, 2017

The progressive implantation of High-speed corridors in Spain allowed not only to connect numerous cities through a newly created and high-performance infrastructure, but to improve travel times in all routes. This also contributed to a more efficient mobility, since there has been transfer of passengers from other means of transport (private vehicle, bus or plane) to the train.

Even though it was built and exploited in standard gauge, the developments in gauge change technologies allowed to avoid the "border effect" that until now existed with the Iberian gauge network. This process began with the start of operation of the Madrid-Seville line, implementing the gauge changeover system with a considerable reduction in travel time.

[8] Source: Atlas High-Speed Rail 2019 and ADIF (Spanish railway administrator)

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7.4. The Madrid-Barcelona High-Speed Corridor, a success story

7.4.1. Line, services and infrastructure

The distance between the Madrid-Puerta de Atocha station and Barcelona-Sants station is 663 kilometres, including Zaragoza and Lleida bypasses.

Looking at the technical characteristics of the infrastructure, the line has double track in standard gauge, is electrified at 25 kV and has a maximum speed of 300 km/h. The rail is 60 kg/m on a concrete sleeper, while the wheelbase is 4.70 meters. It has twelve substations and ERTMS Level 2 signalling.

It counts with the intermediate stations of Guadalajara-Yebes, Calatayud, Zaragoza-Delicias, Lleida-Pirineus and Camp de Tarragona.

It currently counts with 28 services per direction and day provided by RENFE. Twelve of which are direct trains with two hours and a half travel time. The rest of the services have a duration of three hours and ten minutes, with stops in all of the stations of the route.

The line between Madrid and Barcelona has a general Northeast orientation. It starts at the Madrid-Puerta de Atocha station heading south in parallel with the Madrid-Seville high-speed line. At the south of the city, it turns northeast passing near the M-50 motorway and progressively ascending to reach the hills that flank the valley of the Henares River and the heights of La Alcarria reaching Ministra Mountains. In this area the watershed between the central plateau and the Ebro valley is reached, in Alcolea del Pinar, where the route reaches the highest point of the route: 1,218 meters of altitude.

Figure 16: AVE 102 Series (Talgo) nearest Sagides (Province of Soria) – Source: Javier Peña

From there it begins to descend the slopes of the land of Medinaceli and Sierra de Solorio, to cross through tunnels and viaducts the mountains of the Iberian System until Calatayud. In this city the railway line settles in the plains of the Jalón River and abandons its northeast orientation to run east and reach Zaragoza. A few kilometers away, in Moncasí, the line has a bypass that divides it into a branch towards the city center of Zaragoza and the Zaragoza-Delicias station, and another branch that borders the city from the south.

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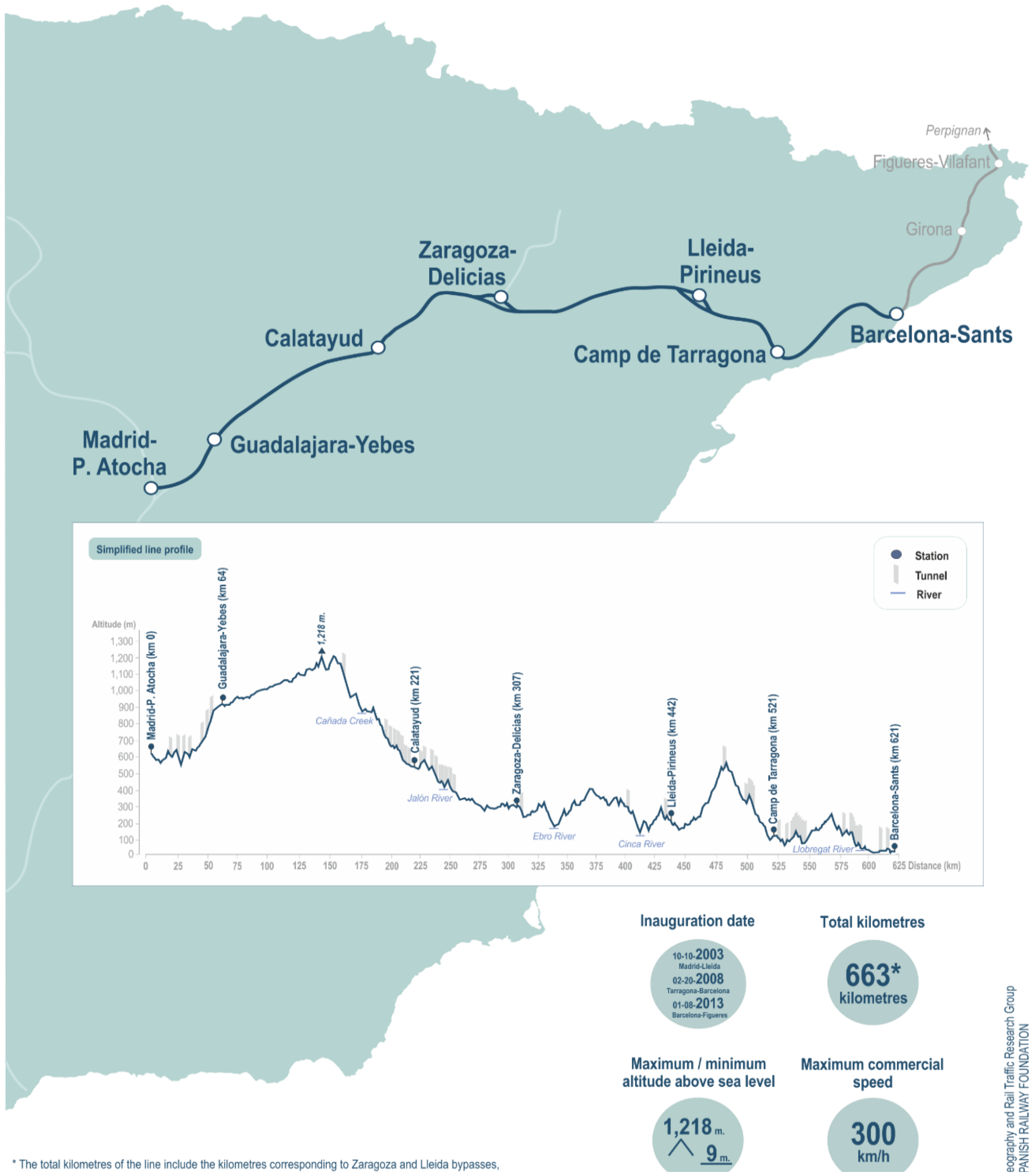

Figure 17: Main characteristics of Madrid-Barcelona High-speed rail infrastructure - Source: Modified from "Atlas High-Speed Rail In Spain". Spanish Railway Foundation, 2017

From Zaragoza, the line runs south of the limits of Los Monegros desert and the lower course of the Cinca River, reaching Lleida. As in Zaragoza, it is divided into two: on the one hand, an underground section through the urban area to the Lleida-Pirineus station, on the other, bordering the city to the south. Both sections meet at the Canal de Urgell. Once again, through tunnels and viaducts, the route crosses the mountainous area of the Catalan pre-coastline, heading south towards Tarragona and Camp de Tarragona station. This is the connection point with the Mediterranean Corridor. At the Penedés region, the route is oriented northeast again to run

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parallel to the A-7 motorway to Martorell. In this town it reaches the Llobregat river valley and heads south to reach El Prat. Finally, following the conventional line between El Prat and the Barcelona-Sants station, it enters through a tunnel in the city of Barcelona. The route has 47 tunnels, being the Paracuellos tunnel (4,783 meters long) and the Las Hechiceras tunnel (2,929 meters) the longests, with the exception of the underground sections in urban areas. It counts with 139 bridges and viaducts, being the longests the Zurita one (Lleida), with 2,476 meters, the one across the Jarama river (2,236 meters), the one across the Jalón river (2,256 meters) and the Plasencia de Jalón one (1,311 meters). As for ramps, the maximum ones oscillate between 20 and 25 thousandths, and with regard to the curve radius, they oscillate between 7,250 and 10,000 meters, typical of high-speed routes.

7.4.2. Evolution of the passengers number in relation to the HS infrastructure

Two periods of time are considered when looking at the data of the evolution of the number of passengers in the Madrid-Barcelona corridor. The first period goes from the opening of the High-Speed section between Madrid and Lleida (2003) until just before the AVE (commercial name of the high-speed services) enters in service (2008). In that period of time, the use of Talgo trains with variable gauge made the duration of the trip less than six hours.Until 2003, the number of passengers on the Madrid-Barcelona railway corridor slightly exceeded half a million. The offer of services until 2003 was very rigid and consisted of five Talgo trains during the day and three night trains, one train express with sleeping coaches (named Estrella Costa Brava) and two Talgo Hotel-trains (Seville-Madrid-Barcelona and Madrid-Barcelona).

As of that year 2003, RENFE programmed a total of 18 services (9 in each direction) between Madrid and Barcelona. This broke the ceiling of half a million passengers, reaching the figure of 756,900 passengers in 2007.

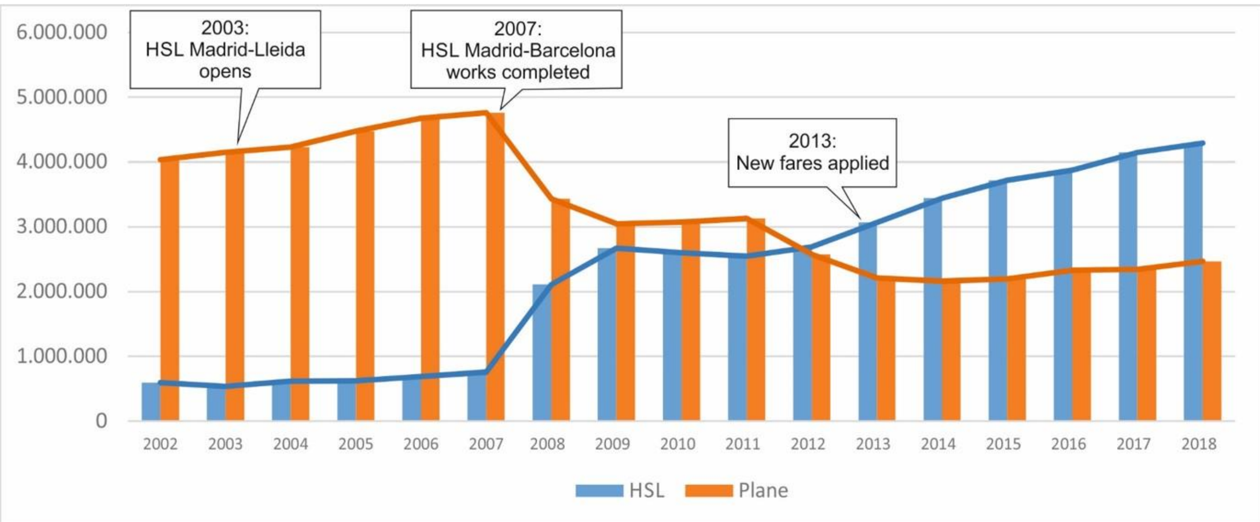

Figure 18: Number of passengers in High-speed Rail and plane - Source: Observatorio del Ferrocarril and Anuario Estadístico de la Ciudad de Barcelona

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The second period begins with the complete opening of the High-Speed line, in such a way that the AVE extends its services to Barcelona. At that time, the growth is spectacular and by the end of the year 2008 there were already more than two million passengers.

Between 2008 and 2009 the growth of the number of passengers was 26%, which indicated the success of this corridor. However, the economic crisis lowered the figures again, although this drop was moderate, and did not get below the two and a half million passengers.

The crisis period and the passengers decrease caused a considerable drop in the income from the sale of tickets in RENFE, not only in High-Speed services, but in all Long Distance products.

7.4.3. Market share

Historically, journeys on the Madrid to Barcelona route had a first revolution at the time when air transport began to develop in Spain, in the 1920s. However, it wasn't until 1927 when regular flights were established between both cities, although there were few services and on alternate days.

It was in the post-war period when commercial flights restarted and, in 1950, Madrid and Barcelona had a go and return flight on alternate days. These services were progressively increased, to 3 daily flights in 1953 and one more the following year.

But the real revolution took place in 1974 with the inauguration of the so-called "Puente Aéreo" (Air Shuttle in Spanish) between Madrid and Barcelona by the governmental company Iberia, which introduced important innovations in the way of managing this type of traffic. Regular schedules were established, priority boarding, exclusive waiting rooms and sale of tickets without reservation and even the construction of a specific passenger terminal in Barajas and El Prat (Madrid and Barcelona airports). From that moment on, the route between Madrid and Barcelona remained in the hands of the air sector compared to land transport and, therefore, rail transport suffered these effects. At this stage, the modal share of air transport was practically 90% over rail.

The Madrid-Barcelona air route became one of the busiest in the world and in the hands of a single airline: Iberia.

However, in the mid-1990s the monopoly was broken and a new company, Air Europa, began to compete. Later on, new companies also entered the market (Spanair, Vueling) and, in parallel, the number of travellers gradually increased, reaching around six million in the early 2000s.

In 2004, one year after the opening of the new high-speed infrastructure to Lleida, the first milestone in rail travel between Madrid and Barcelona was reached, as it exceeded 600,000 passengers a year, which made a rise of one percent in the modal split in favour of rail. The modal share against the aircraft rose up to 12.7% compared to 11.5% of the previous year. The plane in 2004 still maintained 87.3% of the traffic on the Madrid-Barcelona route.

The modal share between 2004 and 2007 for rail remains between 12 and 13%, while the aircraft remains at 87%.

2008 is the year of breakup: the AVE (commercial name of the high-speed services) began its services, offering the possibility of traveling from the centre of Madrid to the centre of Barcelona

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in two and a half hours, without having to pass the exhaustive airport access controls imposed after 9/11 and with more adjusted prices than the plane. This caused a first change in the statistics, since the plane lost more than 1,300,000 passengers compared to the previous year (which the rail won, adding also new travellers transferred from other means). It is the first symptom of the change since, although the rail had 38% of the market, the airplane maintained 62% of the modal share.

The economic crisis of 2008 implied a change of scene worldwide and more specifically, on the route from Madrid to Barcelona, since both means of transport saw the number of passengers decreasing, although in the air sector it was more pronounced (with the loss of almost half a million travellers between 2008 and 2009) while the rail experienced a smoother decline. In these years, the plane had reduced its market share to below 60% and the rail collected part of those users already exceeding 40%, with 2009 registering the highest percentage with 46.7%.

In 2012, between the stability of train passengers and the decrease in air travel, the moment of modal equilibrium occurs, reaching almost 50% of the passengers. Short after, the first time that rail exceeds plane occurred: the AVE Madrid-Barcelona managed to grab 51.1% of travellers compared to 48.9% of the plane.

As indicated in previous paragraphs, 2013 represented a new revolution with the entry into force of the new RENFE fare policy based on the "Revenue Management" method. The reduction in prices generated an increase in demand and at the end of that year, RENFE exceeded three million passengers on this line and definitively broke the modal balance, reaching 58.1%.

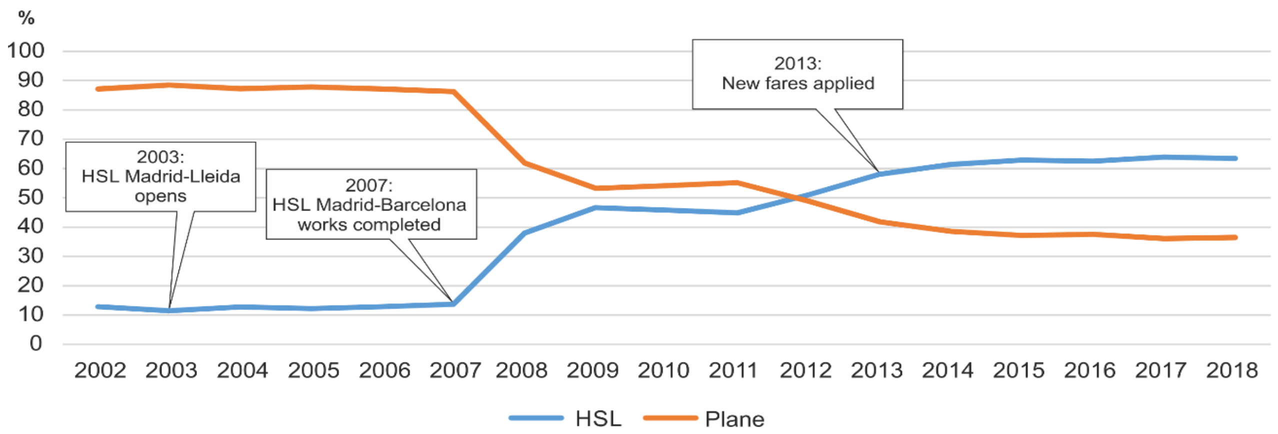

Figure 19: Modal share in High-speed Rail and plane - Source: Observatorio del Ferrocarril and Anuario Estadístico de la Ciudad de Barcelona

Throughout the 2013-2018 period, the rail market share for this route already exceeded 60%, being the year 2017 where the maximum reached so far, with 63.9% of travellers in the Madrid – Barcelona corridor. Regarding the plane, the share has been decreasing, despite the upturn in passengers in recent years with a redesign of the offer in this corridor, underlining that in 2018 it stands at around two and a half million travellers and a 36.5% of the passenger market.

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In the coming years, when the exploitation of the low-cost train "AVLO"[9] and the services of new railway companies began thanks to the liberalisation it is expected that, not only will be new users coming from the plane, but also from the rest of the modes of transport, generating an important modal transfer towards rail.

7.5. The Madrid-Barcelona line and its connection to the Trans-European Transport Network

The improvement of travel time has benefitted the corridor Madrid-Barcelona, but also the international relations. This is because the High-Speed infrastructure has been extended to the north of Catalonia up to the border with France. First, with the construction of the Perthus tunnel in 2010 between Figueres and Perpignan; later, with the inauguration of the section between Barcelona and Figueres (2013); the Spanish high-speed lines are connected to the European network, allowing the establishment of new railway relations.

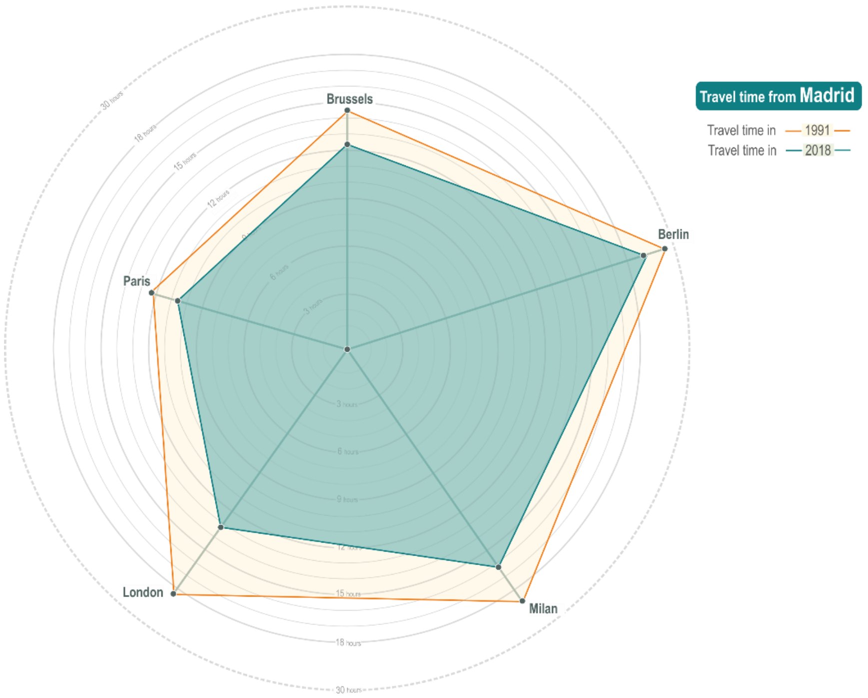

Figure 20: Travel time from Madrid in 1991 and 2018 - Source: "1991 Renfe timetable" guide and 2018 data of RENFE's and SNCF website

[9] The launch of AVLO services were expected to start in April 2020, but have been suspended due to COVID-19 outbreak.

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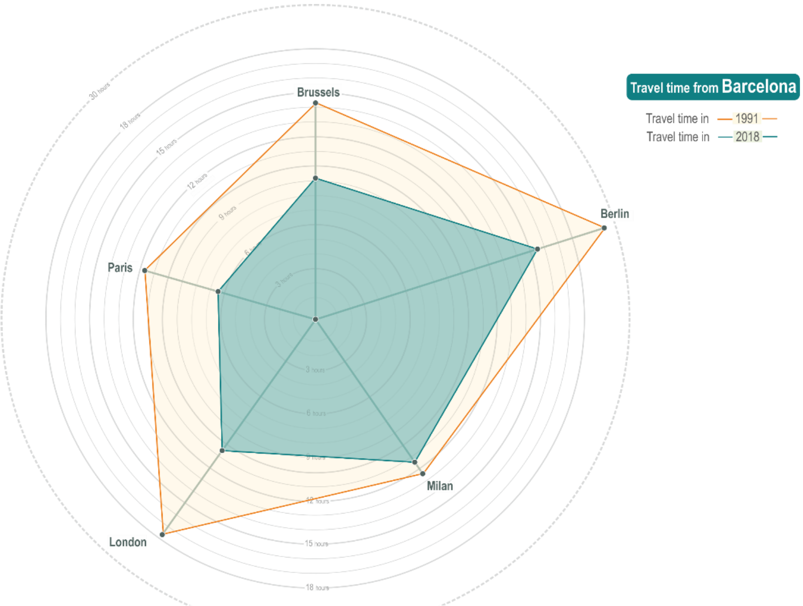

Figure 21: Travel time from Barcelona in 1991 and 2018 –M Source: "1991 Renfe timetable" guide and 2018 data of RENFE's and SNCF website

In this way, even when the connections are not direct (in many cases include train or station changes), current travel times have been reduced, especially with the European capitals that are further away such as Berlin, London, Brussels or Paris.

For example, in the case of Berlin, a train journey from Barcelona prior to the introduction of High-Speed in Europe required a time of almost thirty hours, whereas it currently takes no more than eighteen hours. The same happens with the trip to Paris, requiring 12 hours in 1991 and only half the time nowadays.

7.6. Less CO_2 emissions

The evolution of the railway infrastructure between Madrid and Barcelona throughout the history has significantly reduced the environmental impact of its CO_2 emissions.

Previously, the gradual electrification of the conventional line implied a first reduction in emissions in a line that, until that moment, was operated by steam and diesel locomotives. Since the electrification was completed all traction was carried out with electric locomotives and trains.

The opening of the High-Speed line has also contributed to a greater reduction in emissions to the atmosphere, as demand for other modes of transport, such as bus, car or plane, which incur in higher emissions, has decreased.

In order to illustrate this statement, the following figures can serve as an example: between Madrid and Barcelona, a car produces 65.6 kilograms of CO_2 per passenger and an airplane 115.5 kilograms per passenger, while the AVE, for the same route, generates emissions of 18.4 kilograms

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per passenger (RENFE. Transporte Sostenible). In addition, the transfer of passengers from the car and plane to the train on the Madrid-Barcelona route allows an estimated savings of 200,000 tons of CO_2 per year, similar to the emissions produced by domestic electricity consumption in a city like Zaragoza.

This reduction is possible thanks to the exclusively use of electric traction in passenger services and is also a consequence of:

- Efficient energy consumption: the introduction of regenerative braking technology, where the energy produced in the braking process is returned to the electrical system, reaching a return rate between 6-10% to the electrical grid. Likewise, the use of more efficient refrigeration and air conditioning systems achieve 30% of energy reductions.
- Use of new materials in the construction of trains, which has a lower weight per axle.
- Reduction the weight of control and traction equipment.
- Implementation, as far as possible and depending on the section of the line, of efficient driving strategies on trains: reduction of the use of service brake and partial drift circulation (for example, taking advantage of downhill areas). This allowed savings of up to 30% on some journeys.

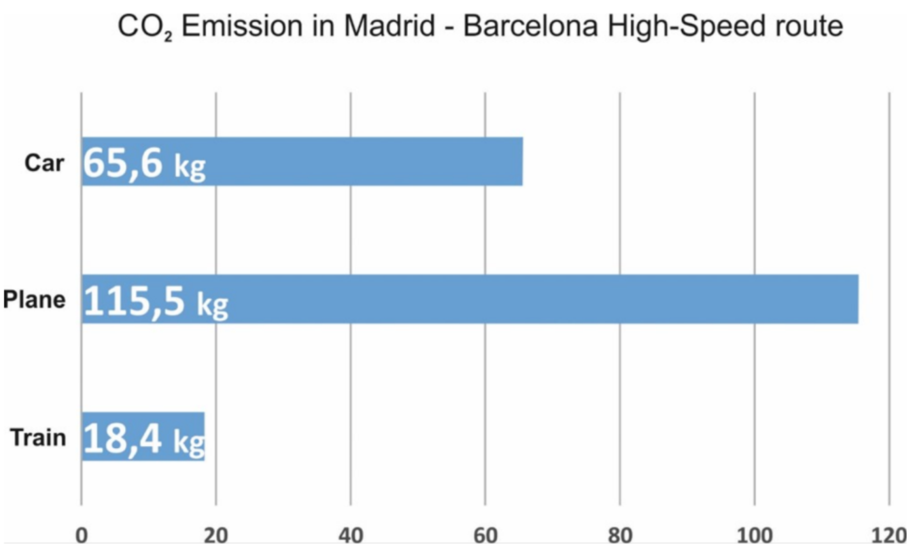

Figure 22: CO2 Emission per passenger in Madrid-Barcelona High-Speed route – Source: RENFE

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7.7. Less external costs

In addition to lower energy consumption and CO_2 emissions, other environmental advantages of the high-speed line Madrid-Barcelona must be added, such as the lower contribution to local pollution in urban areas and the lower acoustic impact. Likewise, other social and economic factors such as lower levels of congestion and accidents must be highlighted.

All this implies that, in Spain, rail transport is the mode of transport that generates the lowest external costs per transported unit. This should be highlighted since the external costs of transport are highly relevant, reaching 7% of national GDP.

8. European rail freight success stories

8.1. Introduction

This section shows two exemplary case studies, and a short insight of the potential impacts of the COVID-19 outbreak on the rail transport. The first case study is dedicated to "longer and heavier trains - The MARATHON train". This case study has been selected for representing a major rail freight transport opportunity. The second is dedicated to "TIGER", which introduced maritime traffic industrial distribution via Dry Ports in Europe. Finally, a short article contains some comments and opinions about the role that rail played in the management of the COVID-19 outbreak in Europe (but not only) in the first half of 2020.

The "Marathon train" may be key in transforming the rail freight ecosystem taking into account its overall potential in terms of:

- Direct impact on business performance;
- Catalyst of rail freight industrialization.

The purpose of this section is to represent the current situation in the EU and major recent and/or ongoing evolutions regarding longer and heavier trains. A particular objective is to highlight research contribution that may accelerate the desired developments. While the progress still looks very slow, the research can contribute to speed up the implementation after everybody accepts its overall feasibility.

The adopted methodology takes advantage of two major sources:

- The Marathon (MAke RAil The HOpe for protecting Nature) Project completed in September 2014. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 265647 www.marathon-project.eu. The following paragraphs mainly refer to Marathon Project source: "Principles and benefits", "Real life traffic and infrastructure tests", "The rail freight industrialization";
- The outcome of CER's large working group continuing to work on this subject, whose papers are summarized in the document "Longer trains, Facts & Experiences in Europe, Results of the CER working group on longer and heavier trains, 2018, 4th edition" http://www.cer.be/publications/latest-publications/longer-trains-facts-experiences-europe-0.

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These papers integrate former documents from UIC (2013). The paragraph "Operational & technical issues still to be fixed", mainly refer to CER source.

According to the approach of the Marathon project, increasing train length is the focus while increasing weight is a consequence. Weight per axle, the other driver of weight increase, is not specifically in scope. Speed is an expected result of operational improvement.

There are two different kinds of longer trains:

- One locomotive with more wagons than standard
- Two locomotives connected over remote control.

The following paragraphs preferably refer to the solutions of two locomotives because it offers higher flexibility from a market perspective due to distributed power delivering better and safer performances. Nevertheless, this is not meant to imply a technical recommendation.

8.2. The "MARATHON 1,500m Train"

8.2.1. Principles and benefits

Longer and heavier trains are deployed in many areas of the world also in Europe, particularly in Russia. These trains have not been developed in Central Europe which is the busiest area of commercial interchanges, is due to a number of reasons. One can indicate only few as examples: lack of technology, old rolling stock, braking and signalling to be upgraded, infrastructures to be upgraded, axel load limited to 22.5 Tons, psychological barriers and, last but not least, the lack of a clear policy in order to operate these trains on the existing lines.
The progress is facilitated by the availability of technologies capable of delivering the required technical standards needed for maintaining and increasing the safety requirements acceptable on the European rail network.
In 2014 the Marathon Project (MAke RAil The HOpe for protecting Nature) developed its conclusion around the concept of running a train of 1500m length by coupling two classical trains of 750m each with the second locomotive radio commanded by the front one. By so doing, the train stability is enhanced and no additional major hazards are envisaged on the train dynamics.

The reference of 750m for each section comes from the general TSI (Technical Specifications for interoperability) that require new infrastructures must allow train circulation for 740m. Nevertheless, due to operational restrictions, the allowed maximum train length is still different by country, as per the following map.

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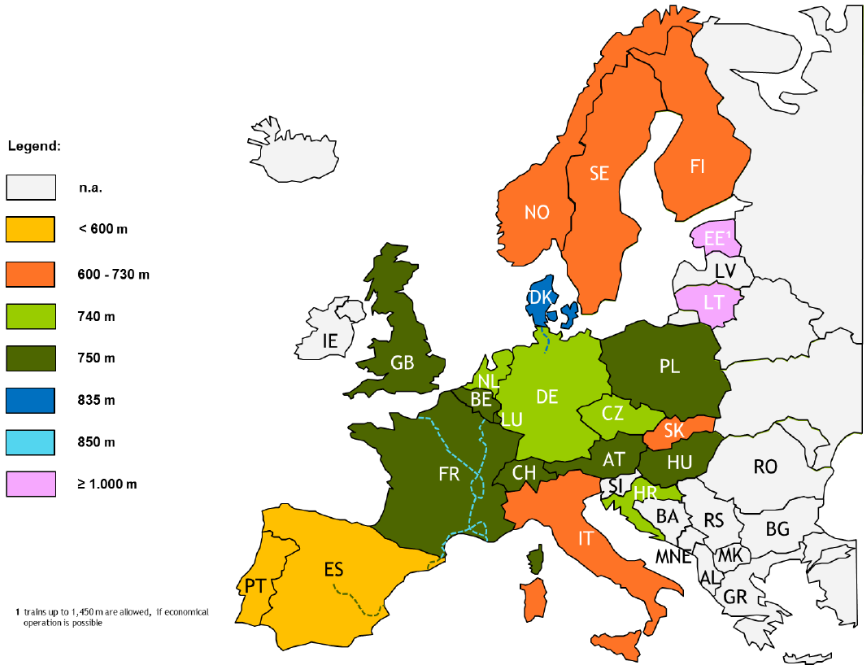

Figure 23: Max. train length per country – Source: CER Longer trains - Facts & Experiences in Europe - Results of the CER working group on longer and heavier trains - 2018, 4th edition

The basic market requirement – as input to the Marathon project - was the need to reduce the rail freight operating costs for inducing in economic term the shift to rail in a sustainable and competitive way within a co-modal frame. In particular the economies of scale generated at sea by the new gigantic vessels require to move containers on land in quantities to be compatible with the maritime transport chain.

These long trains can run on the existing infrastructures between ports and terminals to the hinterland where freight villages and hubs have the required specifications to receive them. Equally, these trains can run between two freight villages/hubs located in the hinterland where the traffic attraction zones reproduce the correct market conditions for having the traffic volumes capable of filling up these trains.

The Marathon trains of 1,500m represent a unique opportunity for dislocating substantial traffic volumes from point to point in an industrial way at much reduced operating costs valued at no less than 30%. In fact, the existing operating cost base is generated by a cost train/kilometre on a profile train length varying generally between 400m to 750m depending on which European Country is the operating theatre.

Also other researches show cost functions with robust efficiencies in case of longer trains.

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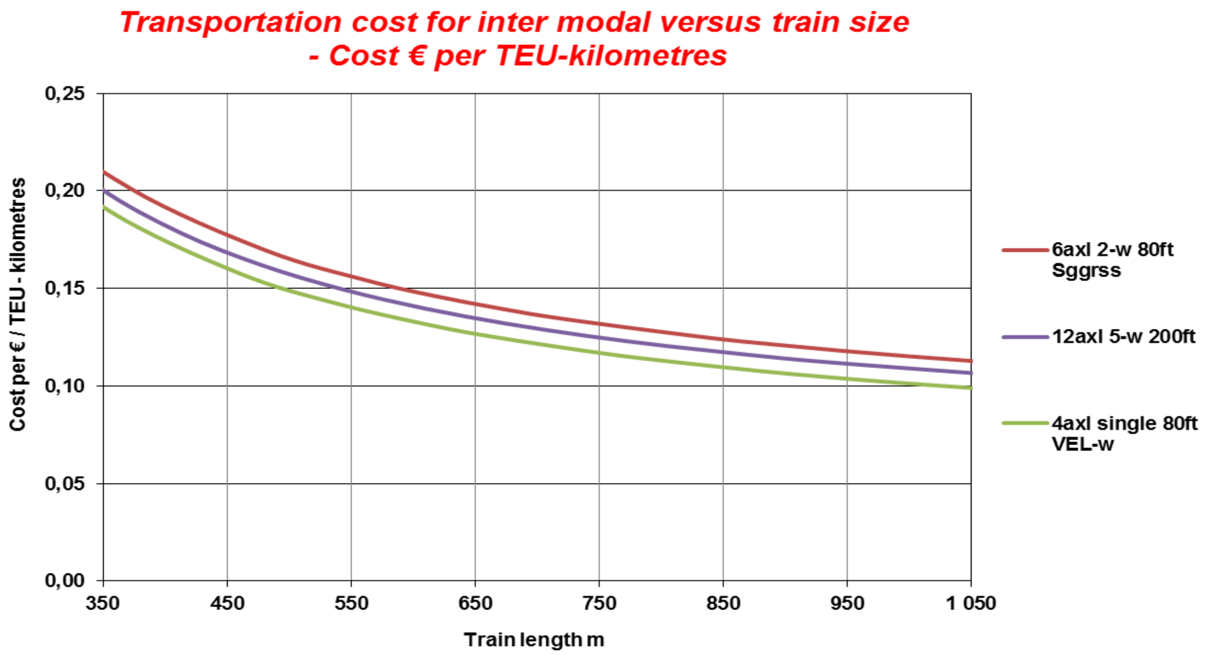

Figure 24: Transport cost reduction by train lengthening - Source - 6th Transport Research Arena April 18-21, 2016 - C4R project increases rail capacity without laying down new tracks - Franco Castagnetti, Armand Toubol, Giuseppe Rizzi

The commercial speed is not impacted in consistent operational conditions. It has to be reminded that in Marathon train concept, trains could be coupled in short time because the two locos remain in action and because the trains are already in running conditions also when they are coupled.
In addition to reduced costs, the Marathon trains generate extra capacity on the traditional rail lines by reducing the rail tracks occupancy hence maximizing the use of the existing resources and minimizing the need of new investments. In particular, it is possible to run 5 Marathon trains in the slot allocated to 6 conventional short trains, equating to carry more than double capacity of freight with an inferior number of trains paths.
Some adjustments to the rail infrastructures are however necessary although in rail terms of relatively modest nature such as lengthening the overtaking rail sidings on the corridors, modification of rail tracks length at the departing and arrival terminals and for assembly and disassembly manoeuvres. The used technologies are adequate for starting operations and that any further improvements on technology development from the pilot tested trials will constitute a marked improvement in terms of both service performances and safety/security. Today the basic technology is available for managing these trains on major European Freight Corridors.

Better use of existing line capacity has become an "obliged choice".
In fact, the only other way to achieve capacity increase in the Rail tracks is through investments in new infrastructures which solution has two major disadvantages that are impossible to be overcome at the same level in the short term:

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- Budget constraints;
- Very long time to market.

On the contrary, the capacity on rail is needed as from now both for providing competitive service to the industries and citizens who are expecting from the key market players as well as from the competent authorities sustainable transport solutions capable of satisfying the growing market needs.

Regarding fulfilling the environmental objectives of reducing the transport carbon footprint, a saving of 10% of energy consumption has been monitored during the test of Marathon project, but this has to be further investigated.

The contribution in reducing the transport carbon footprint would be any case related to the modal shift consequent to the increased rail solutions attractiveness.

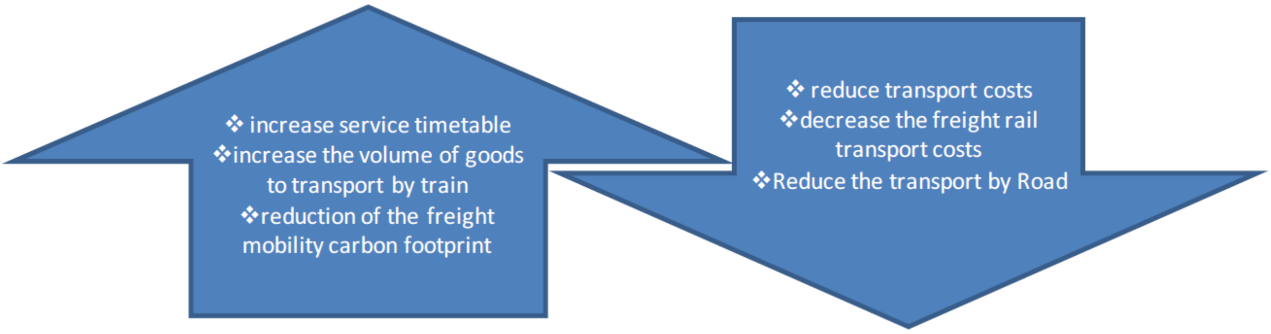

Figure 25: Marathon Train benefits – Source: Handbook Marathon Project - 2014

8.2.2. Real life traffic and infrastructure tests

As said, the Marathon train concept is based on coupling two trains of 750m each with the second locomotive radio commanded by the front one.

Each of the two locomotives contributes to the traction and to the electric and pneumatic braking specifically in accelerating the braking and releasing of the pneumatic braking. The radio remote control is utilized for each of these actions.

The choice of having the slave locomotive active while it is placed in the middle of the train is fitting some technical aspects as:

- To accelerate the venting of the brake pipe from two points of the train (front/middle) in order to master the stopping distance within the authorized limits and to try to reduce the longitudinal compression forces created by the braking system of the first part of the train;
- To increase the pressure in the brake pipe and the auxiliary reservoirs more rapidly in order to release the brakes more rapidly by using the slave locomotive compressor.

The Marathon project executed two trials with Kombiverkehr, not theoretical but effective trains, originating from Germany and destined to Spain.

On the 18th January 2014 Marathon performed the first demonstration phase of the project with

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the operation of a 1.5km long Marathon freight train across France. The test was conducted by Marathon partners with 2 electric locomotives BB37000, from Alstom. It took place between Lyon and Nimes and was very successful in demonstrating the practical developments stemming from the project. The braking system responded like intended and the communication system between the master and the slave locomotive worked without flaws. To add to the accomplishments, the train travelled at 100 km/h for long stretches, the same speed as that of standard freight trains.
The second pilot was carried out on April 12th. What set this apart from the first pilot was the use of two diesel locomotives, whereas the first pilot included two electric locomotives. Two Euro 4000 locomotives from Vossloh with the requested Marathon modifications were used to haul a train of 1,524m length, with 72 wagons and 4,020 tons. The results were equally satisfactory.

As said the corridor infrastructure is basically "ready" for such trains with relatively minor actions (see also the following paragraph "Operational & technical issues still to be fixed").
The Marathon project in particular investigated impact on infrastructure Hallsberg-Malmö in Sweden which is part of the rail freight corridor 3 (Stockholm-Naples):

- The length of the train has not a direct impact on bridges shorter than a 750m train itself.
- A double train up to 1,500m long does not degrade tracks and switches more than two corresponding trains that is half as long. The track superstructure is only impacted by the axle load, speed and the ride dynamics of the wagons. If those parameters does not change then there will be no additional degradation of the track superstructure;
- No problems with the power supply on the studied line is foreseen;
- The existing automatic train protection system ATC 2 cannot be programmed for trains longer than 900m. The ATC 2 will over time be replaced by the new European Train Control System – ETCS. Any upgrading of ATC 2 is therefore in principle not allowed;
- ETCS equipped vehicles can be programmed to handle train lengths up to 4.095m. A special interface module between ETCS and the ATC the so called Specific Transmission Module – STM – has been developed to enable technology migration from the existing to the future train control system. An ETCS equipped locomotive can thus be programmed with a train length of 1,500m. The STM calculated braking curves will however be restrictive which will translate into a reduction of permitted speed;
- A minor modification of the STM is therefore necessary to allow the braking performance of a double train up to 1,500m long to equal that of a train with half the length.

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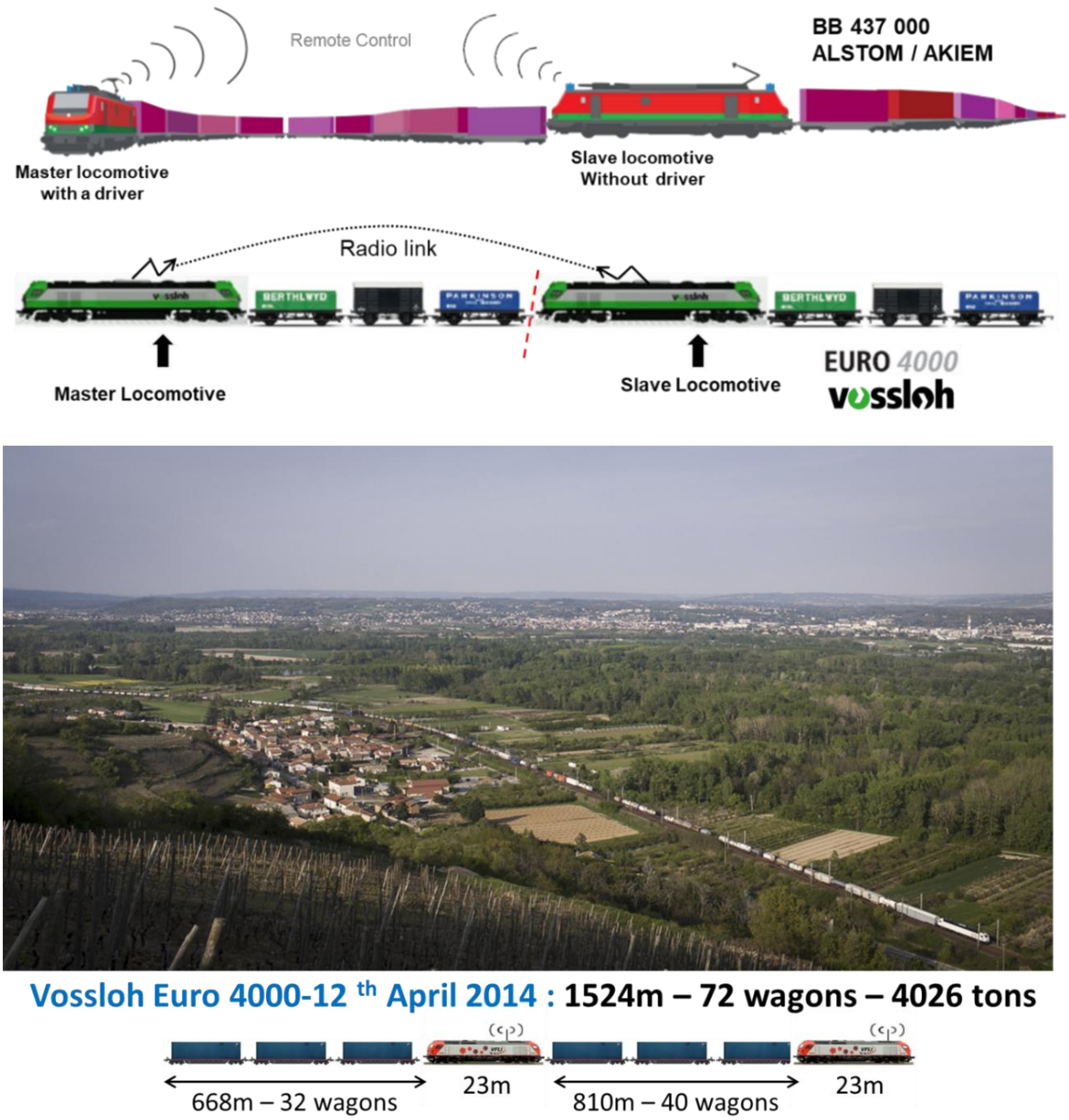

Figure 26: Marathon Train – principle to train coupling and view of the pilot train – Source: Marathon project, 2014 (http://www.newopera.org/newopera-nuovo/publications-newsletters/send/2-publications-newsletters/22-marathon-handbook)

8.2.3. The rail freight industrialization

The implementation of the Marathon train concept with full benefit exploitation entails the application of a completely new business model. In particular, the Marathon train can play a pivotal role in the process of rail freight industrialization. In fact the industrialization concept is

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based on the selling of capacity and the production of regular services to be made available in the market place at a given timetable in order to achieve the proper reply to the paradigm of improving the service quality at lower costs. The industrialization process has to be consistent with the peculiarities of an asset based industry as below summarized for the rail industry leveraging the Marathon train opportunity.

Figure 27: Basic Steps to MARATHON Asset Based Business Model -Source: NEWOPERA Aisbl – Marathon project, 2014

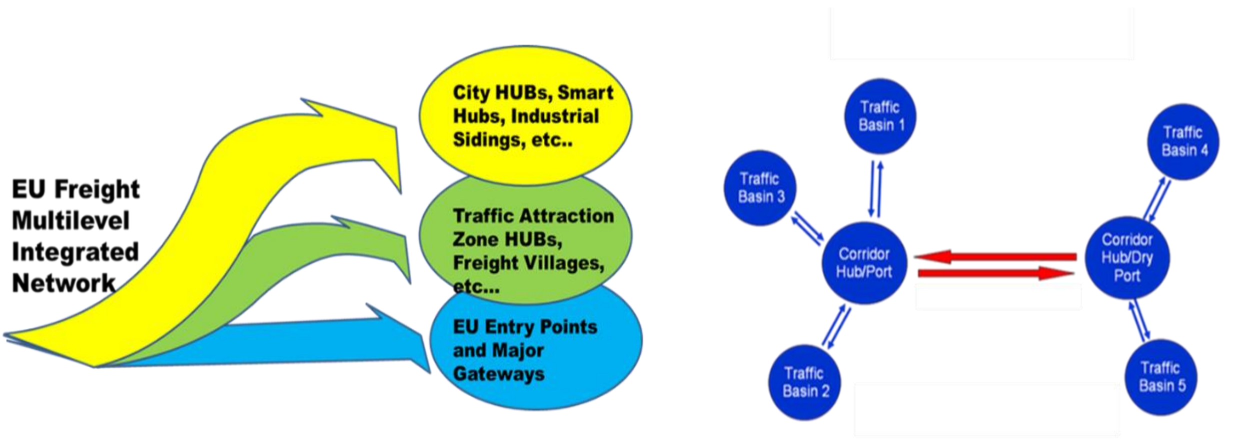

Figure 28: Traffic Scheme where the industrialized approach between Hubs maximize benefits (red arrows) in a freight multilevel integrated network - Source: NEWOPERA Aisbl – Spider Plus project, 2015

All mentioned industrialization principles (in particular selling the capacity) are common practices in assed-based industries and in other modes of transport. Shipping lines are competing between themselves but through slot charter agreements they cooperate for filling up the capacity available on the ships. This happens not only in the liner CTS traffic but also on all other industrial fields.

8.2.4. Potential contribution of research

"Technical" topic

The program Shift2Rail is contributing to the Marathon train research with a specific initiative.

The project "M2O - MAke RAil The HOpe for protecting Nature to future OPERATION" is ongoing with the purpose to sets up a reliable transfer of data and commands between the locos based on GSM-R technology (https://www.marathon2operation.eu/web/). The solution is integrated in the train DPS and the safety of the system is studied to cope with the various operational situations. Having set the radio communication system, the project defines the main possible train characteristics in terms of speed, type of wagons, acceptable load and its distribution along the train by using simulations. These simulations will be monitored in terms of safety to ensure that the various hazards have been correctly taken into considerations while performing the simulations and that the adequate mitigations have been elaborated.

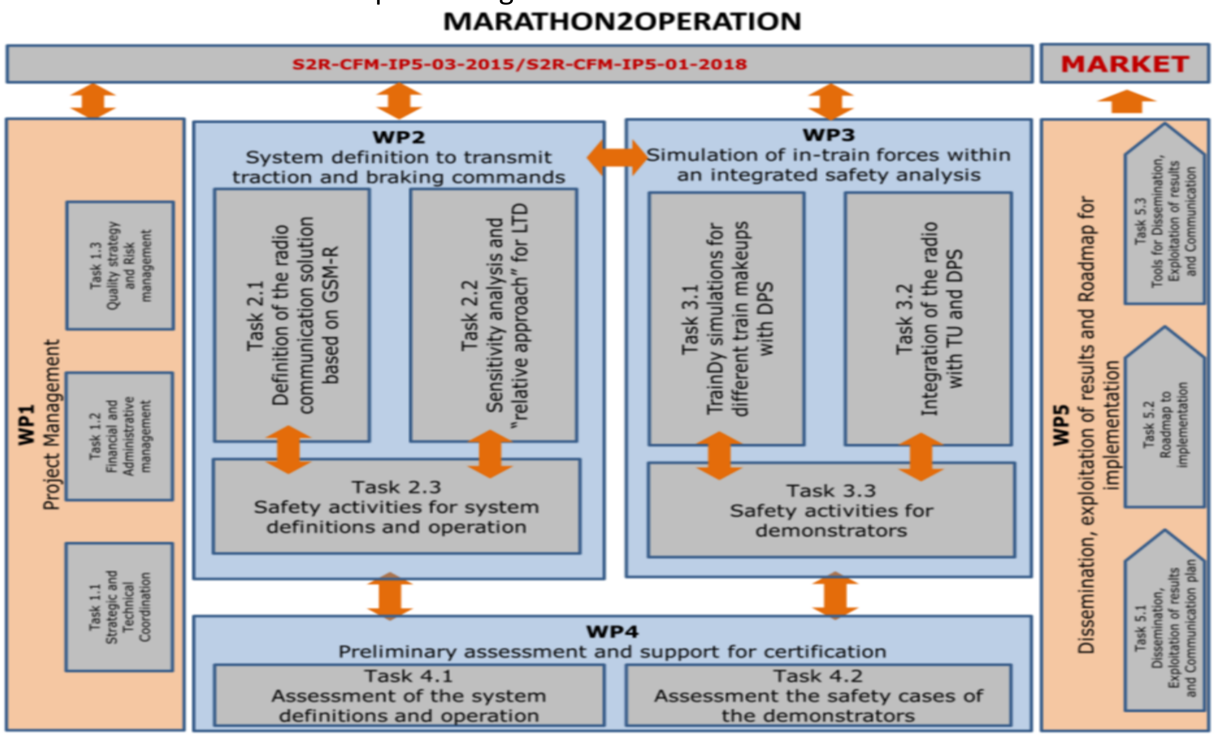

Figure 29: M2O - MAke RAil The HOpe for protecting Nature to future OPERATION - project workplan – Source: NEWOPERA Aisbl, 2019

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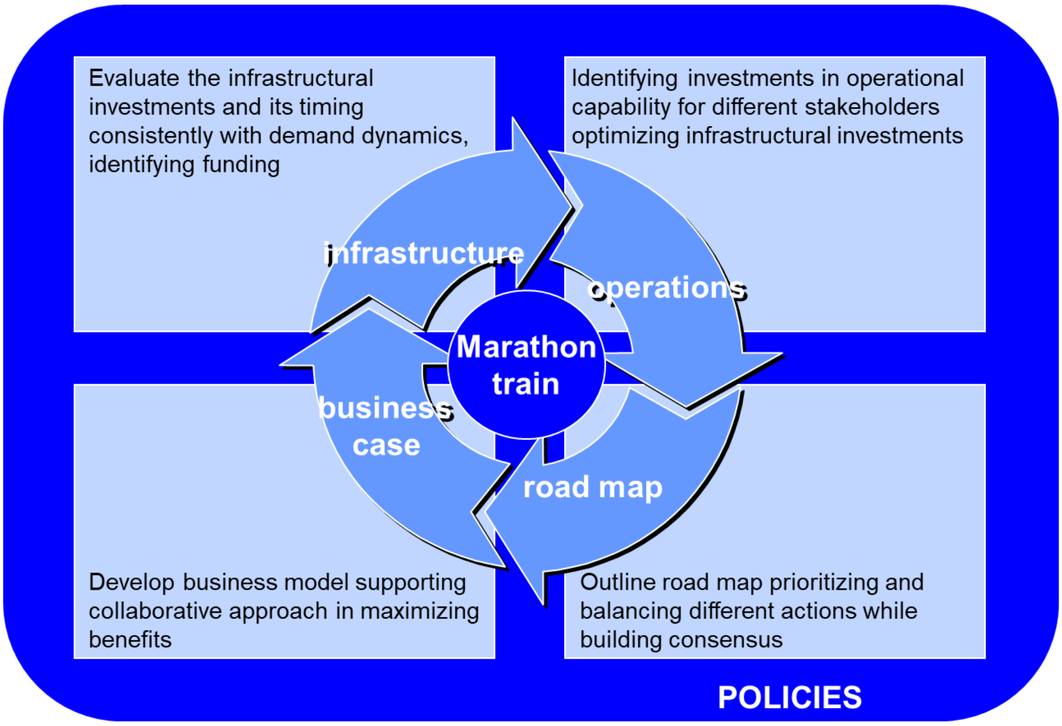

Figure 30: Summary of main research actions for implementing the Marathon train – Source: NEWOPERA Aisbl, 2019

It is useful to remind that business cases are specific for defined traffics and relations, so "business case" groups a cluster a number of individual business cases. To some extent, the same is for the other components highlighted in the above picture (infrastructure, operations and roadmap).
For this reason, as each case is specific even if the approach needs to follow harmonized methodologies, the role of corridor is key. In fact:

- The longest rail connections would get the biggest benefits;
- The future capacity constraints will be perhaps more significant on corridors where the traffic growth can be assumed to be higher;
- The "natural" leading entity would be easily identified among existing ones avoiding the complexity of starting completely new organization.

In addition, on corridors the necessary specific EU support would be more than justified in consistency with policies priorities driving investment funding.
About corridors role it is useful to remind that the total length of freight corridors is about 50,000 km compared with the overall EU rail network of about 220,000 of which about 120,000 are electrified. Therefore, the role of corridors is in any case unavoidable either they lead the process or new entities identified for such tasks take the lead.

8.3. The "TIGER Dry Port"

TIGER is the acronym for **T**ransit via **I**nnovative **G**ateway concepts solving **E**uropean-intermodal **R**ail needs. The TIGER project approach has become the maritime industrial distribution system of choice from the major European Sea Ports. This is a success story well consolidated and adopted

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in large scale in Europe. This report describes the initial pioneering project initiative to be followed by leading Intermodal and Sea Ports operators, Shipping Lines, Dry Ports, Rail Freight traction companies as well as IMs for the rail lines infrastructure adaptations.

The world sea traffic doubled between 2000 and 2006 and continued thereafter with the overland Infrastructures unchanged. The increase in the vessels' sizes exceeding 20,000 TEUs, calling at an inferior number of ports with a greater number of movements, evidenced the inadequacy of the traditional containers' distribution system plagued by port congestion

The objectives of keeping the traffic moving through the European ports increasing the rail market share was the biggest TIGER project's challenge since in 2020 most of the North/South Gateway Ports are expected to reach their technical capacity. The industrial distribution by rail via inland Dry Ports appeared the only viable proposition becoming the TIGER project's objective. The project started in 2009 and ended in 2013.

Project Objectives are listed as follows:

- Introduce a new business model via Dry Ports;
- Reduce port congestion through Dry Ports & Hinterland innovative distribution models;
- Maximize capacity on existing rail lines, better utilizing existing resources;
- Industrialize/Optimize transport (maritime+overland);
- Reduce costs, transit times delivering better services;
- Introduce innovative logistics solutions and best practices;
- Share benefits among multiple actors of the supply chain;
- Internationalize the solutions.

The Dry Port hub, located on major European freight TEN-T corridors' Core or Comprehensive Network constitute the vital nodes where freight bundling, optimization and transport industrialization became effective through the combination of sea bound traffic with the continental one. Mega hubs were examined to be built/expanded/restructured in strategic nodes in traffic attraction zones during the project lifetime. Rail traffic industrialisation was redesigned based on by transferring daily massive traffic flows to Dry Ports via multiple shuttle trains. The O-D Hub functions were studied in order to distribute on a hub and spoke principles, intercepting the additional volumes of the continental European traffic for the final destinations.

TIGER developed these modernization concepts generating effective transport industrialization from the sea to Dry Ports promoting investments by private and public actors in the 4 demonstration ports of Genoa, Hamburg, Bremerhaven Wilhelmshaven, Gioia Tauro and in the Dry Ports of Lehrte, Rivalta, Munich Riem, Nienburg, Duisburg and Poznan.

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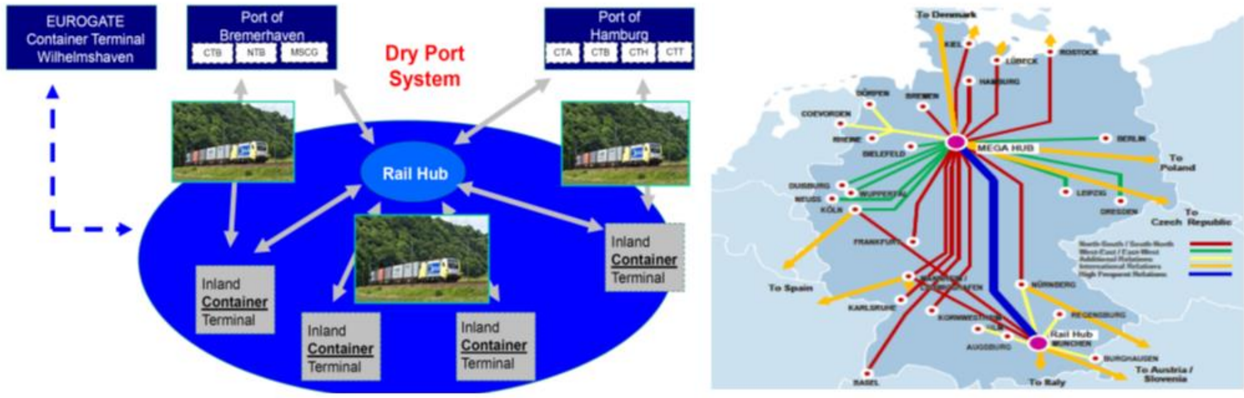

Figure 31: Dry Port system supporting Bremerhaven and Hamburg – Source: TIGER project, 2013

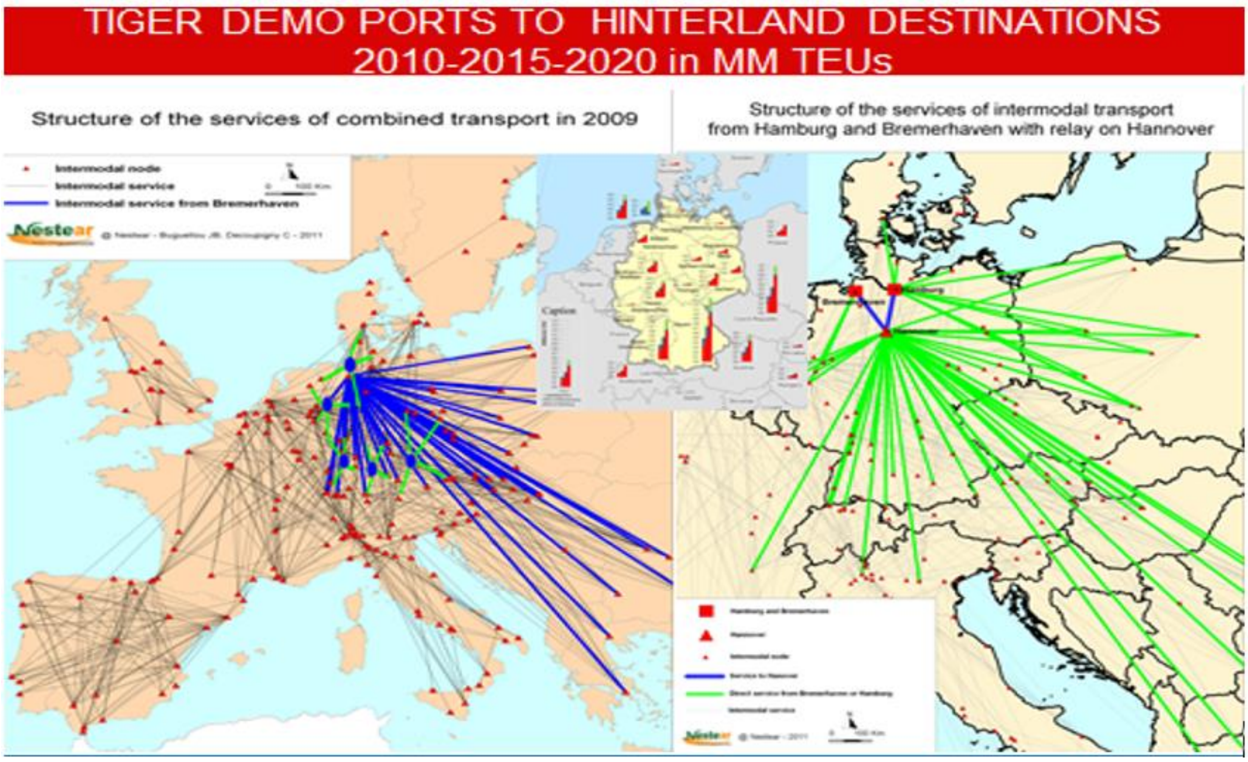

Figure 32: Industrial Container Distribution models. Lehrte Dry Port. – Source : Tiger Project, 2013

The above picture illustrates how the industrial container distribution model evolves by concentrating volumes into the Lehrte Mega Hub where both domestic European overland traffic is mingling with the Sea ports traffic generating additional economies of scale optimizing volumes for the same destinations. At the same time one can further concentrate volumes to another Mega Hub such as Munich Riem in a sort of "Rail Motorway" for southern destinations.

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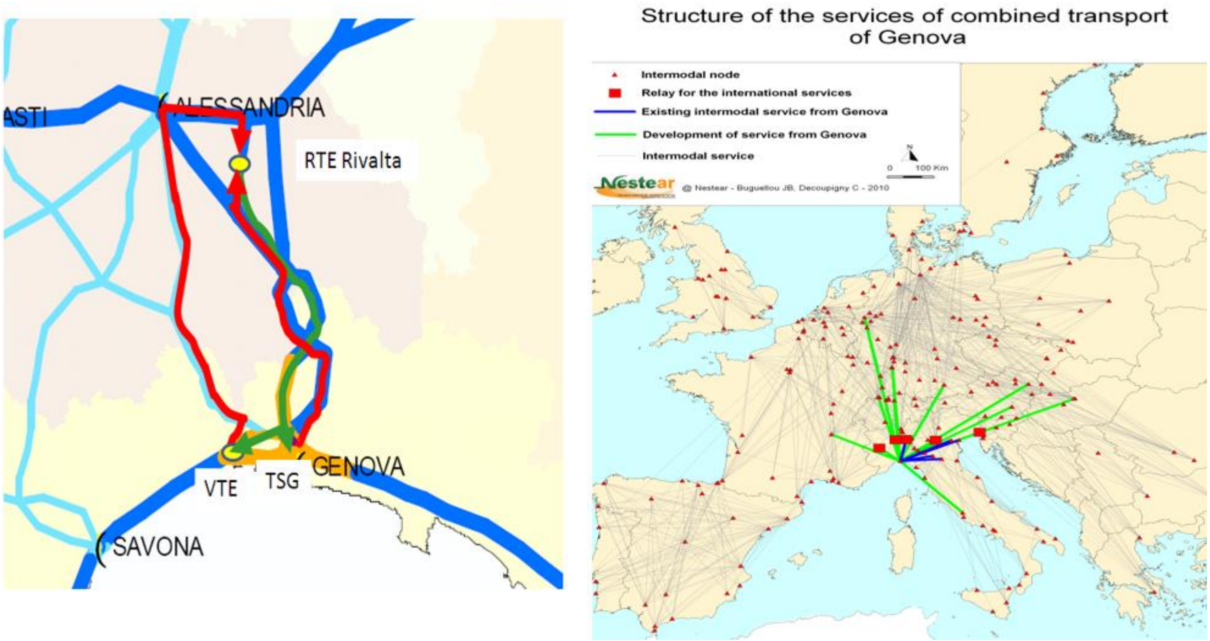

Figure 33: RTE Dry Port system supporting Genoa Port & new competitive reach – Source: TIGER project, 2013

In the Lehrte and Munich Riem hubs, several operating innovations were introduced, such as the "momentum" train positioning under catenary avoiding manoeuvring and the train-to-train container shifting avoiding extra movements and terminal quay usage. In Nienburg, a dismissed marshalling yard, was re-juvinated and a new technique of wagons sorting was introduced. The trains with homogeneous traffic go directly under the ship eliminating handling costs and land usage in the sea terminals. In Genoa, an electronic seal allowed the direct transport from ship to Rivalta Dry Port by rail without customs intervention. From RTE terminal Genoa opened up new rail connections increasing its competitive reach in Central Europe.

These concepts produced immediately visible and tangible effects. Trade as a whole and the Transport Community captured to replicate the TIGER project initiative into a large scale industrial traffic management distribution concept all over Europe. During the project lifetime the following substantial results were achieved:

- Improved management: IT-System in terminal operation including timing control of rail-rail transfer, IT system for train capacity management as well as IT-System for Real-time train monitoring with ETA-information;
- Operating costs reduction increasing train capacity by 15-20%. Also reduced costs in terminals and Mega Hub through increased volumes handled. Reduced sea ports costs avoiding shunting movement inside the port;
- Reduced dwelling & transit time: In Genoa 37% immediate plus 20% planned. Dwell time in Hamburg reduced by 92%;
- Increased slot utilization in Hamburg Seaport Terminal by 100%;
- Service performances improvement through increase punctuality by 85-90%;

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- Reduced port congestion through increased Dry Port-Mega Hub rail connections. 33 new rail connections via Munich Riem up to 70% increased capacity;
- Improved sea ports accessibility together with enlarged competitive reach;
- Reduced emissions and accidents caused by road vehicles.

Other specific service advantages and cost reductions were achieved in other Dry Ports connected to the main North sea ports such as Nienburg – Bremen - Munich Riem - Nuremberg - Mannheim - Frankfurt – Stuttgart, Lehrte , as well as other terminals outside Germany.

The transport chain became more sustainable through a better use of the available resources.

A number of bottlenecks had to be corrected and new management systems/tools had to be introduced.

Modal shift from road to rail is a must through a profound modernisation of the rail economy based on lower costs delivering at the same time better services. This paradigm was solved by generating extra capacity by increased productivity and by new local investments in hardware and software.

TIGER project brought the vessels nearer to the points of cargoes' origin/destination. It reduced port congestion and created an innovative distribution model capable of utilizing existing resources, maximizing capacity of rail lines, reducing transit time and increasing the logistic chain efficiency. TIGER effectively implemented the idea of maritime integrated with overland services in economies of scale through an efficient network of inland Hubs. The TIGER concept proved very successful both in the North European range as well as in the South. In The North the major European Ports increased their market accessibility further into the hinterland. As a result the rail market share compared to the total port throughput increased both in Hamburg, Wilhelmshaven, Rotterdam and Antwerp, whereas in the Mediterranean Genoa and Valencia managed to increase their total port throughput extending their accessible area. Similarly other smaller ports(in containers) such as Trieste doubled their rail component traffic year after year towards both the North and the East. These very successful stories proved the Tiger concept validity. In Germany where economies of scale exists the concept was extended also to Inland navigation terminals such as Duisburg.

The TIGER solutions have been progressively developed and implemented in the main European ports, evidencing the mutual benefits for different modes deriving from an efficient and effective commercial implementation of a synergic approach in the market place.

8.4. COVID-19 & freight transport

The first half of 2020 will be always remembered for the tremendous and unprecedented explosion of the COVID-19 outbreak. "Covid-19" is a corona virus mysterious code name signifying for EU citizens a backward summersault of some decades in terms of lost habits, mobility, freedom, comforts, future generations' dreams and perceptions. All of a sudden, EU citizens feel doubtful and unsecure about their future. The transport sector played a crucial role in the

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management of the outbreak, acting as a key player in the midst of what appears to be a major worldwide disaster. The outbreak can (and probably will) act as a "game changer" in the transport world well after the end of the worldwide crisis.

The lockdown demonstrated incredible EU resilience of the freight transport system. Millions of people have been forced to stay at home, many activities/factories have been closed but all freight transport modes kept operating, bringing essential food/consumers/medical supplies to vicinity shops and supermarkets. In many cases up to our doorsteps. The Transport and logistics community were defined as constituting "essential activities". It is this vital cargo mobility allowing the rest of population to implement effectively the lockdown. The general public in recent years attributed to transport in general negative reputation due to externalities such as traffic, noise, congestion, emissions. Covid-19 contributed to change these perceptions. Transport and logistics are in fact the chains of survival and resilience as long as necessary both in bad and good time.

Road transport, which in recent decades proved invincible for efficiency, punctuality, flexibility, adaptability to changing business conditions demonstrated, for the first time, vulnerability during the COVID-19 crisis. This is due to frontiers closures or increased health controls at borders for limiting the spreading of the virus. Colossal queues were generated as a result bringing disruptions on supplies and pressures on people and road infrastructures. The limiting factors to free international trucks circulation are not going to fade away shortly. The human factor plays a role since drivers do not like to cross the borders under the threat of being forced into quarantine. When this does not happen in the visited country, the introduction into quarantine is certain upon return at the home base. This has an impact on the vehicles productivity, increasing the road transport costs.

To solve this problem one has to look at past history when the transit permits were a limiting factor for crossing bordering countries. In those days, in order to overcome the transit limitations, the change of tractors relay was organized using domestic drivers to uncouple/couple the semitrailers to cover the lack of permit distance. This system was used in long trunk particularly in the North/South corridors between the Mediterranean countries and Scandinavia. Also in some West/East corridors this practice was in use before the introduction of the "Rolling Motorway". May be it will be used again in larger scale although more complicated and expensive introducing new rigidities. This is the modern reproduction of the stage coach system when the horses were changed in the Post Houses.

Rail freight and intermodality including inland waterways, in COVID-19 conditions and thereafter seem to be in a more favorable operating situation. There is no change of pattern applying an industrial transport chain. The human element is much less relevant and in presence of concentrated traffic flows where scale economies are achieved the costs element is reduced substantially also in relativly short distances. For long distances, it is widely known that rail transport is reducing the transported unit cost progressively in proportion to the distance longer length unlike road that produces opposite effects. Also intermodality derives from history. On 19th century Italian wine was transported on wooden barrels over road carts pulled by horses across the Gothard pass up to Basel, and then via the river up North in barges. The return trip was filled with cargo to Genoa. These must have been adventurous trips but this was at the time an established busy routing not only for wine barrels. It was already the father of the busiest North

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South Rail corridor.

Modern logisticians may not be too proud of their solutions since everything had already been invented before. So it is possible that they become under pressure from their Companies may be shifting part of their transport portfolio from road to rail in order to keep a steadier flow in their Supply Chains having to compromise on punctuality. But is punctuality still a deciding factor under COVID-19 trading conditions and thereafter? Which will be the new priorities and the prevailing people's mobility rules? The "just in sequence" logistics approach will survive to the very low cost of money? What will remain of the past "Pull/Push" techniques? The smart work and the use of new technologies will they benefit a more centric industrialized rail freight system opposed to a fragmented one? These questions encompasse the "game changers" for transport and logistics from which Rail Freight Transport might emerge centric in novel EU mobility chain banking on its network capillarity combined with cost reduction needs.

The environmental dimension will be judged differently after COVID-19. The outbreak showed us the unusual image of deserted cities, forlorn individuals lost in the unreal silence of empty streets where only policemen and ambulances with their sirens mark a dramatic change of scenario compared to a short while ago. No cars, no emissions, no gases, no particles, no congestion, no noise. People forced to remain indoor prevented for enjoying the outside, but there is fresh unpolluted air out there. In the surreal silence of the urban conglomerates, rail transport re-affirmed its importance, and claimed a new role in the global transport ecosystem. Rejuvenation of rail might be one of the most disruptive positive externalities of the crisis.

Another misconception on "who is causing what" in city centers and neighborhood villages is abated. The evidence is that this is due to the private cars, not trucks or public transport. To this effect, public transport might gain new energies and boost from this experience, making important steps towards the implementation of the co-modality principles. Integration of rail network with other transport means, such as tram, metro regional/suburban rail, appears during/after the outbreak more than ever, a must.

Figure 34: Past and present (or future) of freight transportation – Source: NEWOPERA Aisbl

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9. Perspectives

Can rail become the backbone of the European transport system of the future? This question accompanied the TER4RAIL consortium through the whole project lifetime. And the answer is Yes. This was demonstrated through the analysis of documents, projects, roadmaps, deliverables, data and statistics collected on all facets of the rail sector by the members. And the answer is yes even when analysing the success stories described in this short report. These are some examples coming from the real world of efficient and effective implementation of rail services in Europe, and these constitute a great demonstration of the disruptive potential rail can have in shaping the future of the transport system, be it public transport, mainline or freight. Rail can become the backbone of the European transport system of the future, and strong arguments are provided in the TER4RAIL project research (and in this report, too). But this is not a process taking place automatically. Strong cooperation is required between rail stakeholders and between rail and experts coming from other sectors/scientific disciplines, bringing added value and concretely making a step towards a multimodal transport system with rail at the centre. To do so, greater levels of financial investment in R&D are also required, and further research on important topics such as digitalization, Artificial Intelligence, machine learning and big data, putting them at the service of the user. Finally, the involvement of the public authorities, the planning bodies and the user's communities is fundamental both for guaranteeing a fruitful deployment of the above mentioned activities and for producing the necessary behavioural step change required.

TER4RAIL
Transversal Exploratory Research Activities for Railway
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10. References

6th Transport Research Arena April 18-21, 2016 - C4R (Capacity4Rail) project increases rail capacity without laying down new tracks - Franco Castagnetti, Armand Toubol, Giuseppe Rizzi

Alta Velocidad en España: Atlas 25 aniversario. Abril 2017. Fundación de los Ferrocarriles Españoles

Andersen, Sven: "High-Speed Rail in Spain, a statement from a foreign expert". 360. Revista de alta velocidad, nº 6, junio 2018. Fundación de los Ferrocarriles Españoles

Anuario Estadístico del Ayuntamiento de Madrid, año 2018

Anuario Estadístico de la Ciudad de Barcelona, varios años

Atlas of High-speed rail. December 2019. UIC and Spanish Rail Foundation (FFE – Fundación de los Ferrocarriles Españoles).

CER and DB Netze "Longer trains Facts & Experiences in Europe Results of the CER working group on longer and heavier trains", 2018

CER Longer trains - Facts & Experiences in Europe - Results of the CER working group on longer and heavier trains - 2018, 4th edition

Diez años del Ave Madrid-Barcelona. Vía Libre nº 627, marzo 2018. Fundación de los Ferrocarriles Españoles

Fernández Jañez, Judith: "Una visión actualizada de la competencia entre el tren de alta velocidad y el avión". 360. Revista de alta velocidad, nº 3, octubre 2015. Fundación de los Ferrocarriles Españoles

García Álvarez, Alberto: "La alta velocidad, necesaria para mantener el tráfico ferroviario de l arga distancia". 360. Revista de alta velocidad, nº 4, diciembre 2016. Fundación de los Ferrocarriles Españoles

García Álvarez, Alberto; Rubio García, Álvaro: "La optimización de las tarifas de alta velocidad". 360. Revista de alta velocidad, nº 4, diciembre 2016. Fundación de los Ferrocarriles Españoles

Horario Guía de Ferrocarriles y Líneas Aéreas, varios años

Informe: Línea de Alta Velocidad Madrid-Barcelona. Vía Libre nº 517, marzo 2008. Fundación de los Ferrocarriles Españoles

Institut National de la Statistique et des Etudes Economiques www.insee.fr

M2O Marathon2Operations Project, 2019

Marathon Project Handbook, 2014

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no. 826055 (TER4RAIL)

Nantes Metropole website and Annual Reports, various years

Notaires de France https://www.notaires.fr/fr

Observatorio del ferrocarril en España 2018. Fundación de los Ferrocarriles Españoles

Spider Plus Project, 2015

Statistics Vienna website www.statistik.wien.at

Renfe: Guía horarios 1991

RENFE. Sostenibilidad y Medio Ambiente. https://www.renfe.com/FR/empresa/RSE/compromisos_y_acciones/sostenibilidad.html

Tiger Project, 2013

UN World Urbanization prospects

Wiener Linien Annual Reports, various years