Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Migration scenarios and paths

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Deliverable 53.2

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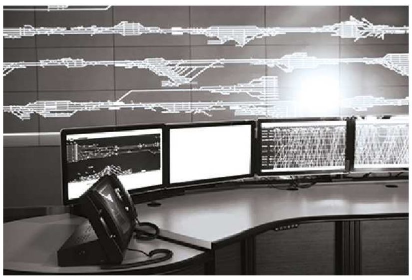




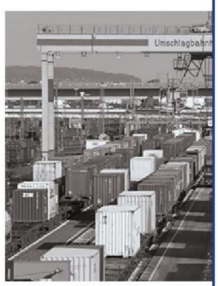

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Executive Summary

This deliverable, D5.3.2 Migration Scenarios and Paths, presents a link between work packages WP5.1, WP5.2 and WP5.4, as well as bridging between the technical SPs (SP1, SP2, SP3 and SP4). This takes targets originally defined in D5.1.1 and looks at how they are applied to the C4R innovations, aims to understand the innovations as well as analyse the specific case study lines and routes and gather data on these to allow innovations be applied specifically within WP5.4. Not all of the case study lines have been used in WP5.4, those that weren't, their analysis and baseline data is presented in this deliverable. However, for those that were used within WP5.4, the detailed data and final scenarios are presented as part of the cost benefit analysis within deliverable D5.4.2/3.

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Abbreviations and acronyms

Abbreviation / Acronym	**Description**
C4R	Capacity4Rail
CBA	Cost-Benefit Analysis
DOW	Description Of Work
KPI	Key Performance Indicator
LCC	Life Cycle Cost
MCA	Multi-Criteria Analysis
RAMS	Reliability, Availability, Maintainability, Safety
SP	Sub-Project
TEN	Trans European Network
TRL	Technical Readiness Level
WP	Work-Package

1 Introduction

One of the very first tasks of CAPACITY4RAIL SP5 was to define a comprehensive roadmap to describe the necessary steps to develop and implement innovation and to progress from the current state-of-the-art to a shared global vision of the 2050 railway along realistic scenarios.

Five major requirements have been defined for all the developments within this project: The future railway system should be affordable, adaptable, automated, resilient and high capacity, the definitions are described in detail in the Capacity4Rail deliverable D5.1.1.

SP5 “Migration Scenarios and Paths” contains the horizontal aspects of C4R, interacting with the four technical pillars of the project. The objectives of SP5 are to set up the assessment framework, describe the collective “Vision” and scenarios, coordinate the demonstrations and conduct the global assessment of the project outputs to finally propose a roadmap for the future research work and implementation of the innovations to ensure the migration of the current railway system towards the targeted vision and align with the ambitions of Shift2Rail.

The work of WP5.1 outlined the available national and European strategies, a global vision for the future railway system requirements, including the definition of five key aspects of the vision: affordability, adaptability, automation, resilience and high capacity. For each of these five criteria, a timeframe for subjects for research and development were setup, scheduling the successive steps of development, demonstration, legislation and implementation.

The assessment framework has been set up in WP 5.2, with the identification of methodologies, collection of needed data, and creation of analysis templates. Work package 5.3 *“Scenarios and migration”* aims to define the selected migration scenarios and paths and to develop the steps to migrate from existing rail system to the one envisioned in WP5.1, taking into account the innovations and technologies identified in SP1 to SP4. However, this work is supposed to set up from the innovations and technologies to be developed by the sub-projects (SP1-SP4) as well as on the common vision and roadmap for railway in 2030/2050 developed in WP5.1. This particular part of the work has also been carried out in very close cooperation with WP5.4 and the assessment and scenarios have been developed together.

This document is structured to reflect the different aims of this deliverable, firstly giving an overview referring to the agreed the terminologies and definitions, the roadmap and defined KPI’s and selected corridors in the C4R project.

In the subsequent chapter the approach regarding the definition of the scenarios is presented, that highlights the distinction between the generic scenarios related to SP1-SP4 innovations and the specific scenarios related to the selected corridors. However, this deliverable describes the possible scenarios in a global way with different possibilities just related to the indicated innovations and technologies of the SP1 to SP4 and describes the initial qualitative analysis which was carried out to identify where the different C4R innovations will impact on the targets set out in the roadmap..

2 Objectives

The overall aim of this document is to identify and describe the migration scenarios and paths, as this work was carried out with WP5.4, the final scenarios which have been assessed are presented within that work package's deliverables. However, in this document the development of the scenarios and the steps to migrate from existing system to the future one agreed in WP5.1, are described, taking into account the innovations and technologies identified in SP1 to SP4. In this regard, the innovations that will be developed within the project will be discussed. The TRL levels of the innovations, and possible time frames to be reached with the expected outputs will be discussed.

The output of this deliverable describes the input for the assessment of the technologies and innovations to be carried out in WP5.4 in terms of CBA, where the migration scenarios have been developed in greater depth for two of the four case studies which have been presented here. The development of the specific migration scenarios have required very in depth discussions with the other Capacity4Rail SPs and persons familiar with the case study routes to fully understand how the migration would occur in a real world scenario.

3 General overview

3.1 Terminologies and definitions

Early on in SP5 the need to identify common definitions was established. These common definitions proved necessary to ensure that the communication within the project was consistent and well understood. The terminology as defined below and also within WP5.1 was developed and is specific to the context of the Capacity4Rail project.

Vision

The Vision represents the overarching aims and aspirations for the railway system as reflected in European Union and National Long-term strategies for Rail. The vision describes the railway which meets the demands of the scenarios developed and defined by representative bodies given specified drivers.

For example a vision to address the scenario of increased demand for commuting journeys from suburban areas into city centres may be "capacity at peak travel times on commuter routes will be doubled by 2050".

Drivers

In the Capacity4Rail project the drivers are, along with the Vision, the potential socio- economic or environmental futures against which the needs and use of the railways will be considered.

The drivers might for example be:

"by 2050 urbanisation continues to increase and 90% of EU populations live in an urban environment and, work places are concentrated in the urban centres increasing the demand for travel from the suburban areas into central business districts and increasing demand for interurban travel"

or an opposing alternative may be

"by 2050 the increase in technology and ubiquity of high speed internet connections lead to an increase home working, halting the rise of urbanisation, existing commuter routes are underutilised and uneconomical. Demands to connect smaller communities to public transport systems is increasing".

Another alternative may centre around the threat of self-driving personal vehicles on the highway

"by 2050 self-driving and self-parking highway vehicles are the transport mode of choice for all long distance and medium distance personal and freight journeys. Autonomous vehicles provide greater comfort, an end-to-end journey and equal or faster total journey times. Public transport reserved for commuting travel into highly congested urban areas or for low earning families unable to afford to purchase or access to personal autonomous vehicles".

Target

Targets are specific, measurable, and have a time reference. Targets are derived from the visions, and it is against the targets that the progress of the Capacity4Rail innovations will be measured. Eg a target may be to halve operational costs on a specific route by 2050.

Scenario

A scenario is a potential 'combination of situations' that the future railway may be required to cope with, including the characteristics of railway routes (infrastructure, local climatic conditions & variations, operations, bottlenecks etc.) and particular combinations of overarching drivers. For example, to meet the vision of doubling freight capacity by 2050 with the socioeconomic driver of increased urbanisation, one scenario might be "24hr freight operations in urban areas".

Within Capacity4Rail several scenarios should be considered, and their likelihood based on current trends should be evaluated. For each scenario, visions should be created for what the characteristics of the railway should be for each scenario.

The role of scenarios in C4R is to both test the outputs and also demonstrate how C4R outputs will help deliver the 2050 vision of a higher capacity passenger and freight railways that can be delivered more efficiently than today's railways through improved reliability, affordability, resilience and automation.

Baseline

The baseline is against which the path will be compared. The baseline to be assessed can be considered as the do minimum/do nothing case. However, it must be assessed against the same criteria as the C4R technology. For example if the technology is being assessed against the freight traffic loads of 2050, the baseline case should also be assessed against the same boundary conditions.

Bottleneck (physical constraints)

In this context bottlenecks are more physical infrastructure constraints such as heavy loaded/operated critical parts of the railway network, i.e. critical nodes, level junctions connecting different routes, heavily operated track sections, etc. Capacity constraint is related to track sections on corridors, where the total traffic demand of freight and passenger trains exceeds the available capacity including consideration of capacity used for maintenance works per section. For example a capacity constraint could include braking performance; vehicles may be also seen as critical components of the railway system as a whole: the technical state and amount of vehicles is critical for the railway operations and its operational flow.

Migration

The migration path is the implementation of a specific technology to achieve a vision. For example a migration path to address the vision of doubling capacity may be "highly reliable slab track which requires minimal maintenance and interventions over its lifetime".

Path

A path is a timeline of migrations and combination of technologies within a scenario for a particular case study.

Case study

Case studies are used to assess the migration path technologies. The case study will compare a technology against a base case for a specific geographical location or route and the physical characteristics of that route/location and traffic characteristics can be applied to assess the impact of the innovation and how far it goes towards achieving the vision.

Boundary conditions

Boundary conditions are part of a case study, they define the boundaries of the assessment, what is in and what is out of the assessment, and define the for example traffic.

Technology

A technology is an innovation or identified technology developed from SP1-SP4 in the Capacity4Rail project which is to be assessed against the baseline case.

Specific parameters (technical objectives)

The specific parameters are the technical objectives for the innovations developed within the C4R project. These technical objectives are defined within the C4R work packages and will contribute towards the targets. (eg a specific parameter may be mean delay time due to maintenance, this specific parameter is directly linked to the target of reduction of train delays due to infrastructure failures.) Each specific parameter has a baseline value and a Scenario 2030 and Scenario 2050 objective.

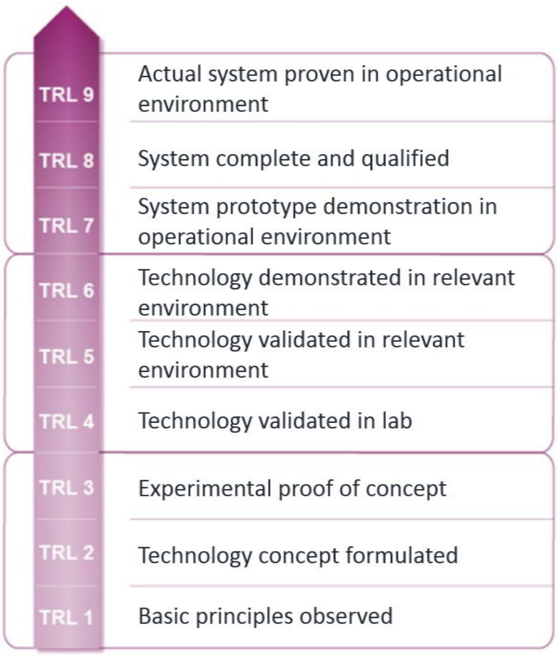
Roadmap

The impacts of the innovation/technology are the extent to which they contribute towards the targets.

The roadmaps set the 2050 vision for an affordable, adaptable, resilient, automated and high capacity European railway. The starting point for each roadmap is the definition of one of the five aspects of the vision. While it is clear that there are interdependencies between the five aspects, for clarity and to reduce duplication, the definitions have been scoped to reduce, as far as practical, interdependencies between them.

Technology Readiness Level –TRL

Technology Readiness Assessment (TRA) is a systematic and metrics-based process used to assess the maturity of new technologies and concepts. TRL tables are a set of nine progressive levels that any technology needs to go through before being considered sufficiently mature to be used in a complex operational system.



3.2 Roadmap, project targets and defined KPI's

The roadmap has been developed within WP5.1 and can be described within Deliverable 5.1.1. This roadmap will be further updated at the end of the project within deliverable 5.6.1, Refined Railway System 2030/2050. The initial roadmap has provides inputs into the project targets and for the definition of the scenarios.

D5.1.1 roadmap - relevant points for the development of the scenarios:

The report provides initial versions of five high-level roadmaps. The roadmaps set the 2050 vision for an *affordable, adaptable, resilient, automated and high capacity* European railway. The starting point for each roadmap is the definition of one of the five aspects of the vision.

The roadmaps have been developed following a review of literature - including key documents such as the *European Commission's White Paper*. They include key metrics and published targets towards delivering the vision, as well as a list of broad-based research and development activities. Research activities undertaken by Sub-Projects 1 to 4 (on infrastructure; new concepts for freight; operations for enhanced capacity; and advanced monitoring) of Capacity for Rail (C4R) project should, therefore, align with these activities. To achieve alignment, a workshop had been held with representatives of all the Sub-Project teams to review the roadmaps in the light of the state of the art information derived by the Sub-Projects.

Following the workshop the high-level roadmaps have been revised and delivered as an important reference for the Capacity4Rail project to show how the project is contributing to the delivery of the overall vision for the European rail network of 2050.

A number of different formats were trialled during the development of roadmaps. Following team reviews, it was agreed that the format for the roadmaps would combine an appropriate level of detail in logical structure that allowed the information to be presented on a single A3 page.

Each roadmap comprises three sections.

- A timeframe showing targets, taken from literature review, that are apposite to the achievement of the key aspects. Targets are grouped under three headings; for example, economic, environmental and safety for an "affordable" railway.
- Relevant outputs that will contribute to (or are associated with) the achievement of the targets, and a set of relevant transport industry trends and drivers.
- Subject for R&D broken down into three broad categories: (a) infrastructure and rolling stock, (b) operating models, (c) documentation. A further breakdown by time and activity type (that is R&D, demonstration projects, legislation and implementation) is provided using colour coded arrows.

*More details on the roadmap and defined targets can be taken from D5.1.1.

Regarding project targets

The crucial research and development benefit of Capacity 4Rail lays in the systemic and holistic approach to the development of new concepts for future infrastructure, vehicles, communications and operation technologies. The capacity issue is addressed in three different ways:

- A more efficient use of existing resources, by optimising operating strategies, enhancing traffic planning, improving trans-shipment procedures and improving automation and operational procedures to reduce the time needed to recover from traffic disruption
- A reduction of the non-operational capacity-consumers, through the design of resilient, reliable and low-maintenance infrastructure and vehicles, non-intrusive inspection, fast renewal and construction processes
- An increase of the performance of existing resources, through significant improvements of wagons maneuverability and equipment to answer freight customers' needs for higher Reliability and performance

Regarding the KPI's define in C4R:

KPIs specifically address among others items the noise reduction, the commercial speed improvement, the punctuality, the energy saving and the maintenance cost reduction on the wagon and on the rail. Defined KPIs for each SP's within C4R are as follows;

SP1

- LCC = 20% less than conventional design
- 50% shorter timeslots for maintenance

SP2

- Overall capacity improvement +20% in 2020 and +50% by 2030

SP3

- + 20% capacity by 2020
- + 50% reliability by 2030
- - 30% operational costs by 2030

SP4

- 50% reduction of track unavailability by 2030

4 Selected corridors

Within D53.1 the whole current railway system was presented as a network of railway corridors and supporting points (real sites) for carrying more comprehensive information gathering for locations for the assessment of the migration to the new C4R systems, within WP5.4.

Real sites/corridors have been chosen in order to prepare the assessment of migration to the future rail system.

The partners involved in SP5 initially agreed to consider the following corridors for developing the scenarios,

- East Coast Mainline in the UK
- Regarding the Scandinavian-Mediterranean corridor (Malmö to Mjölby in Sweden)
- North Sea- Mediterranean (Perpignan, Marseille, Metz, in France)
- Rhine-Alpine (German section)

However, this list was further refined based on the availability of data and detailed baseline data was collected for the following corridors:

- East Coast Mainline in the UK
- Scandinavian-Mediterranean corridor (Malmö to Mjölby in Sweden)
- North Sea- Mediterranean (Perpignan, Marseille, Metz, in France)
- North Sea – Mediterranean (Spanish section - French/Spanish border to Barcelona and Valencia)

Each of these routes are introduced below and detailed baseline data for East Coast Mainline in the UK and the North Sea-Mediterranean Spanish Section are presented in the appendices to this deliverable. Whereas the detailed baseline data for the other routes are presented within the deliverables related to WP5.4. The reason for this is that due to time constraints only two of the corridors were taken forward for assessment in WP5.4 and therefore the detailed baseline data was collected and the scenarios refined as part of that work package.

4.1 Scenario Definitions For a Selected Corridor

On a selected corridor section, a baseline scenario is then defined by the available data about that route. This data should include the following:

- Infrastructure characteristics: Number of tracks, density of S&C
- Monitoring and maintenance strategy
- Track possession strategy
- Train characteristics - maximum loading of vehicles and utilisation
- Traffic scenario – numbers of trains passenger and freight,
- Traffic management principles and signalling system
- Incident and natural hazards

  - Costs related to current infrastructure maintenance and operation costs
  - Value of time and delays
  - Environmental impact (Emissions of CO_2e) and the economic impact from emissions.

For each selected corridor the route is segmented, so that within each segment

- Ensure the availability of data. Each chosen site/corridor will be described in detail incl.:
  - Location (country/countries and regions),
  - Local conditions (climate, natural environment, etc.),
  - Site characteristics, boundaries, infrastructure, constructions
  - Operations,
  - Capacity,
  - Hazards and safety issues,
- Collection and first evaluation of gathered information
- Check if there are appropriate climate issues (flooding, extreme temperature, etc.) on the selected routes

The detailed corridor analysis should also refer to following questions:

- Why these corridors have been selected
- What is not under control?
- What are the weak points, constraints, hazards ("hot spots")?
- Are there any sections where capacity constraints are now or will be in the near future?
- How the C4R technologies/innovations can improve the situation in terms of solving the capacity shortage (in short-term view 2020, mid-term 2030 and long-term view 2050)?
- What are the current investment plans under TEN-T, or national upgrades and the time frames of these?

4.1.1 Comparison to road corridors and road data

The Capacity4Rail targets include increased capacity for future increases to freight and passenger traffic as well as for modal shift from road to rail. As a consequence, the Capacity4Rail scenarios must also consider data from road, including:

- Operational cost of road freight and passenger vehicles
- Utilisation of road vehicles
- Maximum loading of road vehicles
- Value of time/cost of delays for road freight and road passengers
- Environmental emissions and economic value of road vehicle emissions

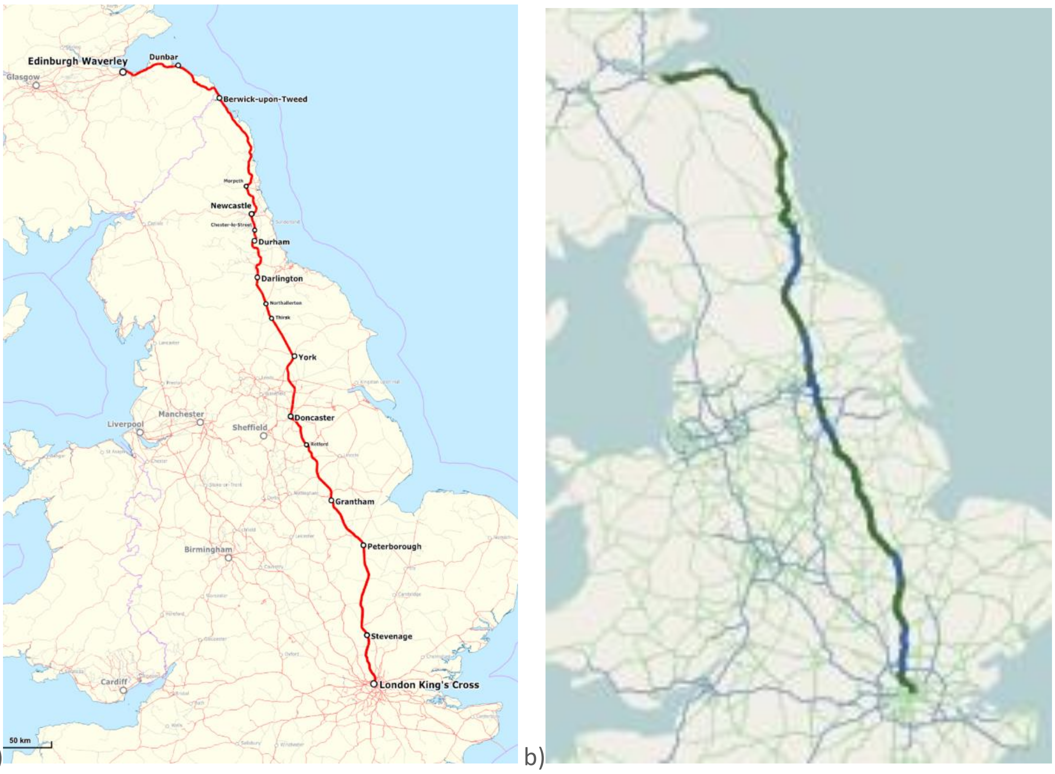
4.2 Overview of Selected Routes/Corridors

4.2.1 East Coast Main Line: Peterborough- Doncaster corridor

The ECML in the UK runs from London to Edinburgh and is a mixed traffic route. The ECML runs for a total length of 632km (Figure 1 a) East Coast MainlineFigure 1), mainly with a 4 track layout, with two tracks (one for each direction) for the slow lines and two tracks (one for each direction) for the fast lines. Mixed traffic runs along the whole route with long distance intercity services mixing with regional stopping services as well as with freight.

The route is also roughly followed by the A1 road (660 km), which passes close to the same urban areas. The A1 has several sections which are upgraded to motorway status (shown in blue in Figure 1), however many sections are still truck road status and in some stretches still single carriageway. The A1 is part of the European route E15, from Algeciras, Spain to Inverness, Scotland.

This case study concentrates on the ECML and A1 sections from Peterborough to Doncaster. In this stretch the freight services are mainly separated over a branch via Lincoln (Great Northern Great Eastern line) to improve capacity and performance on the main passenger route. Over the same stretch from Peterborough to Doncaster the A1 is all dual carriage with between 2 and 3 lanes of traffic in each direction. For most of the stretch from Peterborough to Doncaster the A1 is classified as a trunk road, however, the sections around Peterborough and Doncaster are of motorway classification.



a) b)

Figure 1 a) East Coast Mainline and b) A1 road route

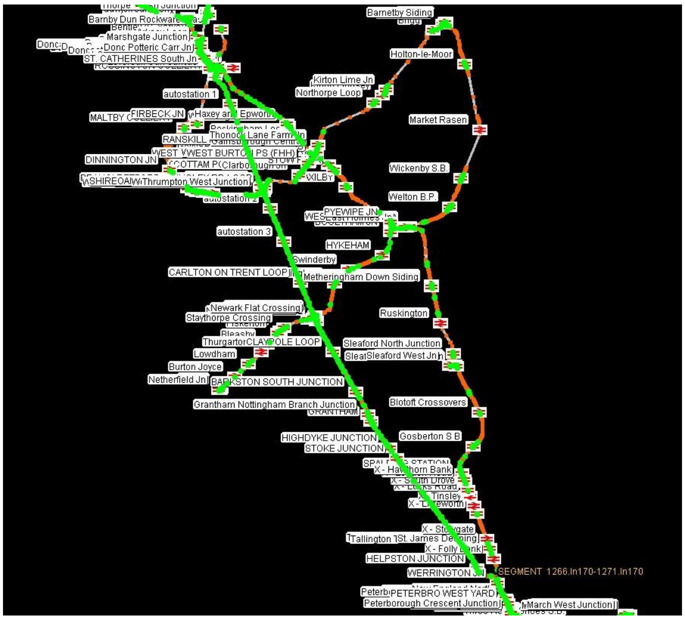


Figure 2 Portion of the ECML between Peterborough and Doncaster

A detailed description of this route, baseline and future scenario data can be found within Appendix 4 of this deliverable.

4.2.2 Scandinavian-Mediterranean corridor (Malmö to Mjölby in Sweden)

Swedish portion of the Scandinavian-Mediterranean TEN-T Corridor, as illustrated in Figure 3.

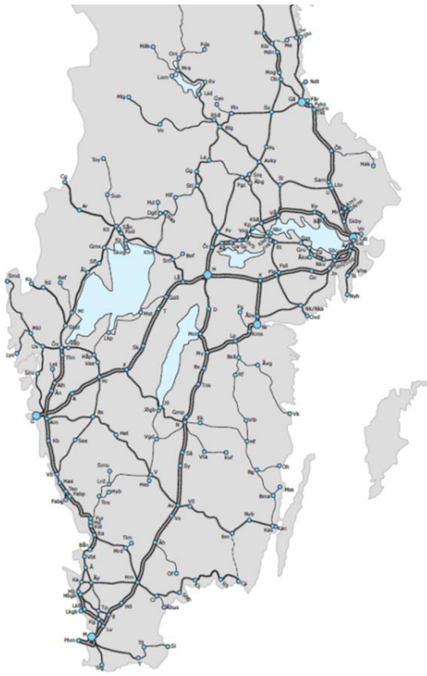


Figure 3 Swedish Section of Scandinavian-Mediterranean Corridor

For this analysis, the considered sections of the Swedish network are presented in **Erreur ! Source du renvoi introuvable.**.

Table 1. Scandinavian-Mediterranean Corridor's Network sections

Rail Corridor Segmentaion					
S5	Stockholm - Katrineholm	**S5**	Nässjö-Alvesta	**S7**	Kungsbacka-Ängelholm
S5	Katrineholm-Hallsberg	**S6**	Alvesta-Lund	**S7**	Ängelholm - Kävlinge via Helsingborg
S5	Katrineholm-Norrköping	**S5**	Lund - Malmö	**S7**	Ängelholm - Kävlinge via Åstorp
S5	Norrköping-Mjölby	**S6**	Oslo-Halden	**S7**	Kävlinge - Lund
S5	Hallsberg - Degerön	**S6**	Halden-Öxnered	**S7**	Kävlinge - Malmö
S6	Degerön - Mjölby	**S6**	Öxnered-Göteborg	**S8**	Malmö - Trelleborg
S5	Mjölby - Nässjö	**S7**	Göteborg - Kungsbacka	**S9**	Malmö - København
Road Corridor Segmentation					
S5	Stockholm - Helsingborg (E4)	**S6**	NO border - Gotebörg (E6)	**S8**	Malmö - Trelleborg (E22)
S5	Helsingborg - Malmö (E20)	**S7**	Göteborg - Helsingborg (E20)	**S9**	Malmö - København (E20)

A detailed description of this route, baseline and future scenario data can be found within deliverable D5.4.2/3.

4.2.3 North Sea- Mediterranean (Perpignan, Marseille, Metz, in France)

A section of the Perpignan – Luxembourg corridor was selected, specifically a section just north of the Spanish border between Montepellier –Béziers, where there is currently a capacity constrain. This can thus be treated as a bottleneck analysis where the main aim is to solve the capacity shortage.

The scenario that is presented here was discussed and agreed during a Workshop Meeting in Paris on April 12 and 13, 2017.

The rail corridor section under analysis extends from Montpellier to Béziers along the Nîmes to Narbonne line that connects to the Spanish border at Perpignan. This is shown on the following map:

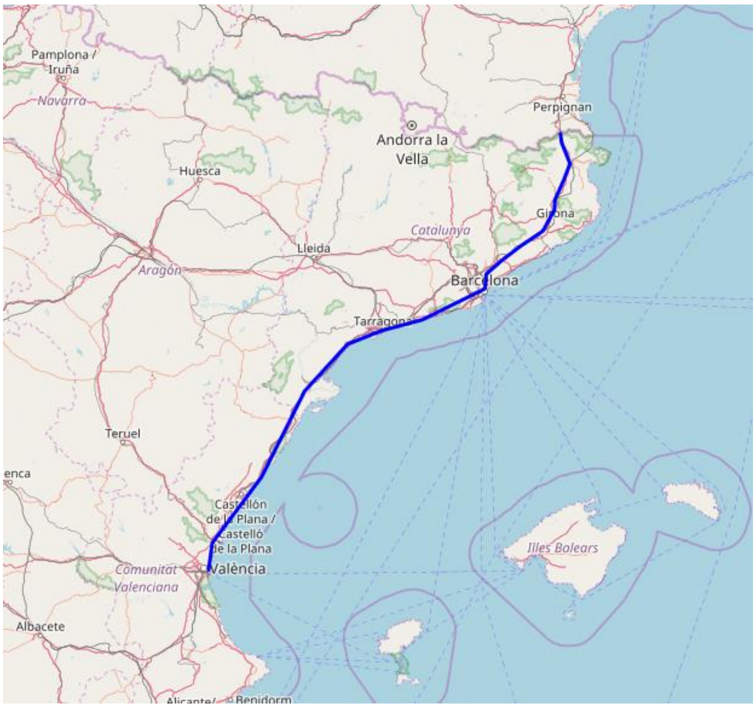
This stretch of rail runs roughly parallel to the A9 motorway between Montpellier and Béziers, which makes this the main road alternative, as shown on this map:

The discussions we had with the partners, including the Workshop carried out in Paris on April 12-13 allowed to characterize the stretch of the corridor as a bottleneck that is limiting further traffic growth due to lack of capacity. For this reason, we treated in in our analysis as being currently operating at 100% capacity.

A detailed description of this route, baseline and future scenario data can be found within deliverable D5.4.2.

4.2.4 North Sea – Mediterranean (Spanish section - French/Spanish border to Barcelona and Valencia)

The Spanish section of the Mediterranean TEN-T corridor from the French/Spanish border to Barcelona and Valencia was also analysed as a possible case study line and analysed for bottlenecks.



A detailed description of this route, baseline data and analysis can be found within Appendix 5 of this deliverable.

4.2.5 Analysis of the Mediterranean Corridor

In addition, the Mediterranean corridor was assessed for bottlenecks and its potential as a whole corridor case study, however, there was a lack of detailed data for the whole of this route. This analysis is contained within Appendix 6 of this deliverable.

5 Development of the scenarios

5.1 Definition of the Baseline scenario

Work package 5.3 “Scenarios and migration” aims to define the global and selected migration scenarios and paths, and to identify the steps to migrate from existing rail system to the one envisioned in WP5.1, taking into account the innovations and technologies identified in SP1 to SP4.

By defining the scenarios a distinction between the generic scenarios (related to SP1-SP4 innovations) and the specific scenarios (related to the selected corridors) have been made. However, in the following sections the possible scenarios are described in a global way with different possibilities, related to the indicated innovations and technologies of the SP1 to SP4, whereas the specific scenarios related to the selected corridors and routes are described partly in the annex to this deliverable for the East Coast Mainline and for the Spanish part of the Mediterranean corridor, and the specific scenarios for the Swedish part of the Scan-Med corridor and from Montepellier –Béziers are described in detail in D5.4.2.

The defined scenarios should refer to the C4R targets such as

- The fragility of some key component of the infrastructure system (especially in extreme weather conditions) such as switches may impact the efficiency of the whole system. The resilience of switches to any kind of known failure will be reinforced, as well as the ability of the operation system to recover from incidents (SP1)
- Intermodal integration within the global transport system will be improved through enhanced transshipment of passengers and freight (SP2)
- Capacity enhancements will also be achieved by higher speed freight vehicles, allowing an optimized interleaving of freight trains into mixed traffic, and improved planning models for operation (SP3)
- New concepts for low maintenance infrastructure, using standardized and “plug-and-play” concepts will be proposed. Non-intrusive innovative monitoring techniques or self-monitoring infrastructure will be investigated, allowing low or no impact (SP4)

However, the detail of the innovations has been dependent upon input from the different technical sub-projects. For example detailed descriptions of the innovations have been provided from SP2 regarding rail freight innovations (Appendix 7) and the close working relationship with SP2 has led to the refinement of the specific scenarios within WP5.4.

The baseline scenario(s), taking selected corridors or sections with the relevant characteristics of the railway routes (boundary conditions, properties, future demands, capacity constraints etc.) serve as a base to compare the current situation (without innovations) with the future situation (with the innovations of C4R). In addition, it is necessary to take into account the investment on specific corridors from the TEN-T projects, or other national investment schemes that will happen even without the Capacity4Rail innovation. For the different case study lines these investment schemes will occur at different times and the investment might only be applied to one part of the corridor first before being further expanded. This can have the impact that potentially the investment may start on some sections and depending upon the technology being implemented the benefits may not be realised until the upgrades have been completed on the whole route. For example infrastructure investments to allow for longer trains may not show any benefit until they applied to the whole route so that longer trains can operate on the full length. On the other hand there may be stretches, for example from a port to an inland terminal, which would see immediate benefit from the innovations being applied just to that stretch. To allow us to consider these possibilities the routes have been segmented, for the assessment, so that it is possible to see the costs and benefits as modifications and upgrades are made on different sections at different times. It is also possible to implement scenarios where the rolling stock is migrated over a period of time.

In terms of migration the time when the innovation will be available to be implemented (TRL 9) is very important.

Each innovation will have different aims – tackling different C4R priorities, different TRL levels and therefore the availability and accuracy of cost, reliability, availability, safety and capacity data will different.

5.2 Definition of the C4R scenarios

A scenario is a potential 'combination of situations' that the future railway may be required to cope with, including the characteristics of railway routes (infrastructure, local climatic conditions and variations, operations, bottlenecks etc.) and particular combinations of overarching drivers. For example, to meet the vision of doubling freight capacity by 2050 with the socioeconomic driver of increased urbanisation, one scenario might be "24hr freight operations in urban areas".

Within Capacity4Rail several scenarios should be considered, and their likelihood based on current trends should be evaluated. For each scenario, visions should be created for what the characteristics of the railway should be for each scenario.

It is also important to take into account scenarios for the future of road transport, if innovations in road freight, for example heavier loads and driverless vehicles reduce the costs of road freight this is expected to impact on the targets for modal shift from road to rail.

The role of scenarios in C4R is to both test the outputs and also demonstrate how C4R outputs will help deliver the 2050 vision of a higher capacity passenger and freight railways that can be delivered more efficiently than today's railways through improved reliability, affordability, resilience and automation.

In this approach the scenarios are set up from the C4R innovations and their key parameters related to the capacity enhancement. So the scenarios are derived from the C4R innovations with the associated technical parameters contributing to Reliability, Availability and Capacity, i. e. reduction of infrastructure down time and time for recover. However, a scenario could be also a combination of C4R innovations (set of various scenarios on the related routes). "If you use this type of innovation or combined innovations, it could help to increase the capacity and to cope with existing and future constraints of the selected corridor".

It should be emphasized that these C4R innovations are just one part of the EU vision and thus should be included in the System Approach for the desired European Railway Network 2050. The Migration Strategy and Vision for the 2050 Railway are provided through the SP5 work-stream. In this way the C4R innovations will be geared to produce outputs and outcomes that support the vision, and contribute towards EU vision.

Approach for the definition of the Scenarios

First, there was a need to clarify the difference between bottlenecks and capacity constraints. Bottlenecks are more physical infrastructure constraints such as heavy loaded/operated critical parts of the railway network, i.e. critical nodes, level junctions connecting different routes, heavily operated track sections, etc. Capacity constraint is related to track sections on corridors, where the total traffic demand of freight and passenger trains exceeds the available capacity including consideration of capacity used for maintenance works per section. For example, a capacity constraint could include braking performance.

In order to distinguish between what C4R innovations can influence and what they cope with (e. g. politics, demand), we have to look at current practices for short-term view (2020) as well as beyond current practices (take a long-term view to 2050), i. e. having those technologies to handle the future demands and higher capacity, always with regard to the migration (from existing to future situation, from TRL 1 to TRL 3)

In the context of C4R the scenarios are set up from the C4R innovations (SP1-SP4 innovations) and their key parameters related to the capacity enhancement. So the scenarios are derived from the C4R innovations with the associated technical parameters/ properties contributing to Reliability, Availability and Capacity, i. e. reduction of infrastructure down time and time for recover. Scenario could be also a combination of C4R innovations (set of various scenarios on the related routes). "If you use this type of innovation (also combination of innovations), it could help to increase the capacity and to cope with the existing and future constraints of the selected corridor".

These are the innovations/technologies that are developed by the SP's and the scenarios are focussed on:

SP1: Design of resilient & reliable low maintenance infrastructure

- WP1.1: Modular integrated design of new concepts for infrastructure (new slab track)
- WP 1.3: Switches & Crossings for future railways, enhanced resilience to failure

SP2: Improved specs for rolling stock and trans-shipment procedures

- WP2.2: New freight wagons with higher axle loads (> 25T/axle), automatic coupling with electrical connection, lighter wagons, track friendly running gear etc. More specifically the SP2 innovations refer to:
  - Innovation 1: 6 axle car design for transport of light automotive and heavy intermodal freight (maximising usable length) – using articulated bogies or shared wheel sets between wagons
  - Innovation 2: Increase flexibility of wagons to carry different containers by extending carrying capability over the buffers between wagons allowing carrying of 45' as well as 40' containers
  - Innovation 3: Improved braking to reduce maintenance costs – Electrically controlled braking valve on each wagon to ensure simultaneous braking leading to ability to have longer and heavier trains and reduced maintenance costs

SP3: Use of traffic management as an innovation, incident recovering by improved traffic planning and operating strategies

SP4: Integration of Advanced Monitoring Systems in the design & built-in process for easier to monitor infrastructure with low cost and low impact inspection

- New monitoring systems (WP4.3, WP4.4)

For the definition of the scenarios sophisticated templates have been created to be able to gather all the relevant information and boundaries from the SP's. At first step the set of key parameters with regard to each SP are described, which are relevant for capacity and project targets. With respect to each SP, the top targets and requirements of C4R have been determined. These top targets are based on the roadmap, defined KPI's of C4R project as well as on the EU White Paper scenarios. To compare the actual situation with the future situation (implies the use of the C4R innovations) it was necessary to identify the differences between the baseline (current situation, 2015), short-term view with 2030 and long-term view with 2050 for the definition of the top targets as well as the specific parameters, which is shown in the following for SP1 exemplary.

TABLE 2 DEFINITION OF THE TOP TARGETS EXEMPLARY FOR SP1

Top targets for Scenarios with respect to SP1			
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**
LCC (NPV, €)	100%		80%
Shorter timeslots for maintenance MTTR (hours)	100%	50%	-
Specific CO2 emissions by 2030 with respect to 1990, including embodied carbon		50%	-
Unavailability/Disruptions due to EW events (measured by infrastructure down-time); innovative design of infrastructure being resilient to severe weather conditions	100%	40%	80%

In the next step the specific parameters (technical parameters), being relevant for the scenarios with respect for each SP, have been defined. As this was not that easy task for the SP's, several adjustment steps and coordination work between the SP's were necessary to refine these scenario templates. Since the scenario templates are considered to serve as input for SP3, the focus was both to decide on the specific parameters with realistic values and to provide useful input for SP3 capacity simulation. This is shown below exemplary for SP1.

TABLE 3 DEFINITION OF THE SPECIFIC PARAMETERS WITH RESPECT TO SP1

Specific Parameters (technical objectives) for Scenarios with respect to SP1			
Parameters	**Baseline**	**Scenario 2030**	**Scenario 2050**
Modular integrated design of new concepts for infrastructure - Innovative New Slab Track (WP 1.1)			
Reliability (MTBF)	100%		200%
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%
Unavailability due to inspection - (MDT)	100%	50%	20%
Maintainability/Installation of track (MTTR)	100%		50%
Flexible system			
CO2 embodied emissions	100%		50%
Low noise and vibration	compared to track system on the selected corridor	-5 dB(A)	-10 dB(A)
Innovative High Speed Track (WP 1.2)			
Optimisation of design (same LCC while increasing maximum speed)			
Innovative S&C (WP 1.3)			
Reliability of S&C (MTBF)	100%		200%
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%
Unavailability due to inspection - (MDT)	100%	50%	20%
Maintainability/Installation of track (MTTR)	100%		50%

It can be stated, that the scenarios definitions have been agreed with the SP leader and WP leader after reviewing.

Finally, the impact of the C4R innovations with the associated technical parameters on the five key aspects has been indicated qualitatively by each SP. In this regard, each SP had to answer how far his concerned innovation will contribute to the C4R project targets. The qualitative analysis has been carried out in order to determine the optimum benefit that the C4R innovations or their combinations may provide (see appendices). It should be noted, that the qualitative analysis has been discussed and agreed within SP1 to SP4.

The following table illustrates the approach regarding the combinations of the scenarios and innovations respectively.

TABLE 4 DEFINITION OF POSSIBLE COMBINATIONS OF THE SCENARIOS (EXEMPLARY)

Physical constraints of the selected route (hot spot) related to capacity	C4R innovations to cope with the constraints (what can be influenced by C4R innovations)	Strong impact on C4R targets (qualitatively guess by the concerned SP)	TRL of the concerned innovation (reg. Migration)	Additional contribution by other SP's innovation (considering of TEN-T projects already planned)	TRL of the concerned innovation (reg. Migration)	Scenarios based on combination of innovations to solve the existing constraints	Overall impact (assessment of the benefits based on the outcomes from WP5.4 and SP3)	Definition of the Migration paths
			2016/2030/2050		2016/2030/2050			2016 to 2050
Infrastructure constraint (conventional track system): big delays, high Maintenance activities and costs	**SP1 Infrastructure - Innovative New Slab Track**	Reduction of infrastructure LCC; Reduction of train delays due to Infrastructure; Increase of capacity for passenger & freight;	TRL of the innovative new slab track (SP1)	SP4: use of sensing technology, pre-failure detection (based on improved real-time data), reduced infrastructure (Maintenance) costs	TRL of the innovative sensors (SP4);	SP1 + SP4: Innovative New Slab Track combined with embedded sensor	Reliable infrastructure easy and rapidly to install due to modularity (RAMS and LCC oriented design)	
Infrastructure: capacity constraint, big delays, low Availability	**SP1 Infrastructure - Innovative High Speed Track**	Reduction of infrastructure LCC	TRL of the innovative high speed track (SP1)	SP2: Novel freight vehicles (e. g. train length, bundling of trains)	TRL of the innovative vehicle (SP2);	SP1+SP2: Innovative High Speed Track with novel rail freight vehicles	Flexibility to cope with traffic volumes changes by extending trains length safely with EP braking and central couplers	
constraints on a track section (e. g. bridges): disruptions (extreme weather), no Monitoring of structural health, high Maint. & inspection activities, low Reliability	**SP4 Non-intrusive innovative monitoring techniques**	Reduction of infrastructure LCC; Reduction of train delays due to IF (& EW); Increase of capacity for passenger & freight; Reduced unavailability (MDT) by using AMS	TRL of the innovative sensors (SP4)	SP1: sensors in precast track elements	TRL of the innovative infrastructure (SP1)	SP4 + SP2: Innovative sensors embedded in regular trains	more and better real-time data of the infrastructure for predictive maintenance	

Appendix 1 and Appendix 2 show the KPIs defined for C4R and the completed scenario templates respectively.

Evaluation of the Impact of C4R Innovations

As a first step, a list of the bottlenecks and capacity constraints respectively should be developed and then mirrored against the C4R innovations. That is to say that scenarios need to be defined that can mitigate these identified constraints and enhance the capacity. In this regard, there is a link between scenarios and assessment in WP5.4. For this purpose WP5.3 and WP5.4 have carried out an interview of each sub-project in order to understand the benefits of the innovations/technologies developed in C4R and how this will feed into the SP5 assessments (CBA). For this purpose WP5.3 has developed this interview template with the concerned questions (more details see WP5.4).

The more forward quantitative analysis then should start with a simple single line analysis and then build up to a system model (capacity simulation) performed by SP3. However, the final assessment of the benefits of the C4R innovations has to be performed by SP3 including the MCA, whereas the CBA is carried out in WP5.4 of SP5. Given that, the SP3 capacity simulation implies the capability trade-offs to enhance the capacity, considering different innovations on the selected corridors (sections) by comparison with and without innovations (also combination of innovations). The assessment results of SP3 and WP5.4 are supposed to feed in WP5.6 Guidelines and Follow-up Actions.

6 Definition of migration scenarios/paths towards 2030/2050

- *By defining the baseline cases and scenarios we should also consider when the C4R innovations will be ready for use (TRL 9), as an issue of defining the Migration paths. For instance, will the new slab track be built from now until 2030/2050?*
- *What if the innovations are not ready to be implemented until 2030/2050 and the impact on the evaluated targets in WP5.4? Of course, the best case would be if the C4R innovations/technologies are available to be implemented (TRL 9) before 2030, but not after 2050.*

In fact, scenarios/paths will pave the way of migration, the change from the existing rail system to the one envisioned in WP 5.1. According to the DOW the (global) migration scenarios should be considered in a global sustainable approach, including their financial, social and environmental impacts.

The migration path is the implementation of a specific technology to achieve a vision. For example a migration path to address the vision of doubling capacity may be “highly reliable slab track which requires minimal maintenance and interventions over its lifetime”. A path is a timeline of migrations and combination of technologies within a scenario for a particular case study.

The definition of the Migration paths is corridor specific and describes the implementation of the innovations/technologies of C4R project. However, the migration paths depend on many aspects, amongst others on technical (the defined TRL of the innovations), geographical, time frame, organizational, legal, market etc. aspects. Besides the implementation of the C4R innovations will be different with respect to each SP, but requires a step by step migration.

Migration scenarios to 2030/2050:

- TRL from the innovations
- Migration timeline: 2016 – 2050
- Migration on real corridors
- To be discussed and decided with other SP’s

By developing the migration paths it is necessary to look at current practices for short-term view (2020) as well as beyond current practices (take a long-term view to 2050), i. e. having those technologies to handle with the future demands and higher capacity with regard to the migration (from existing to future situation, from TRL 1 to TRL 3). Looking at the Migration issues and the issue on Cost Benefit Analysis (CBA): we have to consider that if the CBA goes from 2016-2050 some technologies may not be installed until 2040 so only 10 years of benefits.

6.1 Migration issues to be considered

There are various migration issues which should also be considered as part of the assessment within WP5.4. These include the disruption during installation and therefore, not only should the capital costs of installation be considered but the costs of the interventions due to train cancellations, or diverted or reduced services during the migration to the new technology. If there are to be major disruptions due to the upgrade work occurring over a long period of time, the possibility of it causing a temporary or permanent modal shift away from rail should be also be considered as a risk, for example logistics companies invest more heavily in road freight whilst the disruption is occurring and then continue to use road for the lifetime of their investment in new road vehicles. This effect is very difficult to quantify and use within the CBA, but should be considered as a risk, especially for technologies such as slab track, where the disruption may mean that such systems can only be used in new lines and are not a feasible solution for upgrading existing lines.

The migration should also consider the likely implementation phase, for example will new rolling stock be phased in over a period of 2 years or 20 years, and if it implemented over a longer period, at which percentage new rolling stock will the benefit begin to be realised. If implementation is too slow, the new investments may not start paying back in a reasonable timeframe, however, if implementation is too quick this may result in the writing off of significant values of existing assets. Similarly investment in track forms, switches and signalling systems could see the same effect.

7 Conclusions

This deliverable and WP5.3 has the aim of bringing together the background on each of the Capacity4Rail innovations as well as developing the specific scenarios related to the routes and corridors, to be used in WP5.4. Within this deliverable, the background and the targets for the different innovations have been gathered and collated, the task of gathering information from the other SPs and to understand the compatible combinations of innovations has also been carried out.

Presented in this deliverable is also baseline data and scenarios and route analysis for the lines which were originally selected, but due to time constraint were not used for the assessments within WP5.4. The baseline data and scenarios that have been used for the cost benefit analysis are presented in detail within D5.4.2 and therefore not repeated in this deliverable.

Appendices

APPENDIX 1 KPI'S DEFINED FOR C4R

KPI	area	Migration	Boundary conditions	Capacity Assessment	Economical assessment
LCC = 20% less than conventional design	Track concepts	T112 - Track concepts generation, selection and design	Climatic conditions - floods		
		T114 - Upgrade infrastructure to meet new freight demand			
50% shorter timeslots for maintenance	VHS	T122 - New track design specifications for VHS			
	S&C	Innovative designs minimizing S&C loads and material deterioration and designs for resilient S&C	Climatic and weather conditions (?)		
Overal (carrying?) capacity improvement +20% in 2020 and +50% by 2030	System		**D211 : Requirements towards the freight system of 2030/2050 (M15 + M30)** - Demand for rail freight flows in Europe - Customer requirements for different market segments		
	Vehicles	**D222: Identification of the characteristics of future rail vehicles in different scenarios (M26):** Most usefull innovations to be introduced, per market segment and type of service offered			
	Terminals	**D234: Application of design methodologies for terminals innovative operational measures**			**T325: operational costs of newly designed terminals**: business cases and cost effective analysis
+ 20% capacity by 2020 + 50% reliability by 2030 - 30% operational costs by 2030	Capacity	T323 : Define scenarios using groupings of capacity innovations		**D322: Capacity impact of innovations**	
	Resilience		D321 - Evaluation measures and selected scenarios	**T333 - Optimal operational strategies for traffic management and incident management**: Impact of development from SP1,2,4	
				T335 - Evaluation of strategies using scenarios simulated in 3.2.1	
50% reduction of track unavailability by 2030	Sensors energy and communication technologies	T422 - Identifying and evaluating sensor and harvesting technologies T423 - Identifying and evaluating communication and data integration technologies			
		D532 - Migration scenarios and paths	Selection of sites/corridors	T541: LCC assessment methodology & template	T541: Operational assessment methodology & template
				T542 : Probabilistic assessemnt of technologies an	
				D556 - Final evaluation and assessment	

APPENDIX 2 SCENARIO TEMPLATES

Regarding SP1

Boundaries	Baseline 2015	Scenario 2030	Scenario 2050
LCC (NPV, €)	100%		80%
Shorter timeslots for maintenance MTTR (hours)	100%	50%	-
Specific CO2 emissions by 2030 with respect to 1990, including embodied carbon		50%	-
Unavailability/Disruptions due to EW events (measured by infrastructure down-time); innovative design of infrastructure being resilient to severe weather conditions	100%	40%	80%

Parameters	Baseline	Scenario 2030	Scenario 2050
Reliability (MTBF)	100%		200%
Unavailability due to maintenance - (MDT)	100%	50%	MDT < 365 hrs per year
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%
Unavailability due to inspection - (MDT)	100%	50%	20%
Maintainability/Installation of track (MTTR)	100%		50%
CO2 embodied emissions	100%		50%
Low noise and vibration	compared to track system on the selected corridor	-5 dB(A)	-10 dB(A)

Regarding SP2

Top targets for Scenarios with respect to SP2				
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**	**Source**
Capacity requirements for freigth [tonne-kilometres]	100%	130%	160%	SP2 - standard
	100%	150%	180%	SP2 / SP5 / D-Rail - WP low
	100%	210%	300%	SP2 / SP5 / D-Rail - WP high
Noise pollution [dB(A)]		-5	-10	SP5 (noise e. g. from brake)
Transport-related greenhouse gas [tonne/tonne-kilimetres]	xx%	50%	50%	SP5
Specifiy energy consumption [Megajoule/tonne-kilometres]	72%	50%	50%	SP5
Absolut energy consumption [Megajoule/tonne-kilometres]	94%	50%	50%	SP5
Exhaus emision (Nox and PM10) [/tonne-kilometres]	xx%	60%	60%	SP5
Standardized loading gauge (on RCF)	G2 and P/C 410	G2 and P/C 432	GC and P/C 432	SP2
Customer's Cost for Rail Freight Transport (referred to road freight)		-20%	-50%	SP2
Severe weather conditions tbd	tbd	tbd	tbd	see SP3
Winter (snow) resilience				
water (rain) resilience				
storm (wind) resilience				

Parameters	Baseline	Scenario 2030	Scenario 2050	Source
Infrastructure				
Max speed [km/h]	100	120	160	SP2
Max. axle load on RCF [t]	22,5	25	30	SP2
Max. meter load on RCF [t]	8,0	8,0	8,3	SP2
Max. loading gauge wagon load	G1	G2	G2	SP2
Max. loading gauge inter modal	P/C 400	P/C 432	P/C 450	SP2
Novel rail freight vehicles: Wagons				
Automatic couplers [%]	2	50	100	SP2
Running gear brakes	Cast brakes	50% LL Brakes	disc brakes	SP2
Electronic brake control [%]	0	40	100	SP2
Novel rail freight vehicles: Locomotives				
Duo Locos [%]	2	40	80	SP2
Tractive effort [kN] 4-axl loco	300	350	400	SP2
Novel rail freight vehicles: Train performance				
Max. train length [m]	740	835	1.050	SP2
Bundling of trains in some corridors	0	2x750m	2x1000m	SP2
Max train weight [t]	2.200	4.400	10.000	SP2
Novel rail freight vehicles: Wagon performance				
Wagon Load - max axle load	22,5	25	30	SP2
Tare weight per wagon meter index	100	98	93	SP2
Load weight per wagonmeter	100	117	150	SP2
Intermodal container wagon - max axle load	22,5	22,5	25	SP2
Tare weight per wagon meter index	100	98	93	SP2
Load weight per wagonmeter	100	101	115	SP2
Intermodal trailer wagon - max axle load	22,5	22,5	25	SP2
Tare weight per wagon meter index	100	98	93	SP2
Load weight per wagonmeter	100	101	115	SP2
Co-modal transhipment and interchange/logistics:				
Marshalling yard automation	5%	50%	100%	SP2
Feeder trains	Diesel	50% Duo-locos line	100% Duo-locos li	SP2
Co-modal transhipment and interchange/logistics:				
End-point lines	100%	75%	50%	SP2
Linear with inter mediate stops	0%	25%	50%	SP2
Terminal performance	None automated	Some automated	Fully automated	SP2

Regarding SP4:

Top targets for Scenarios with respect to SP4				
Boundaries	**Baseline 2015**	**Scenario 2030**	**Scenario 2050**	**Source**
Reduction of Track Unavailability	100%	50%		DOW
Increase of Infrastructure Reliability	100%	150%		DOW
Reduced infrastructure (Maintenance) cost	100%	-	50%	SP5-Roadmap
Robust rail infrastructure (in terms of contribution to Maintainability of the Infrastructure and to reduction of disruptions)	100%	140%	180%	SP5-Roadmap (SP1)

Specific Parameters (technical objectives) for Scenarios with respect to SP4				
Parameters	**Baseline**	**Scenario 2030**	**Scenario 2050**	**Source**
Non-intrusive innovative monitoring techniques or self-monitoring infrastructure: Monitoring Technologies & Sensor (WP4.2), Implementation in new structures (WP4.3) and				
Reliability of Infrastructure thanks to early pre-failure detection (effecting on unavailability of track due to failure/unplanned disruptions and late weather warning)	100%	150%	150%	C4R target (KPI, reg. SP4)
Inspection and Maintenance costs (incl. cost saving due to energy harvesting)	100%	80%	50%	C4R target (KPI, reg. SP1)
Higher Maintainability of the Infrastructure thanks to earlier and more accurate diagnoses and monitoring	100%	120%	150%	assumed

APPENDIX 3 QUALITATIVE ESTIMATION OF THE IMPACT OF THE C4R INNOVATIONS AND TECHNOLOGIES

Legend				
++ strong positive	+ noticable positive	o insignificant	- noticable negative	-- strong negative

Regarding SP1

Legend: ++ strong positive; + noticable positive; o insignificant; - noticable negative; -- strong negative

Specific Parameters (technical objectives) for Scenarios with respect to SP1				Impact of the innovation/technology on													
Parameters	Baseline	Scenario 2030	Scenario 2050	Affordability				Adaptability			Resilience		Automation			Capacity	
				TARGET Decrease of Infrastructure LCC	TARGET Decrease of Train operating costs	TARGET Decrease of specific CO2 emissions	TARGET Elimination of operating noise problem sites	TARGET Seamless train movement	TARGET Interoperability	TARGET Infra capability to respond to new operational requirements from traffic demand	TARGET Reduction of train delays (MDT) due to EW	TARGET Reduction of train delays (MDT) due to infrastructure failures	TARGET Reduction of track unavailability by using AMS	TARGET Automated Freight System by 2050	TARGET Track unavailability due to inspection	TARGET Capacity for passenger traffic	TARGET Capacity for freight traffic
				infrastructure LCC	train operational costs	CO2 emissions incl. carbon emissions	noise & vibration	Adaptability of freight wagons to cope with different freight containers	bundling of freight rolling stock	ability to change operational parameters with small interventions	perturbations due to flooding and low temperatures	perturbations due to infrastructure failures	Advanced Monitoring System (AMS) integration	Co-modal transhipment and interchange/logistic	inspection time	increase in overall passenger capacity to meet capacity required for 50% shift of medium distance passenger road traffic to rail	increase in overall freight capacity to meet capacity required for 50% of road freight over 300 km to rail
Modular integrated design of new concepts for infrastructure – Innovative New Slab Track (WP 1.1)				+	o	-	+	o	o	+	+	+	o	o	o	+	+
Reliability (MTBF)	100%		200%	x								x					
Unavailability due to maintenance (MDT)	100%	50%	MDT < 365 hrs per year	x								x				x	x
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x							x	x					
Unavailability due to inspection (MDT)	100%	50%	20%	x								x				x	x
Maintainability/Installation of track (MTTR)	100%		50%	x							x	x				x	x
Flexible system										x							
CO2 embodied emissions	100%		50%			x											
Low noise and vibration	compared to track system on the selected	-5 dB(A)	-10 dB(A)				x										
Innovative High Speed Track (WP 1.2)				+	o	o	o	o	o	o	o	o	o	o	o	o	o
Optimisation of design (same LCC while increasing maximum speed)				x													
Innovative S&C (WP 1.3)				+	o	o	o	o	o	+	+	+	o	o	+	+	+
Reliability of S&C (MTBF)	100%		200%	x								x			x		
Unavailability due to maintenance (MDT)	100%	50%	MDT < 365 hrs per year	x								x				x	x
Unavailability/Disruptions due to EW events (MDT)	100%	50%	<50%	x						x	x						
Unavailability due to inspection (MDT)	100%	50%	20%	x								x			x	x	x
Maintainability/Installation of track (MTTR)	100%		50%	x		x				x	x	x				x	x

Regarding SP2

Parameters	Impact of the innovation/technology on													
	affordability				adaptability			resilience		automation			capacity	
Infrastructure	**-**	**+**	**++**	**-**	**++**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**+**	**++**
Max speed [km/h]		x	xx	-									x	xx
Max. axle load on RCF [t]		x	xx	-	xx									xx
Max. meter load on RCF [t]	-	x	x	-	xx									xx
Max. loading gauge wagon load	o	x	x	-	xx									xx
Max. loading gauge inter modal	o	x	x	-	xx									xx
Novel rail freight vehicles: Wagons	**o**		**+**	**+**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**+**	**+**
Automatic couplers [%]		x												x
Running gear brakes		x	x	x										x
Electronic brake control [%]		x	x	x									x	x
Novel rail freight vehicles: Locomotives	**o**	**+**	**-**	**o**	**++**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**+**
Duo Locos [%]		x	-											x
Tractive effort [kN] 4-axl loco		x												x
Novel rail freight vehicles: Train performance	**o**	**+**	**++**	**o**	**++**	**++**	**o**	**o**	**o**	**o**	**o**	**o**	**+**	**++**
Max. train length [m]		xx	xx		xx	xx								xx
Bundling of trains in some corridors		xx	xx		xx	xx							x	xx
Max train weight [t]		xx	xx		xx									xx
Novel rail freight vehicles: Wagon performance	**-/x**	**++**	**++**	**-/x**	**++**	**++**	**+**	**o**	**o**	**o**	**o**	**o**	**+**	**++**
Wagon Load - max axle load														
Tare weight per wagon meter index	x	x	x	x	o	o	x	o	o	o	o	o	o	x
Load weight per wagonmeter	-	xx	x	-	o	o	x	o	o	o	o	o	x	xx
Intermodal container wagon - max axle load														
Tare weight per wagon meter index	x	x	x	x	o	o	x	o	o	o	o	o	o	x
Load weight per wagonmeter	-	xx	x	-	o	o	x	o	o	o	o	o	x	xx
Intermodal trailer wagon - max axle load														
Tare weight per wagon meter index	x	x	x	x	o	o	x	o	o	o	o	o	o	x
Load weight per wagonmeter	-	xx	x	-	o	o	x	o	o	o	o	o	x	xx
Co-modal transhipment and interchange/logistics:	**o**	**++**	**++**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**+**
Marshalling yard automation														x
Feeder trains		xx	xx											x
Co-modal transhipment and interchange/logistics:	**o**	**++**	**o**	**o**	**o**	**+**	**o**	**o**	**o**	**o**	**o**	**o**	**-**	**++**
End-point lines		xx												xx
Linear with inter mediate stops		xx											-	xx
Terminal performance		xx				x								x
High Speed Freight	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**	**o**

Regarding SP4

Parameters	Impact of the innovation/technology on													
	Affordability				Adaptability			Resilience		Automation			Capacity	
	TARGET Decrease of Infrastructure LCC	TARGET Decrease of Train operating costs	TARGET Decrease of specific CO2 emissions	TARGET Elimination of operating noise problem sites	TARGET Seamless train movement	TARGET Interoperability	TARGET Infra capability to respond to new operational requirements from traffic demand	TARGET Reduction of train delays (MDT) due to EW	TARGET Reduction of train delays (MDT) due to Infrastructure failures	TARGET Reduction of track unavailability by using AMS	TARGET Automated Freight System by 2050	TARGET Track unavailability due to inspection	TARGET Capacity for passenger traffic	TARGET Capacity for freight traffic
	infrastructure LCC	train operational costs	CO2 emissions incl. carbon emissions	noise & vibration	Adaptability of freight wagons to cope with different freight containers	bundling of freight rolling stock	ability to change operational parameters with small interventions	perturbations due to flooding and low temperatures	perturbations due to infrastructure failures	Advanced Monitoring System (AMS) integration	Co-modal transhipment and interchange/logistic	inspection time	increase in overall passenger capacity to meet capacity required for 50% shift of medium distance passenger road traffic to rail	increase in overall freight capacity to meet capacity required for 50% of road freight over 300 km to rail
Non-intrusive innovative monitoring techniques or self-monitoring	+	o	o	o	o	o	o	++	++	+	o	+	+	+
Reliability of Infrastructure thanks to early pre-failure detection (effecting on unavailability of track due to failure/unplanned disruptions and late weather warning)	x							x	x	x		x	x	x
Inspection and Maintenance costs (incl. cost saving due to energy harvesting)	x							x	x	x		x		
Higher Maintainability of the Infrastructure thanks to earlier and more accurate diagnoses and monitoring	x							x	x	x		x	x	x

APPENDIX 4 EAST COAST MAINLINE – UK BASELINE DATA, FUTURE INVESTMENTS AND SCENARIOS

Overview

Case Study Description

The ECML in the UK runs from London to Edinburgh and is a mixed traffic route. The ECML runs for a total length of 632km (Figure 1 a) East Coast MainlineFigure 1), mainly with a 4 track layout, with two tracks (one for each direction) for the slow lines and two tracks (one for each direction) for the fast lines. Mixed traffic runs along the whole route with long distance intercity services mixing with regional stopping services as well as with freight.

The route is also roughly followed by the A1 road (660 km), which passes close to the same urban areas. The A1 has several sections which are upgraded to motorway status (shown in blue in Figure 1), however many sections are still truck road status and in some stretches still single carriageway. The A1 is part of the European route E15, from Algeciras, Spain to Inverness, Scotland.

This case study concentrates on the ECML and A1 sections from Peterborough to Doncaster. In this stretch the freight services are mainly separated over a branch via Lincoln (Great Northern Great Eastern line) to improve capacity and performance on the main passenger route. Over the same stretch from Peterborough to Doncaster the A1 is all dual carriage with between 2 and 3 lanes of traffic in each direction. For most of the stretch from Peterborough to Doncaster the A1 is classified as a trunk road, however, the sections around Peterborough and Doncaster are of motorway classification.

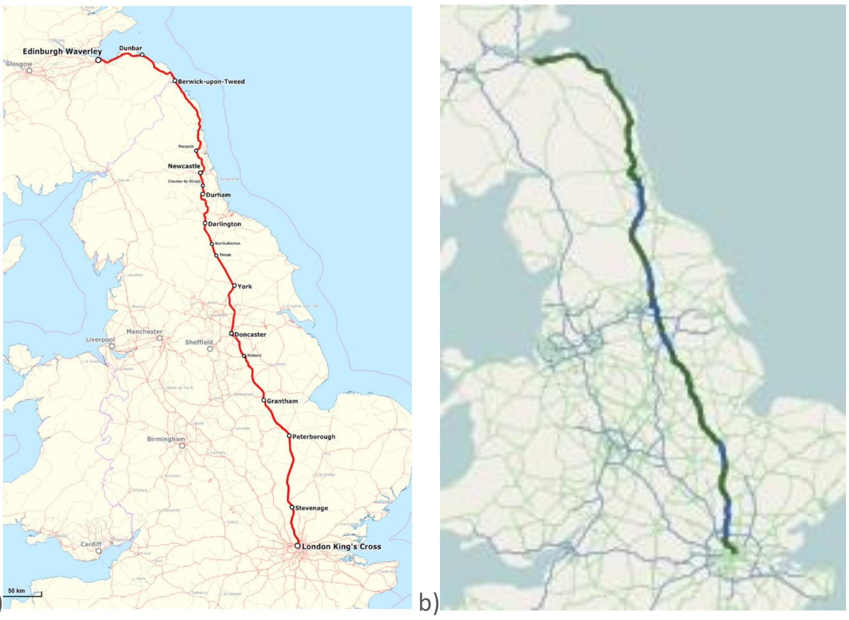
a) b)


FIGURE 4 A) EAST COAST MAINLINE AND B) A1 ROAD ROUTE

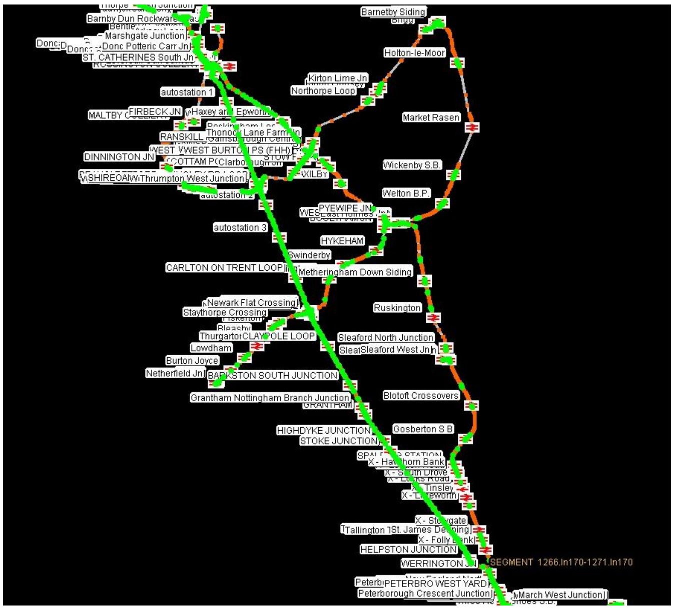


FIGURE 5. PORTION OF THE ECML BETWEEN PETERBOROUGH AND DONCASTER

Corridor segmentation of ECML and A1 between Peterborough and Doncaster, with the major segments being the segments between main urban, and more detailed segments presented in the columns for ECML, A1 and the alternative freight branch. This allows the segments to be approximately overlaid.

TABLE 5 A1 SEGMENTATION

Major Segment	Segment with traffic data	Number of Carriage Ways	Number of Lanes	Lanes per carriage way	Length of section
Peterborough-Stamford	A605 Oundle Road - A6118 London Road	2	4	2	6.6
	A6118 - A43 Worthorpe	2	4	2	8
Stamford-Grantham	A43 Worthorpe - LA Boundary	2	4	2	0.3
	A151/B676 - B1174	2	4	2	8.4
	B1174 - A607	2	4	2	3.2
Grantham-Newark	A607 Eastbound - A52 where slip roads connect A1	2	4	2	2.35
	A52 where slip roads connect A1 - B1174	2	4	2	3.75
	A6075 Newark Road - A6075 Ashvale Road	2	4	2	0.5
Newark-Retford	A6075 - A57/A638	2	4	2	4.4
	A57/A638 - A57/A614	2	4	2	8.7
	A57/A614 - A620	2	4	2	2.2
Retford-Bawtry	A620 - spur to A634	2	4	2	6.1
	A634 spur - A614	2	4	2	2.6
Bawtry-Doncaster	A57/A614 - A620	2	4	2	2.2
	A630 - M18	2	4	2	3

TABLE 6 ECML RAIL SEGMENTATION

Major Segment	Segment	Segment length	Tracks
Peterborough-Grantham	Peterborough East Jn - Werrington Jn	4.928604	5
	Werrington Jn - Helpston Jn	3.661249	5
	Helpston Jn - Stoke Jn	29.04859	4
	Stoke Jn - Highdyke Jn	2.937046	2
	Highdyke Jn - Grantham	6.276426	3
Grantham-Newalk	Grantham - Newark North Gate Jn	23.5366	2
Newark-Retford	Newark North Gate Jn - Carlton on Trent	9.092771	2
	Carlton on Trent - Retford	20.70014	2
Retford-Doncaster	Retford - Ranskill	7.563898	2
	Ranskill - Rossington Colliery	12.93507	2
	Rossington Colliery - Doncaster	7.423081	3

TABLE 7 GREAT NORTHERN GREAT EASTERN (GNGE) LINE SEGMENTATION

Major Segment	Segment	Segment length	Tracks
Peterborough-Sleaford	Peterborough East Jn - Werrington Jn (part of ECML)	4.92	5
	Werrington Jun - Sleaford South Jn	50.15	2
	Sleaford South Jn - Sleaford North Jn	2.32	2
Sleaford-Lincoln	Sleaford North Jn - Lincoln Area	30.01	2
Lincoln-Gainsborough	Lincoln Area - Gainsborough	22.4	2
Gainsborough-Retford	Gainsborough - Retford	13.78	2
Retford-Doncaster	Gainsborough - Doncaster	31.87	2

CBA investment levels

The CBA evaluates different scenarios including different sets of C4R innovations, as well as some changes to boundary condition. In each scenario, the net costs and benefit are computed from the comparison of two investment levels

Baseline and planned investment– which considers the system's current conditions in terms of infrastructure characteristics rolling stock or maintenance costs. These will conditions will change with other planned investment, eg for ECML ETCS level 3 is planned for implementation by 2043.

C4R scenario, which assumes the implementation of a given set of C4R innovations

In each investment level both investment costs and parameters are set to the assumed values, as discussed in the following section. The main scenario, described as follows, which we call C4R Scenerio 1 (All) assumes the implement of all considered innovations in all sections of the rail network. All other scenarios follow the same pattern, always using Scenario 1 as a base upon which changes are introduced.

Input data for C4R Scenario 1 (All)

Reference values, the same as Swedish section of Scan-Med corridor, as

- 40-year time horizon with 2015 as base year and 2016 as year 1
- Financial and social discount rates of 4%
- Shadow price conversion factor of 0.95

Network restrictions on ECML and GNGE

Train length

Present maximum train length - 443m [1]

Maximum train length after 2043

ECML – 775m [2]

GNGE - 1461.5m [2]

Maximum axle loading [3] [4]

ECML 24.1 Tonnes

GNGE 2016-2019 22.8 Tonnes 2019 onwards 25.4 Tonnes

Main classes of freight vehicles on ECML and GNGE [5]

Class 4 – 75mph capable freight – up to 1,600 tonnes trailing load – intermodal container traffic and empty coal or aggregate wagons

Class 6 – 60mph capable freight – up to 2,400 tonnes trailing load – coal, aggregates

Table 8 Baseline case until line upgrades in 2019

	Train load	Wagon Load	IM Container
Length (m)	344	298	307
Tare Weight (T)	586	559	541
Axle Load (T/axle)	22.4	22.4	22.4
Cargo Capacity (T)	1071	1098	1206
Average Load Factor	50%	55%	50%
Average Load (T)	535.5	603.9	603
Average Gross Weight (T)	1121.5	1162.9	1144

	gCO_2e per tonne km			
	CO_2	CH_4	N_2O	Total
Rail Freight	28.5	0.050	3.060	31.6

[6]

Table 9 Baseline case after line upgrades in 2019

	Train load	Wagon Load	IM Container
Length (m)	344	298	307
Tare Weight (T)	586	559	541
Axle Load (T/axle)	23.3	23.6	22.4
Cargo Capacity (T)	1266.5	1190	1206
Average Load Factor	50%	55%	50%
Average Load (T)	633.3	654.5	603
Average Gross Weight (T)	1219.3	1213.5	1144

Freight wagons and locos based on Freight Liner UK fleet [7].

Road freight vehicles (same as Swedish Scan-Med corridor values) – GHG emissions data from UK study below

	Baseline	**After TEN-T**	**Low-cost 1**	**Low-cost 2**	**Future SE**	**European**
Maximum Load (T)	40	43.5	40	43.5	50	26
Average Load Factor	60%	60%	60%	60%	60%	60%
Average Load (T/vehicle)	24	26.1	24	26.1	30	15.6
Operating Costs [€/(T·km)]	0.0508	0.0475	0.0292	0.0318	0.0433	0.0712
Tax [€/(T·km)]	0.0121	0.0115	0.0117	0.0069	0.0107	0.0160
GHG Emissions [kg/(T·km)]	0.0320	0.0310	0.0320	0.0310	0.0290	0.0420

Body Type	**Gross Vehicle Weight**	**% weight laden**	**UK av. goods carried per vehicle, tonnes**	**gCO$_2$e per tonne km**			
				CO_2	**CH_4**	**N_2O**	**Total**
Rigid	>3.5-7.5t	43%	0.86	599.4	0.29	6.27	605.9
Rigid	>7.5-17t	36%	1.82	388.0	0.19	4.06	392.3
Rigid	>17t	52%	4.91	196.2	0.10	2.05	198.4
All rigid	**UK average**	***50%***	***3.30***	***259.0***	***0.13***	***2.71***	***261.8***
Articulated	>3.5-33t	45%	5.56	146.6	0.14	1.53	148.3
Articulated	>33t	61%	11.31	85.7	0.08	0.90	86.7
All articulated	**UK average**	***60%***	***10.93***	***88.5***	***0.08***	***0.93***	***89.5***
ALL HGVs	**UK average**	***55%***	***7.20***	***127.2***	***0.11***	***1.91***	***129.2***

[6]

Freight value of time road and rail

TABLE 10 VALUES OF TIME (EURO/HOUR PER VEHICLE OR VESSEL, PRICE LEVEL 2010) [8]

	Road	Rail	Air	Inland waterways	Sea
Container	*[2-40t truck]:* 59	*[full train]:* 880	*Not applicable*	*[ship waiting for a quay]:* 98 *[ship waiting for a lock/bridge]:* 340	*[ship waiting for a quay]:* 760
Non-container	*[2-15t truck]:* 23 *[15-40t truck]:* 44 *[all non-container]:* 37	*[bulk]:* 1200 *[wagonload train]:* 1100 *[all non-container]:* 1200	*[full freighter aircraft]:* 13000	*[ship waiting for a quay]:* 65 *[ship waiting for a lock/bridge]:* 300	*[ship waiting for a quay]:* 830
All	*[2-40t truck]:* 38	*[full train]:* 1100	*[full freighter aircraft]:* 13000	*[ship waiting for a quay]:* 69 *[ship waiting for a lock/bridge]:* 300	*[ship waiting for a quay]:* 820

Notes:
- All these values are combined values from shippers and carriers and were obtained after rounding off.
- The values for rail are for a train (not a wagon).
- The values for inland waterways and sea refer to a ship.

Forecast for rail passenger growth [9]

Baseline – 2017

2023 – 47% total increase

2043 – 105% total increase

Passenger numbers, available seats and train utilisation along ECML - [10]

Although the average utilisation looks low, the utilisation of seas varies heavily throughout the day with much higher utilisation on peak services.

	Passengers / week day	**Total capacity / seats per week day**	**Utilisation**
Peterborough-Grantham	28400	63390	45%
Grantham-Newalk	27200	63390	43%
Newark-Retford	26200	63390	41%
Retford-Doncaster	25000	63390	39%

Reference passenger train

Length 273m

Tare weight 563T

Average load factor 42%

Number of seats 600

Average CO2 emission - 0.0565kg CO2e per passenger km

Rail	gCO_2e per passenger km				Source*
	CO_2	CH_4	N_2O	Total	
International rail	15.0	0.010	0.090	15.1	Average figures from Eurostar for London to Brussels and Paris routes
National rail	53.4	0.060	3.030	56.5	Emission factor based on ORR (2009)
Light rail (and tram)	71.0	0.030	0.440	71.5	Average of UK light rail and tram systems
London underground	73.1	0.030	0.450	73.6	Transport for London's 2010 environmental report

Notes: * Source is for CO_2 data only; CH_4 and N_2O emissions have been estimated by other means.

[6]

Average operating cost 0.1€/(p km) from Scan-Med example

Road passenger – from ScanMed – but see below another survey on CO2 emissions

- Average load: 1,2 passengers/car;
- Average operating costs: 0.35 €/(p·km);
- Average CO_2 emission: 0.166 kg/(p·km). (Study below – approx. 200gCO2e/km per vehicle – so would expect approx. 166gCO2e/km passenger)

<table>
<tr><th rowspan="3">Vehicle Type</th><th rowspan="3">Engine size</th><th rowspan="3">Size label</th><th colspan="5">Final New 'real-world' 2011 GHG Conversion Factors[1]</th></tr>
<tr><th colspan="4">gCO_2 per km</th><th rowspan="2">MPG</th></tr>
<tr><th>CO_2</th><th>CH_4</th><th>N_2O</th><th>Total</th></tr>
<tr><td rowspan="4">Petrol car</td><td>< 1.4 l</td><td>Small</td><td>170.1</td><td>0.16</td><td>0.84</td><td>171.1</td><td>37.6</td></tr>
<tr><td>1.4 - 2.0 l</td><td>Medium</td><td>211.1</td><td>0.16</td><td>0.84</td><td>212.1</td><td>30.3</td></tr>
<tr><td>> 2.0 l</td><td>Large</td><td>298.1</td><td>0.16</td><td>0.84</td><td>299.1</td><td>21.7</td></tr>
<tr><td></td><td>Ave</td><td>207.6</td><td>0.16</td><td>0.84</td><td>208.6</td><td>30.9</td></tr>
<tr><td rowspan="4">Diesel car</td><td><1.7 l</td><td>Small</td><td>143.3</td><td>0.05</td><td>1.67</td><td>145.0</td><td>52.2</td></tr>
<tr><td>1.7 - 2.0 l</td><td>Medium</td><td>179.2</td><td>0.05</td><td>1.67</td><td>181.0</td><td>41.7</td></tr>
<tr><td>> 2.0 l</td><td>Large</td><td>241.6</td><td>0.05</td><td>1.67</td><td>243.3</td><td>31.0</td></tr>
<tr><td></td><td>Ave</td><td>191.8</td><td>0.05</td><td>1.67</td><td>193.5</td><td>39.0</td></tr>
<tr><td rowspan="4">Car (unknown fuel)</td><td>(2)</td><td>Small</td><td>165.7</td><td>0.14</td><td>1.03</td><td>166.8</td><td>40.5</td></tr>
<tr><td>(2)</td><td>Medium</td><td>200.2</td><td>0.12</td><td>1.16</td><td>201.5</td><td>34.5</td></tr>
<tr><td>(2)</td><td>Large</td><td>268.0</td><td>0.10</td><td>1.31</td><td>269.4</td><td>26.7</td></tr>
<tr><td>(2)</td><td>Ave</td><td>203.3</td><td>0.12</td><td>1.15</td><td>204.6</td><td>33.6</td></tr>
</table>

[6]

Value of time passenger

Value of time - Passengers [11] weighted to 2014 values – values €/hr.

Executive Summary Table: Values of Travel Time Savings

<table>
<tr><th rowspan="2">Values of Travel Time Savings</th><th rowspan="2">Distance</th><th>Comm-ute</th><th>Other non-work</th><th colspan="5">Business</th></tr>
<tr><th>All modes</th><th>All modes</th><th>All modes</th><th>Car</th><th>Bus</th><th>'Other PT'</th><th>Rail</th></tr>
<tr><td>WebTAG (2014 prices and values)</td><td>All</td><td>7.62</td><td>6.77</td><td>25.47</td><td>24.43</td><td>15.64</td><td>24.72</td><td>30.07</td></tr>
<tr><td rowspan="4">All modes</td><td>All</td><td rowspan="4">11.21</td><td rowspan="4">5.12</td><td>18.23</td><td>16.74</td><td>-</td><td rowspan="4">8.33</td><td>27.61</td></tr>
<tr><td><20 miles</td><td>8.31</td><td>8.21</td><td>-</td><td>10.11</td></tr>
<tr><td>20 to 100 miles</td><td>16.05</td><td>15.85</td><td>-</td><td rowspan="2">28.99</td></tr>
<tr><td>>=100 miles</td><td>28.62</td><td>25.74</td><td>-</td></tr>
</table>

Notes: All values distance-weighted, non-work VTTs based on all distances and income option 1, business VTT distance-banded based on income option 1 and employers paying, VTT imputed for PT trips with zero cost, VTT taken from SP1 at Δt=10, Tool version 1.1.

Freight increase in demand

Predicted forecasts for growth in demand of freight traffic by type [12] in tonnes per year

Type	Lower scenario	Central case forecasts
Bulk (shift from coal to biomass for energy sector)	No significant increase	No significant increase
Intermodal (Domestic and international average) 2013 reference values	No significant increase at 2023 372% increase in by 2033 (6.79% annual growth)	283% increase by 2023 (10.9% annual growth 2013-2023) 461% increase by 2033 (5.01% annual growth 2023-2033) 670% increase by 2043 (3.81% annual growth 2033-2043)

Current split of rail freight type UK proportion [% mass/mass] – assume that the same proportions of freight types on ECML and GNGE as nationally [13]

Financial Period	Coal	Construction	Domestic Intermodal	Infrastructure	International	Metals	Oil and Petroleum	Other
2016-17	11%	18%	36%	8%	3%	8%	7%	11%

Freight delays average for UK network 10.7 Delays/ 100 T km [13]

Reference values for infrastructure – same as ScanMed

Parameter	Baseline Value	
Maintenance Costs	Fixed	Variable
Track, Signaling and Elect.	30,000 €/(year·km)	130 €/(MGT·km)
Switches and Crossings (S&C)	10,500 €/(year·km)	130 €/(MGT·km)
Switch Density	0.14/km	
Buffer times and Crossing Buffer	5% of travel time	
Supplement for Track Maintenance	5h	

Using values provided by Network Rail

	Maintenance costs		
	Track Signalling and Elect €/(year km)	**S&C €/(year S&C)**	**Switch density**
Peterborough East Jn - Werrington Jn	140629.11	40850	12.2
Werrington Jn - Helpston Jn	140629.11	40850	0.8
Helpston Jn - Stoke Jn	140629.11	40850	0.6
Stoke Jn - Highdyke Jn	140629.11	40850	1.7
Highdyke Jn - Grantham	140629.11	40850	1.1
Grantham - Newark North Gate Jn	140629.11	40850	1.3
Newark North Gate Jn - Carlton on Trent	120155.94	25108	1.5
Carlton on Trent - Retford	120155.94	25108	1.0
Retford - Ranskill	120155.94	25108	0.9
Ranskill - Rossington Colliery	120155.94	25108	1.2
Rossington Colliery - Doncaster	120155.94	25108	11.6
Werrington Jun - Sleaford South Jn	97346.00	23232	0.2
Sleaford South Jn - Sleaford North Jn	97346.00	23232	1.3
Sleaford North Jn - Lincoln Area	97346.00	23232	0.9
Lincoln Area - Newark East Jn	97346.00	23232	0.6

Lincoln Area - Gainsborough	97346.00	23232	0.3
Gainsborough - Retford	97346.00	23232	1.7
Gainsborough - Doncaster	120155.94	25108	2.5

Rail traffic baseline

	Passenger		**Freight**	
	Year	**(trains/day)**	**Year**	**(trains/day)**
Peterborough East Jn - Werrington Jn	2016	567	2016	81
Werrington Jn - Helpston Jn	2016	414	2016	45
Helpston Jn - Stoke Jn	2016	414	2016	45
Stoke Jn - Highdyke Jn	2016	405	2016	27
Highdyke Jn - Grantham	2016	423	2016	36
Grantham - Newark North Gate Jn	2016	459	2016	36
Newark North Gate Jn - Carton on Trent	2016	477	2016	45
Carlton on Trent - Retford	2016	360	2016	18
Retford - Ranskill	2016	405	2016	36
Ranskill - Rossington Colliery	2016	351	2016	18
Rossington Colliery - Doncaster	2016	486	2016	108
Werrington Jun - Sleaford South Jn	2016	27	2016	27
Sleaford South Jn - Sleaford North Jn	2016	27	2016	27
Sleaford North Jn - Lincoln Area	2016	117	2016	45
Lincoln Area - Newark East Jn	2016	108	2016	54
Lincoln Area - Gainsborough	2016	36	2016	36
Gainsborough - Retford	2016	45	2016	54
Gainsborough - Doncaster	2016	468	2016	99

Road traffic baseline vehicles per weekday

	Roads	Lanes	Length	Count year	Passenger vehicles	All HGVs	All Good Vehicles incl.light goods	All Motor Vehicles
Peterborough-Stamford	A605 Oundle Road - A6118 London Road	4	6.6	2014	33758	5260	10826	44584
Peterborough-Stamford	A6118 - A43 Worthorpe	4	8	2014	35560	6425	12907	48467
Stamford-Grantham	A43 Worthorpe - LA Boundary	4	0.3	2013	34758	7727	13378	48136
Stamford-Grantham	A151/B676 - B1174	4	8.4	2014	22529	6541	11056	33585
Stamford-Grantham	B1174 - A607	4	3.2	2013	21744	6713	10710	32454
Grantham-Newark	A607 Eastbound - A52 where slip roads connect A1	4	2.35	2014	24354		11998	36352
Grantham-Newark	A52 where slip roads connect A1 - B1174	4	3.75	2014	26012	6186	11020	37032
Grantham-Newark	A6075 Newark Road - A6075 Ashvale Road	4	0.5	2013	23136	8049	12844	35980
Newark-Retford	A6075 - A57/A638	4	4.4	2014	24354	8472	13520	37873
Newark-Retford	A57/A638 - A57/A614	4	8.7	2014	32284	8314	15584	47868
Newark-Retford	A57/A614 - A620	4	2.2	2013	24971	7664	13322	38293
Retford-Bawtry	A620 - spur to A634	4	6.1	2013	28856	7924	13187	42043
Retford-Bawtry	A634 spur - A614	4	2.6	2013	24692	8128	12868	37560
Bawtry-Doncast	A57/A614 - A620	4	2.2	2013	24971	7664	13322	38293
Bawtry-Doncast	A630 - M18	4	3	2013	43745	13199	25235	68980

Interventions scheduled in the baseline

ECML - GB

Investment Scenario

COSTS ARE IN Million EUROS

	Investment Projects	:ffec	Included in			NPV	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			Baseline	ETCS L2 Deployment	C4R Scen		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
BS1	Carlton Panel refurb		Yes	No			-	-	-	-	-	-	-	0.021	0.034	0.196	0.751	0.610	0.059	-	-	-	-	-	-	-
BS2	Doncaster area rectrl for condition		Yes	No			-	-	-	-	-	-	-	-	0.013	0.067	0.066	1.234	1.375	0.191	0.004	-	-	-	-	-
BS3	Doncaster Ints		Yes	No			-	-	-	-	-	-	-	1.228	1.695	13.607	37.191	25.670	3.694	8.762	13.638	0.541	-	-	-	-
BS4	Doncaster LEW DON		Yes	No			-	-	-	-	-	-	-	-	1.638	14.053	0.826	-	-	-	-	-	-	-	-	-
BS5	Doncaster Panel Renewal		Yes	No			-	-	-	-	-	-	-	-	0.196	0.329	1.834	7.144	5.840	0.563	-	-	-	-	-	-
BS6	East Midlands ctrl renewal		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.002	0.449	0.425	-	-	-
BS7	East Midlands external renewals		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BS8	East Midlands IXL renewal		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.040	0.045	0.523	0.985	0.484
BS9	Eastfield LEW		Yes	No			-	-	-	-	-	-	-	-	-	0.024	0.109	0.109	2.095	2.265	0.242	0.001	-	-	-	-
BS10	Eastfield LEW ECS		Yes	No			-	-	-	-	-	-	0.283	2.409	0.142	-	-	-	-	-	-	-	-	-	-	-
BS11	Gainsborough TJn resignalling		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	0.031	0.210	0.208	3.689	4.367	0.803	0.033
BS12	GNGE resignalling		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.689	1.145
BS13	Grantham rectrl for condition		Yes	No			-	0.018	0.081	0.081	1.557	1.688	0.184	0.001	-	-	-	-	-	-	-	-	-	-	-	-
BS14	LNE ctrl renewal		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	0.081	0.472	0.019	-	-	-	-
BS15	LNE ETCS L3		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.029
BS16	LNE external renewals		Yes	No			-	-	-	-	-	-	-	-	-	-	0.660	0.725	9.585	14.553	10.270	6.764	3.019	16.790	27.517	55.454
BS17	LNE IXL renewal		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.035	0.066	0.446
BS18	LNE rectrl		Yes	No			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.035	0.036
BS19	LNE relock		Yes	No			-	-	-	-	-	-	-	-	-	-	-	0.050	0.578	1.008	8.402	13.116	5.659	1.788	3.852	7.589
BS20	Peterborough Ints		Yes	No			-	-	-	-	-	1.229	3.697	1.526	4.693	1.905	4.316	9.083	0.012	-	-	0.500	1.499	-	-	-
BS21	Peterborough Re-control		Yes	No			-	-	0.091	0.151	0.845	3.298	2.681	0.258	-	-	-	-	-	-	-	-	-	-	-	-
BS22	Swinderby renewal		Yes	No			-	-	-	0.113	0.112	1.589	8.342	18.699	0.059	-	-	-	-	-	-	-	-	-	-	-
ET1	Doncaster area rectrl for condition		No	Yes			-	-	-	-	-	-	-	-	0.013	0.067	0.066	1.234	1.375	0.191	0.004	-	-	-	-	-
ET2	Doncaster LEW DON		No	Yes			-	-	-	-	-	-	-	-	1.638	14.053	0.826	-	-	-	-	-	-	-	-	-
ET3	East Midlands ETCS ctrl renewal		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET4	East Midlands ETCS IXL renewal		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET5	Eastfield LEW ECS		No	Yes			-	-	-	-	-	-	0.283	2.409	0.142	-	-	-	-	-	-	-	-	-	-	-
ET6	Enh Werrington GSJ		No	Yes			-	-	0.078	0.129	0.723	2.823	2.295	0.221	-	-	-	-	-	-	-	-	-	-	-	-
ET7	G.05 ECML ETCS		No	Yes			-	-	-	-	-	-	-	2.326	10.465	10.973	201.236	217.633	26.718	3.735	67.562	72.805	7.791	0.017	-	-
ET8	G.20 ECML ETCS		No	Yes			-	-	-	-	-	-	-	-	-	-	-	0.115	0.517	0.542	9.946	10.717	1.147	0.003	-	-
ET9	G.21 ECML ETCS		No	Yes			-	-	-	-	-	-	-	-	-	-	-	0.318	1.432	1.502	27.545	29.682	3.176	0.007	-	-
ET10	G.23 ECML ETCS		No	Yes			-	-	-	-	-	-	-	-	-	-	-	0.417	1.876	1.968	36.084	38.884	4.161	0.009	-	-
ET11	Grantham rectrl for condition		No	Yes			-	0.018	0.081	0.081	1.557	1.688	0.184	0.001	-	-	-	-	-	-	-	-	-	-	-	-
ET12	H.16 ECML ETCS		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET13	LNE ETCS ctrl renewal		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET14	LNE ETCS IXL renewal		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET15	Peterborough Re-control		No	Yes			-	-	0.091	0.151	0.845	3.298	2.681	0.258	-	-	-	-	-	-	-	-	-	-	-	-
ET16	Swinderby renewal		No	Yes			-	-	-	0.113	0.112	1.589	8.342	18.699	0.059	-	-	-	-	-	-	-	-	-	-	-
ET17	Thrumpton and W Burton rectrl for condition		No	Yes			-	-	-	-	-	-	-	-	-	-	-	-	-	0.081	0.472	0.019	-	-	-	-

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APPENDIX 5 FRENCH/SPANISH BOARDER TO BARCELONA AND VALENCIA

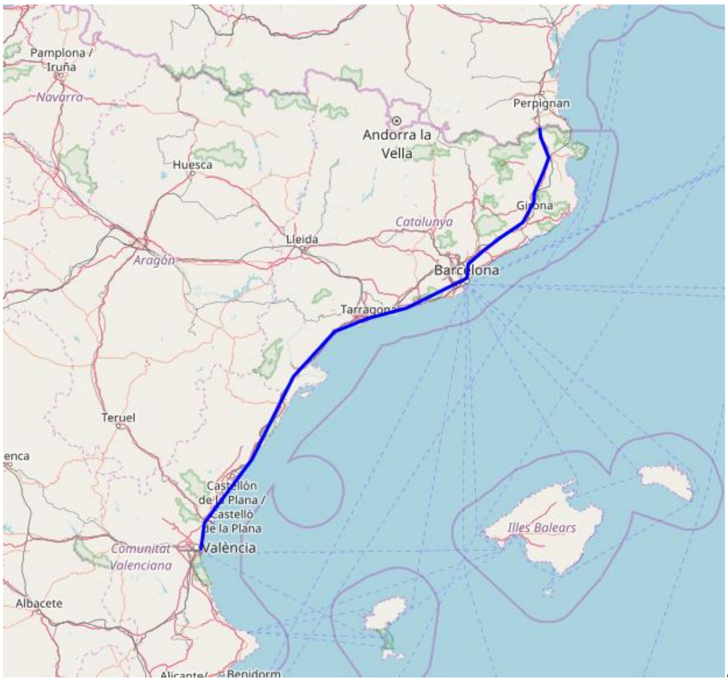

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FIGURE 6 CORRIDOR SECTION

VALÈNCIA – SAGUNT

Traditionally, this section has a double-way track with Iberian gauge (1.6678 m) and was used to freight and passengers traffic. The construction of the Mediterranean corridor has forecast the implementation of the third rail to perform a mixed gauge in the whole section by 2020. (1)

The third rail implementation will allow trains length of 750 m.

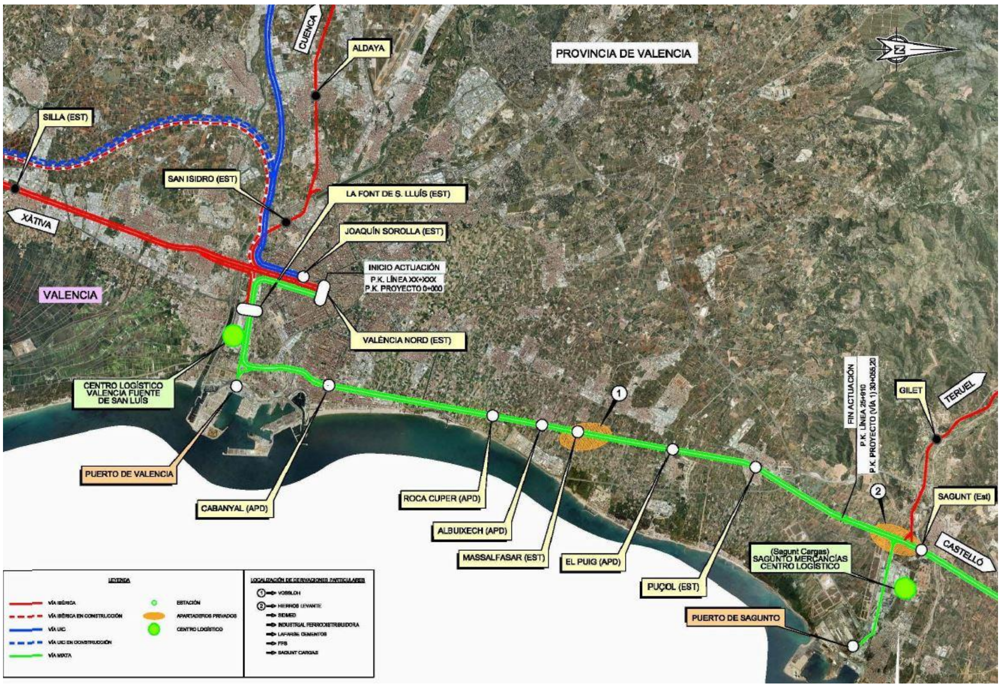


FIGURE 7 FORECAST SITUATION OF THE SECTION VALÈNCIA – SAGUNT (1)

The total number of switches and crossings is 98, from which 15 have Iberian gauge and 83 International gauge.

RAILWAY STATIONS AND SIDINGS

In this part are listed all the stations. In order to define the sidings and the number of tracks projected, the forecast layout is represented for the main stations.

In all the figures attached, the red lines represent Iberian gauge, the blue lines mean International gauge and the green lines symbolize mixed gauge.

- València Nord: It is an end-of-line facility and the freight trains are not allowed.

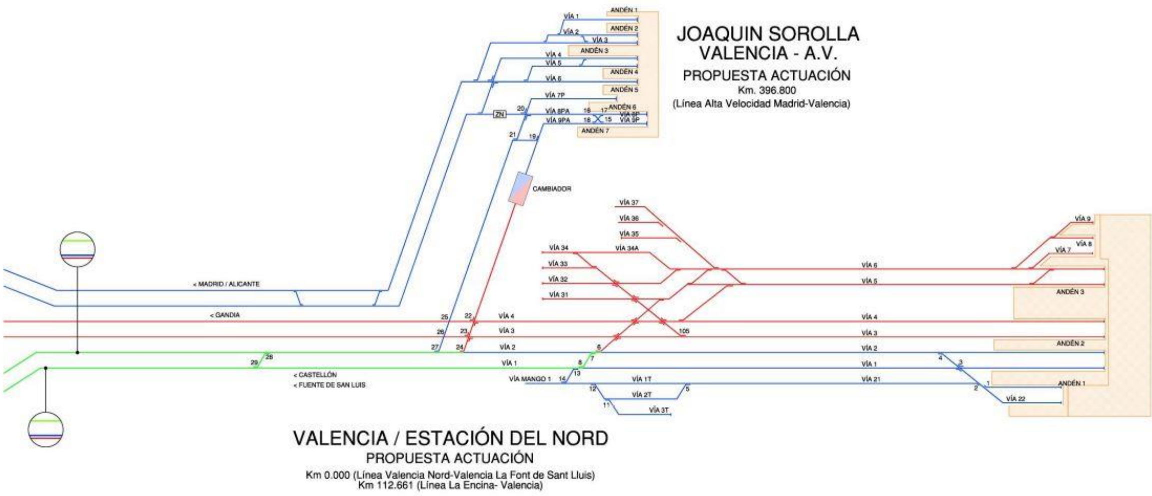


FIGURE 8 VALÈNCIA NORD AND JOAQUÍN SOROLLA STATIONS (1)

- Joaquín Sorolla: It is also an end-of-line facility with access to all the tracks through platforms.

- Font de Sant Lluís: There are three passenger tracks with access through platforms and three freight tracks that do not have access through platforms. Font de Sant Lluís station is the main railway node in Valencia, due to its connection with the harbour.

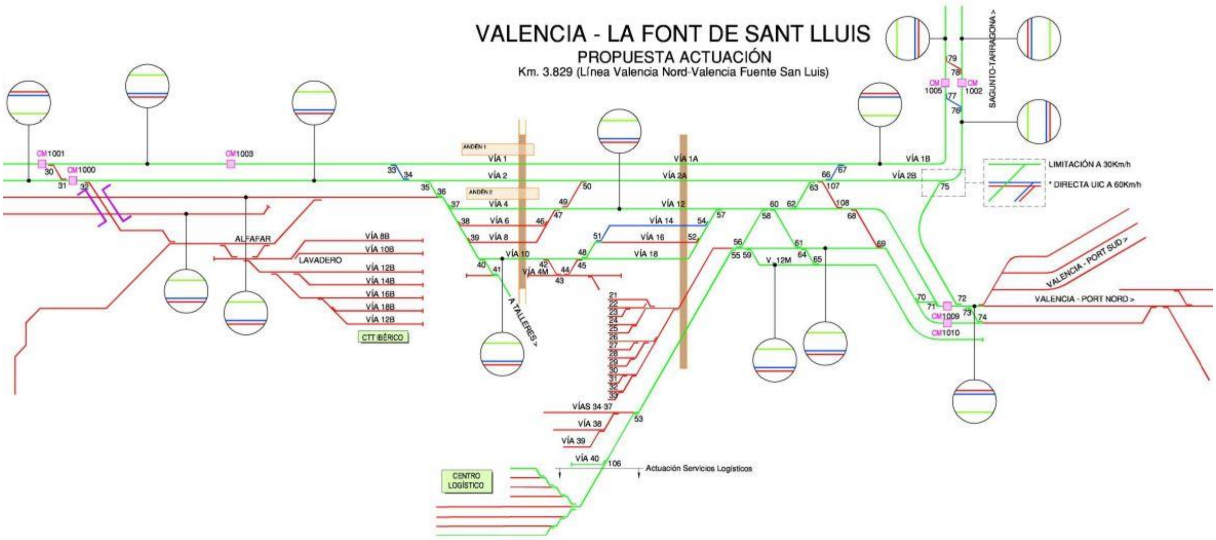


FIGURE 9 LA FONT DE SANT LLUIS STATION (1)

- Cabanyal: No sidings. Double-way track with mixed gauge.

- Roca Cúper: No sidings. Double-way track with mixed gauge.

- Albuixech: No sidings. Double-way track with mixed gauge.

- Massalfassar:

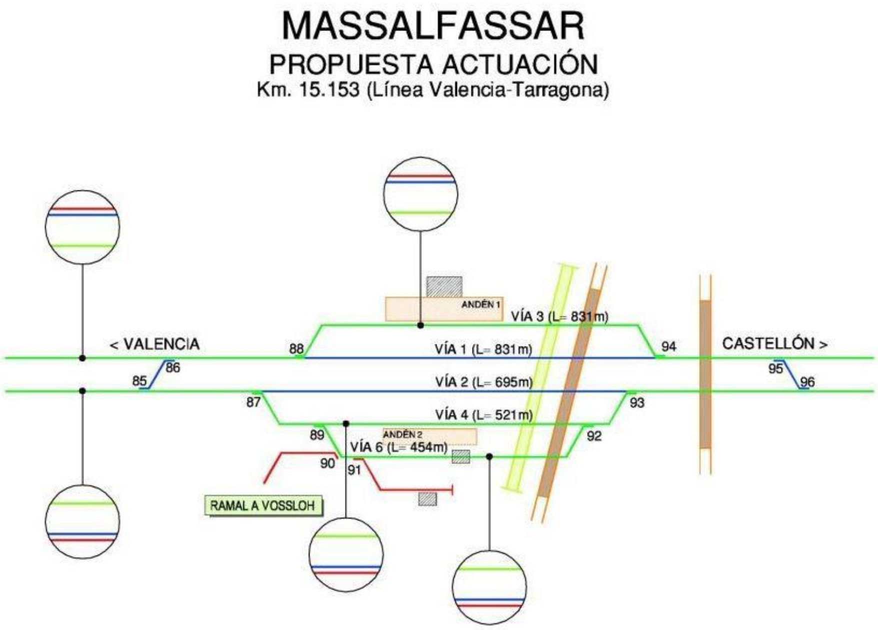


FIGURE 10 MASSALFASSAR STATION (1)

- El Puig: No sidings. Double-way track with mixed gauge.

- Puçol:

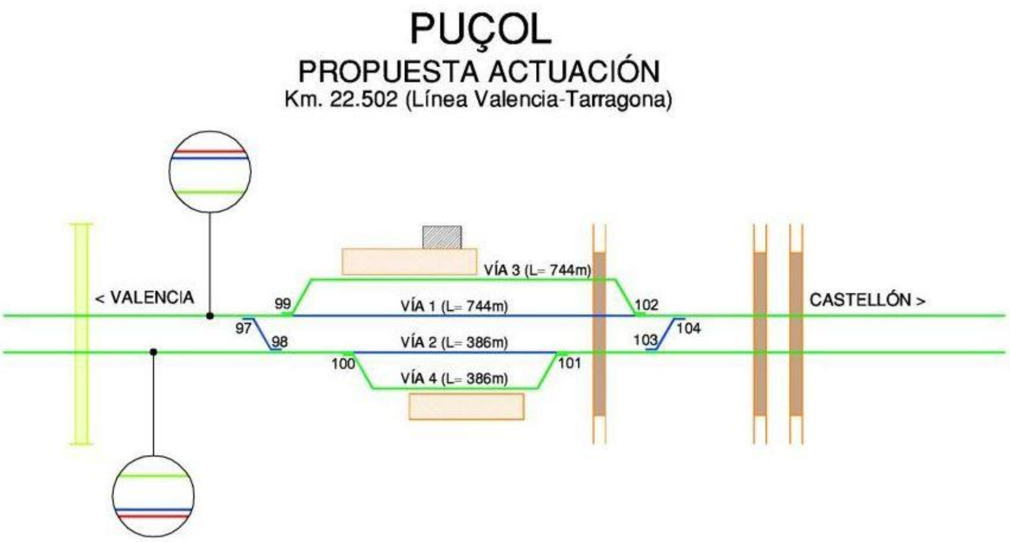


FIGURE 11 PUÇOL STATION (1)

SPEED AND TRAFFIC

Maximum speeds in each sub-section are:

- València Nord – Valencia Cabanyal: 120 km/h

-València Cabanyal – Vinival: 160 km/h

- Vinival – Sagunto: 220 km/h

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2)

TABLE 11 REAL TRAFFIC 2016 (WEEKLY MEAN) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Valencia Nord	Valencia AG A.V.	788	106	182	495	1	4
Valencia AG A.V.	Valencia – La Font	905	223	182	495	1	4
Valencia – La Font	VFSL – AG KM. 1,3	440	130	68	197	44	2
VFSL – AG KM. 1,3	FSL – AG KM 2,3	699	198	105	311	79	6
FSL – AG KM 2,3	Puçol	699	198	105	311	79	6
Puçol	Sagunt – A.Km 28,3	698	198	105	311	79	5

Sagunt – Castelló

The initial situation of the line is a double-way track with Iberian gauge. However, a third rail will be implemented on one way and international gauge rail on the other way, as is shown in Figure 6. The section has 41.43 kilometers (between PK 25+915 and PK67+345) and the implementation of third rail forecasts an admissible train length of 750 m.

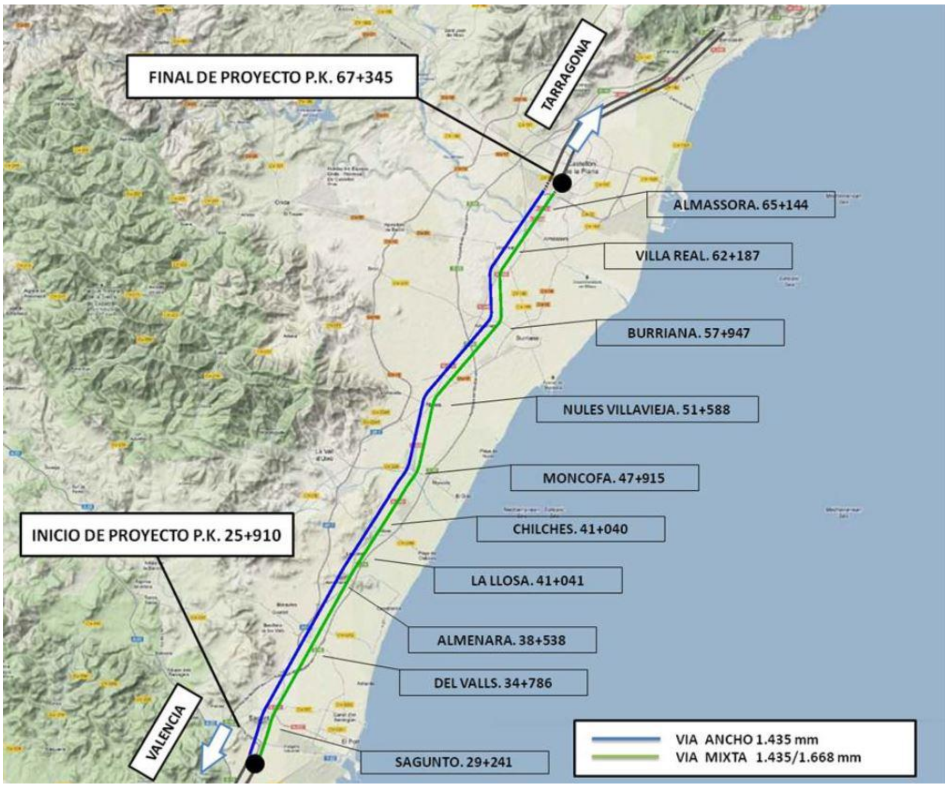


Figure 12 Projected situation of the section Sagunt – Castelló (3)

The switches and crossings displayed are 39 of Iberian gauge and 64 of International gauge.

Railway stations and sidings

The affected stations will have the following layout.

-Sagunt:

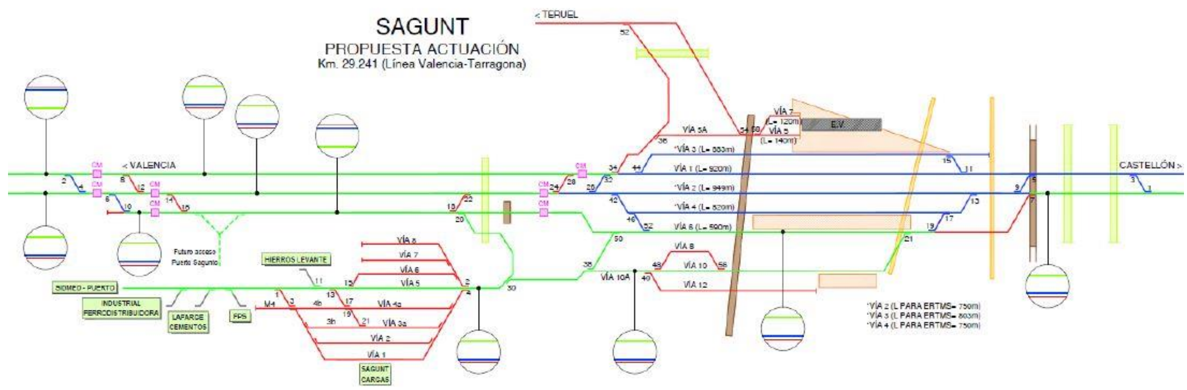


Figure 13 Sagunt station (3)

-Les Valls: No sidings. Valencia – Castellón way has International gauge and Castellón – Valencia mixed gauge.

-Almenara:

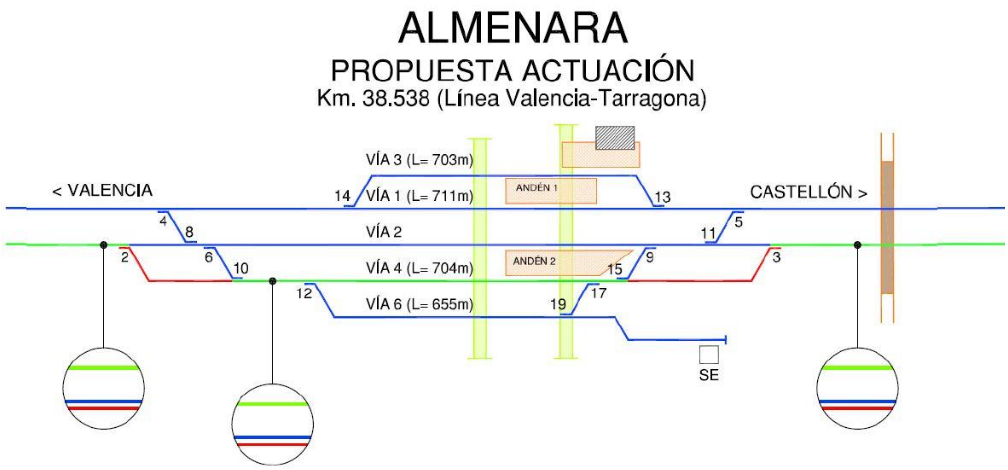


Figure 14 Almenara station(3)

-La Llosa: No sidings. Valencia – Castellón way has International gauge and Castellón – Valencia mixed gauge.

-Chilches: No sidings. Valencia – Castellón way has International gauge and Castellón – Valencia mixed gauge.

-Moncofa:

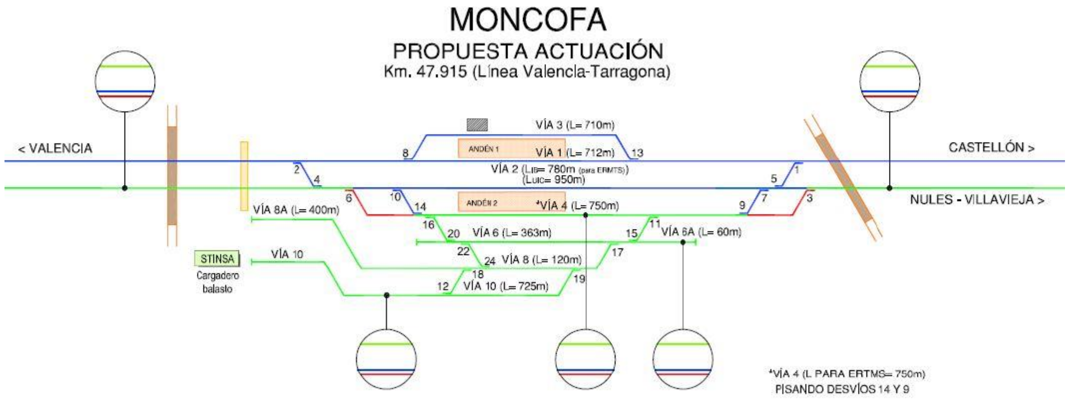


FIGURE 15 MONCOFA STATION (3)

-Nules – Vilavieja: No sidings. Valencia – Castellón way has International gauge and Castellón – Valencia mixed gauge.

-Burriana – Alqueria Niño perdido:

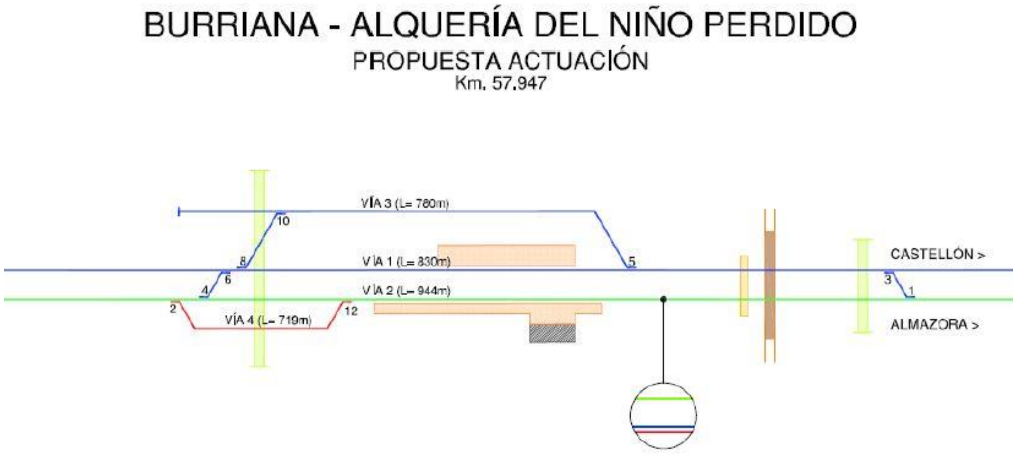


FIGURE 16 BURRIANA - ALQUERIA DEL NIÑO PERDIDO STATION (3)

-Villa Real:

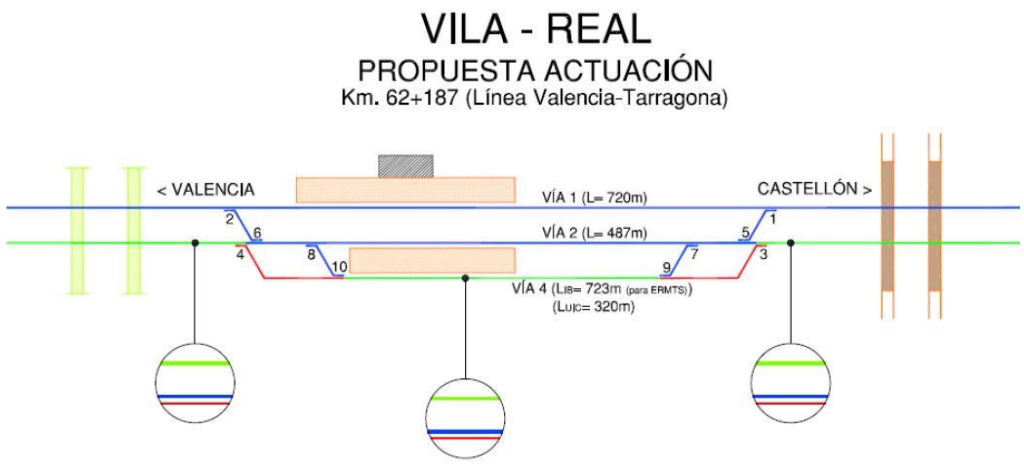


FIGURE 17 VILA-REAL STATION (3)

-Almassora: No sidings. València – Castellón way has International gauge and Castellón – València mixed gauge

SPEED AND TRAFFIC

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2)

TABLE 12 REAL TRAFFIC 2016 (WEEKLY MEAN) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Sagunt – A.KM. 28,3	Sagunt	692	198	105	311	74	4
Sagunt	Almenara	594	198	55	287	51	4
Almenara	Vila-Real	594	198	55	287	50	4
Vila-Real	Castelló de la Plana	592	198	55	286	49	3

Castelló – Vinaròs

The Mediterranean corridor forecasts double-way tracks with International gauge (1.435 m) by 2020. The previous structure has double-way track with Iberian gauge in the whole section. The maximum train length allowed will be 750 m.

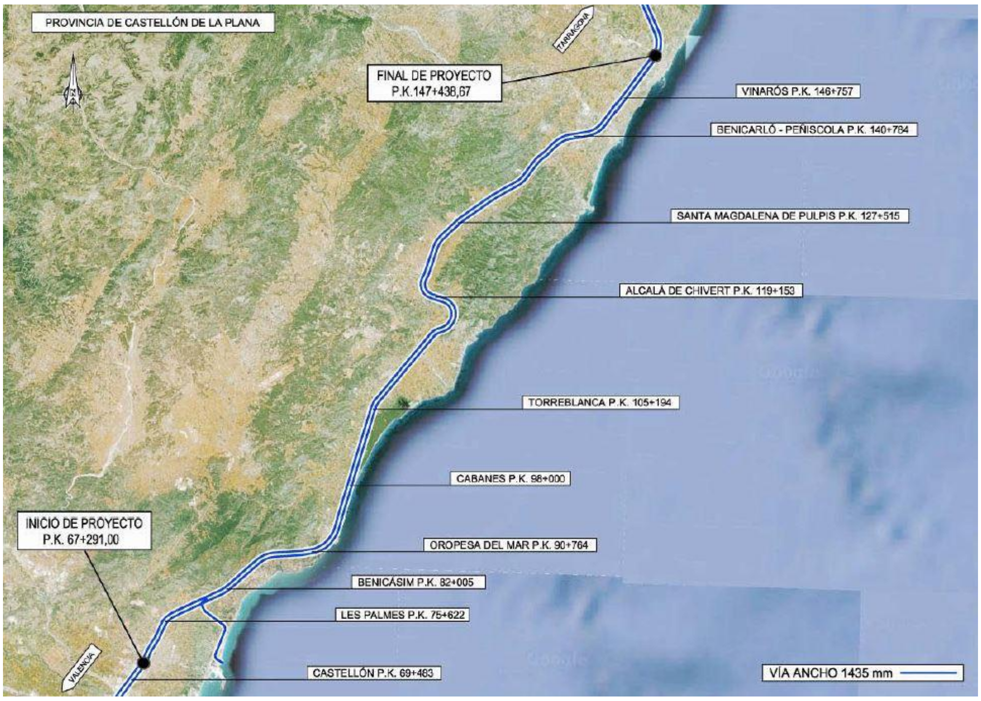


Figure 18 Forecast situation of the section Castelló – Vinaròs (4)

The total number of switches and crossings will be 57 (International gauge) (4)

Railway stations and sidings

In order to define the sidings and the number of tracks projected, the forecast layout is represented for the main stations.

- Castelló:

Figure 19 Castellon station (4)

- Les Palmes:

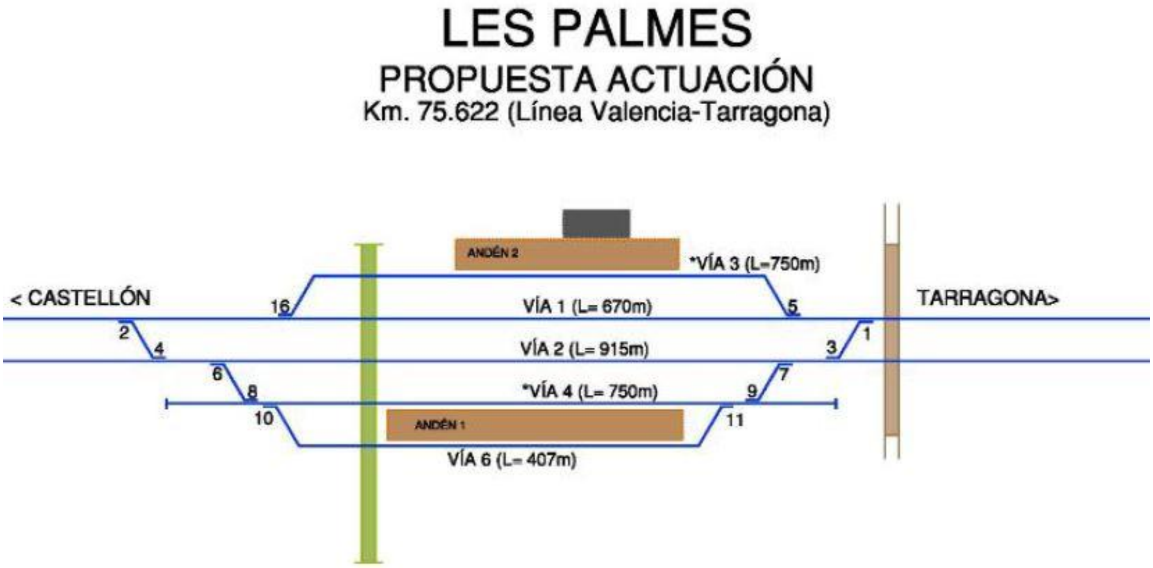


FIGURE 20 LES PALMES STATION (4)

- Benicàsim:

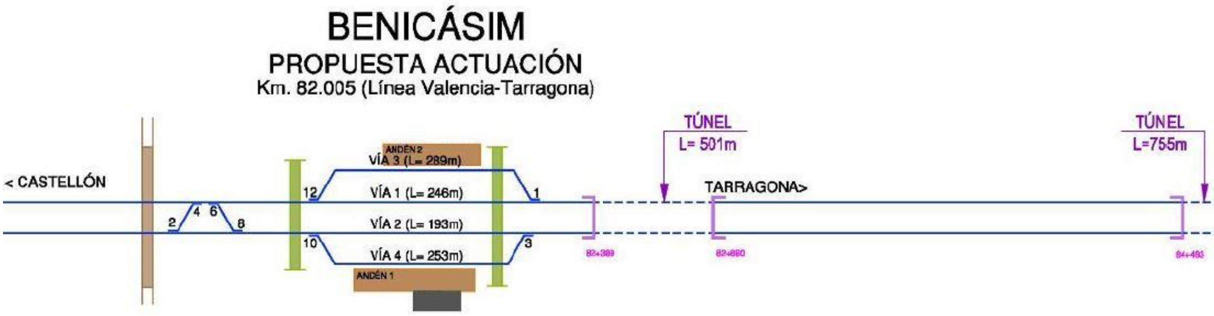


FIGURE 21 BENICÁSIM STATION(4)

- Oropesa del Mar:

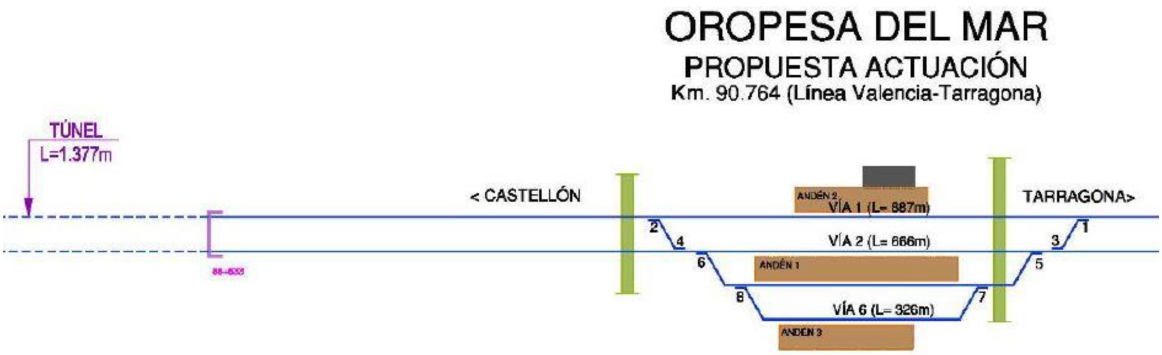


FIGURE 22 ORPESA DEL MAR STATION (4)

- Cabanes: No sidings. Double-way track with International gauge.

- Torreblanca:

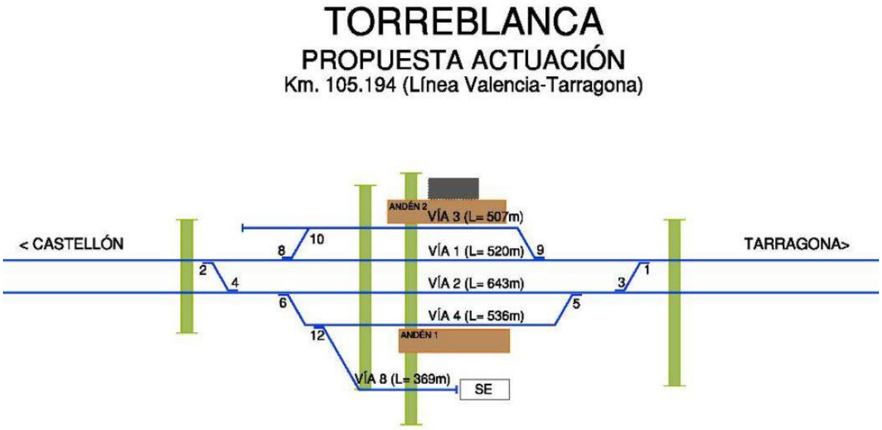


FIGURE 23 TORREBLANCA STATION (4)

- Alcalá de Chivert:

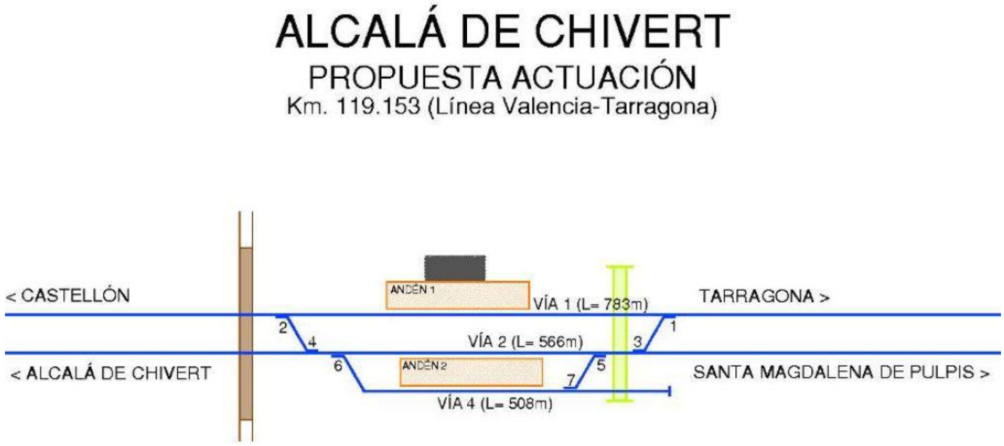


FIGURE 24 ALCALA DE CHIVERT STATION(4)

- Santa Magdalena de Pulpis:

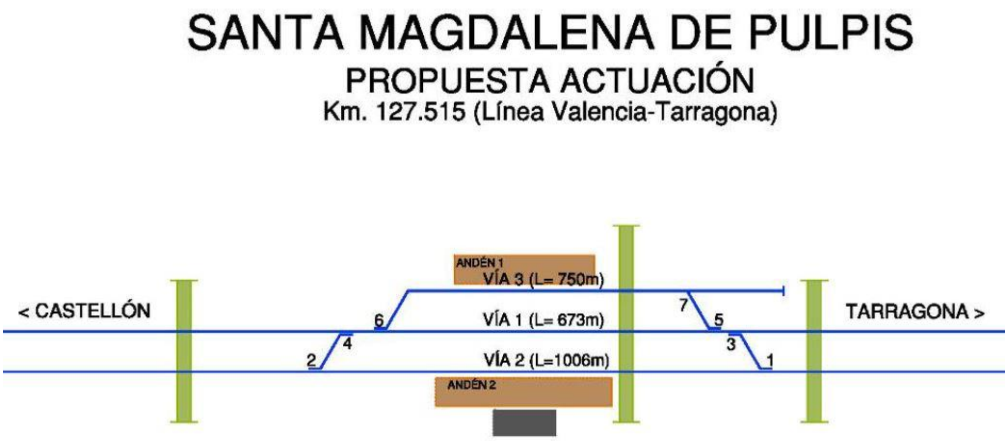


FIGURE 25 SANTA MAGDALENA DE PULPIS STATION (4)

- Benicarló-Peñíscola: In this station, there are two main tracks (track number 1 and 2) and six siding tracks (number 3, 5, 7, 9, 11 and 13).

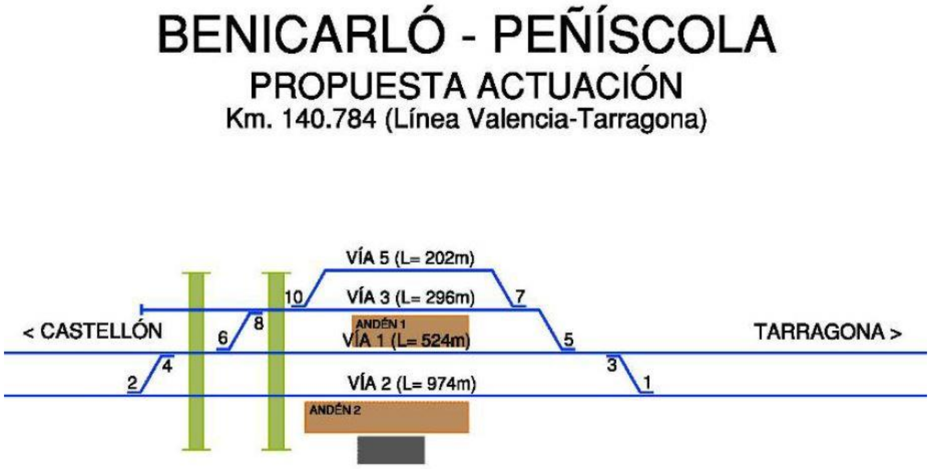


FIGURE 26 BENICARLÓ - PEÑÍSCOLA STATION (4)

- Vinarós:

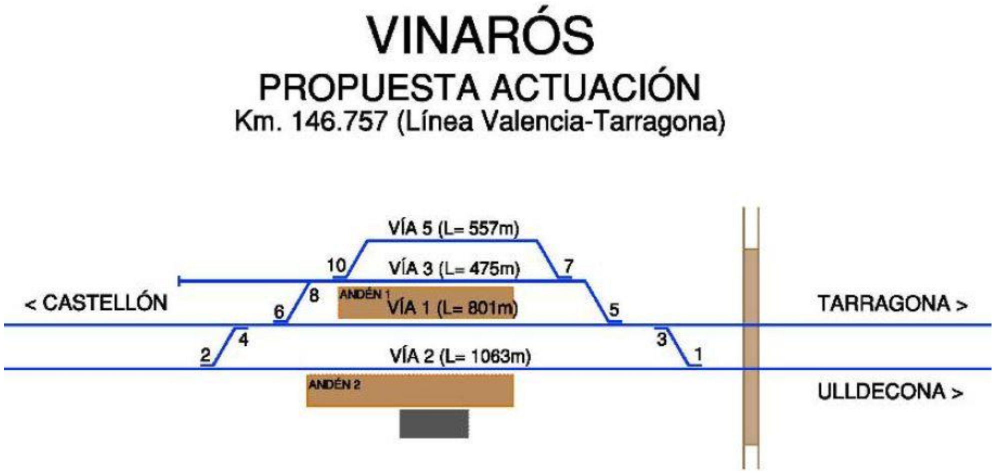


FIGURE 27 VINARÓS STATION (4)

SPEED AND TRAFFIC

Nowadays, the speed is between 200 and 220 km/h, with a punctual speed reduction to 140 km/h in Castellón and 150 km/h between Torreblanca and Alcalá de Chivert stations.

Considering the kilometre points of track 1, the velocities are detailed below.

PK INICIO	PK FIN	VELOCIDAD (km/h)
0+000,000	3+853,464	140
3+853,464	9+922,891	200
9+922,891	33+762,300	220
33+762,300	34+921,161	205
34+921,161	42+333,535	220

PK INICIO	PK FIN	VELOCIDAD (km/h)
42+333,535	50+800,926	150
50+800,926	51+127,067	220
51+127,067	60+412,770	210
60+412,770	79+825,695	205
79+825,695	80+147,081	210

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016)(2)

Table 13 Real traffic 2016 (weekly mean)(2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Castelló de la Plana	Les Palmes	300	192	55	2	49	2
Les Palmes	Orpesa	298	192	55	0	49	2
Orpesa	Vinaròs	294	187	54	0	49	3

VINARÒS – VANDELLÒS

This section has a double-way track with Iberian gauge. However, the forecast is to implement International gauge along the whole section by 2020. (Between P.K.147+438 – P.K.214+611). The maximum train length allowed will be 750 m.

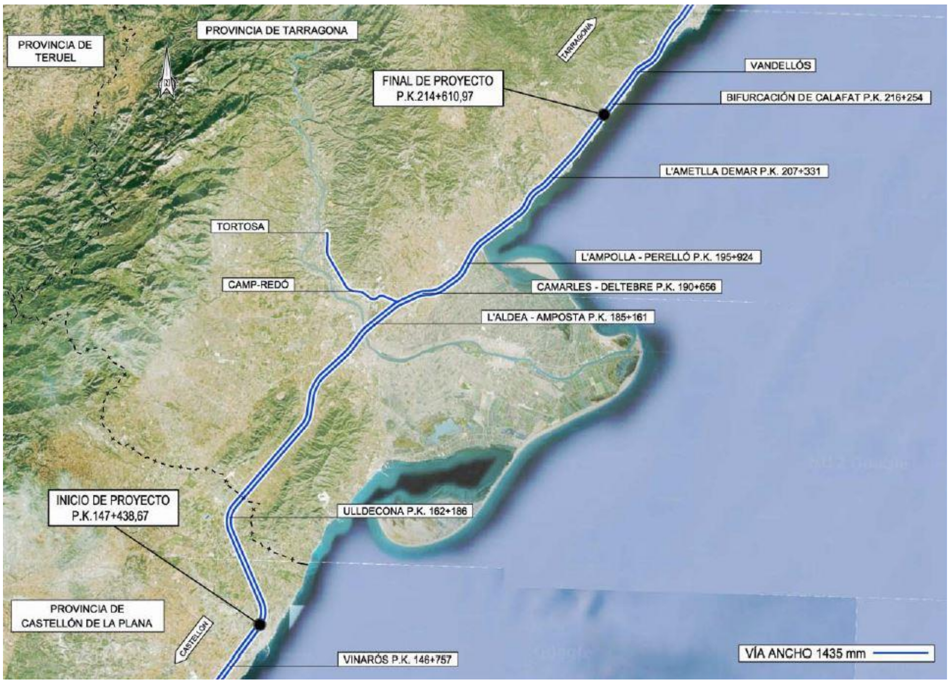


FIGURE 28 PROJECTED SITUATION OF THE SECTION VINARÒS – VANDELLÒS (5)

This section need 30 switches and crossings with International gauge.

RAILWAY STATIONS AND SIDINGS

The main stations are detailed in this section to be aware of the sidings.

- Ulldecona:

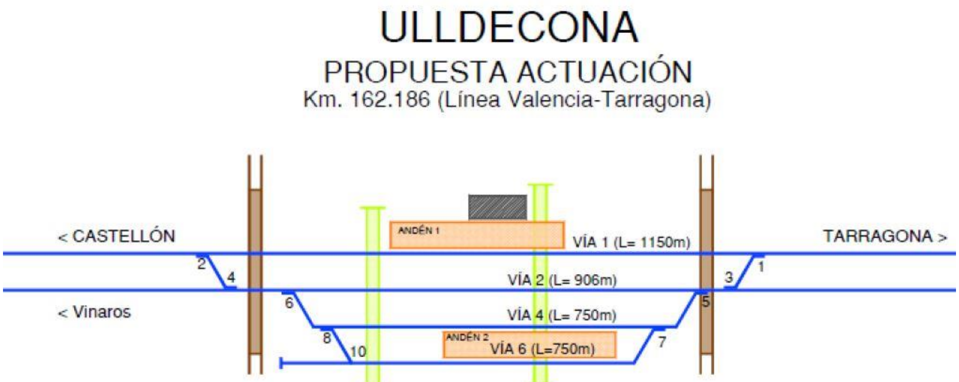


FIGURE 29 ULLDECONA STATION(5)

- L'Aldea – Amposta

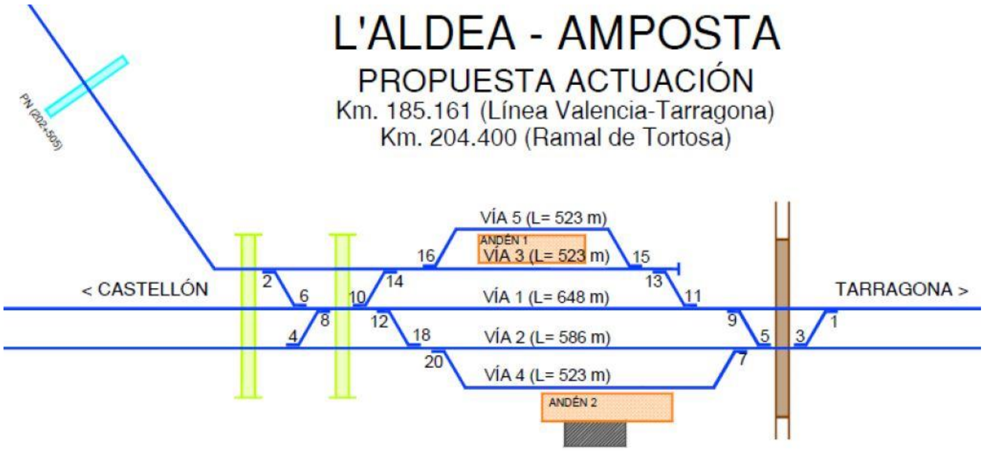


FIGURE 30 L'ALDEA - AMPOSTA STATION (5)

In Aldea – Amposta station there is a railway branch to reach Tortosa. The stations of Camp redó and Tortosa are part of this branch and can be useful thanks to the international gauge constructed.

- Camarles Deltebre: No siding. Double- way track with International gauge.

- L'àmpolla – Perelló: No siding. Double- way track with International gauge.

- L'Ametlla de Mar:

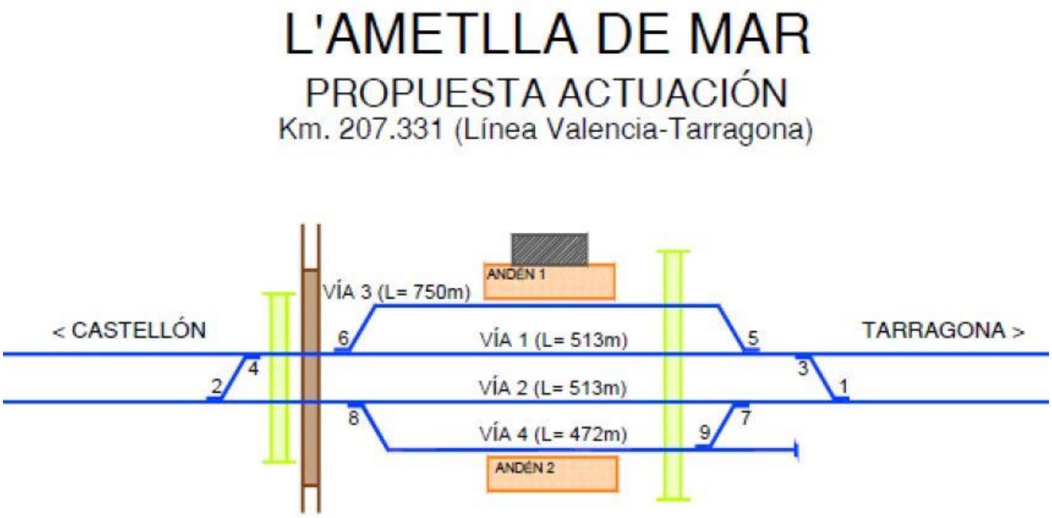


FIGURE 31 L'AMETLLA DE MAR STATION (5)

Speed and Traffic

The commercial speed is 210 km/h until Ametlla de Mar station then, it can reach 220 km/h.

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2)

Table 14 Real traffic 2016 (weekly mean) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Vinaròs	Ulldecona – Alcana	306	186	68	0	49	2
Ulldecona – Alcana	L'Aldea	305	186	68	0	49	2
L'Aldea	Bif. Calafat	379	186	137	0	49	7
Bif. Calafat	Vandellòs	378	186	137	0	49	6

The branch in l'Aldea has a daily capacity of 120 trains and only 30 trains are running daily in both ways. Therefore, the saturation of this branch is 25% and can be used for the main line management.

Vandellòs – Nus de Vilaseca

This section has a single track with Iberian gauge. However, double-way track with International gauge is under construction and should be operative by 2020. The objective is to join this section with the high speed line Madrid – Barcelona.

The total length of the section is 37 km with mixed traffic. Now, the maxim basic length of the freight trains can be 450 m, but the new line will allow trains of 750 m length.

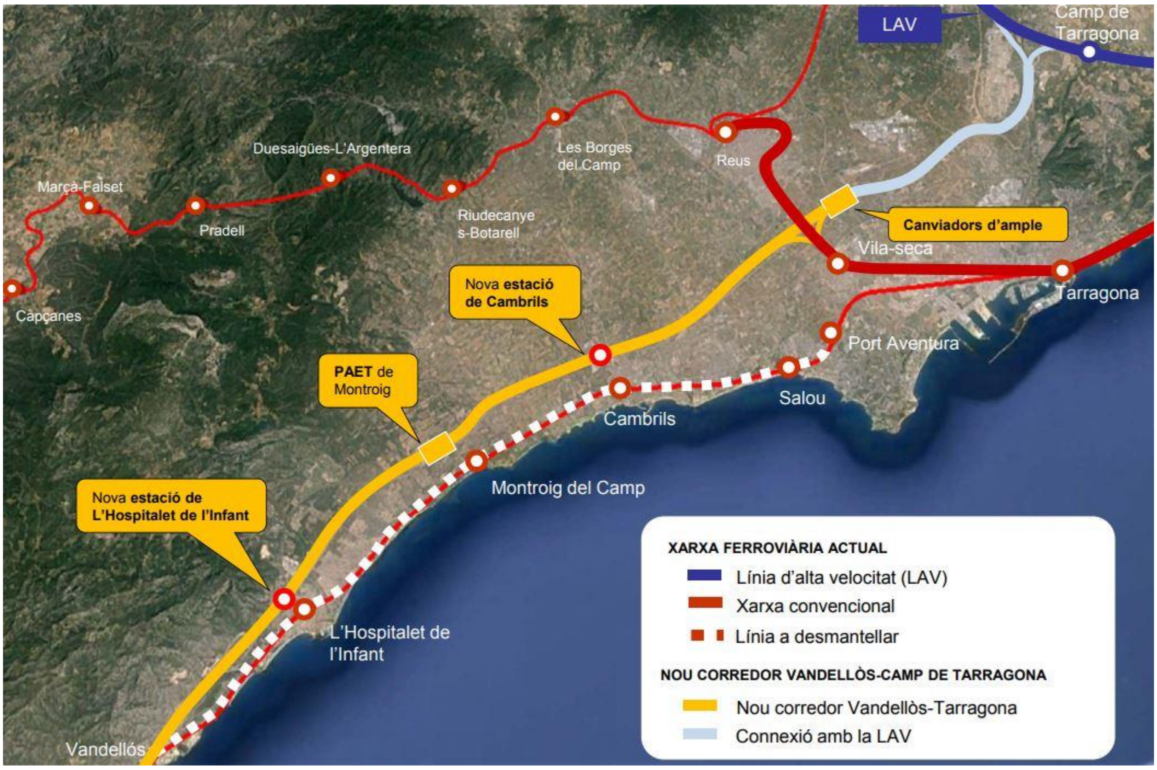


Figure 32 Situation of the section Vandellòs – Vilaseca (6)

Figure 33 Stations and connections (7)

STATIONS AND SIDINGS

The existing track will be substituted by a new infrastructure with different path. Therefore, all the stations are new and the construction is adapted to an efficient performance (8). The stations will be:

- Hospitalet de l'Infant / Vandellòs (PK 8+309.265 to PK 8+7729.265): There are 2 general tracks and 2 siding tracks (400 m)

- PAET Montroig (PK 15+930.6 to PK 16+350.6): 2 general tracks and 2 siding tracks (750 m + vías mango de seguridad de 25 m de longitud útil)

- Cambrils (P.K. 23+157.675 to P.K. 23+357.675): 2 general tracks and 2 siding tracks (200 m of effective length)

- Vila seca: The layout of Vila-Seca station is attached in the following section.

- Estació central (PK 35+720 to 36+160): 2 general tracks and 4 siding tracks (400x10 m and 226x8 m for the interior and exterior siding tracks respectively)

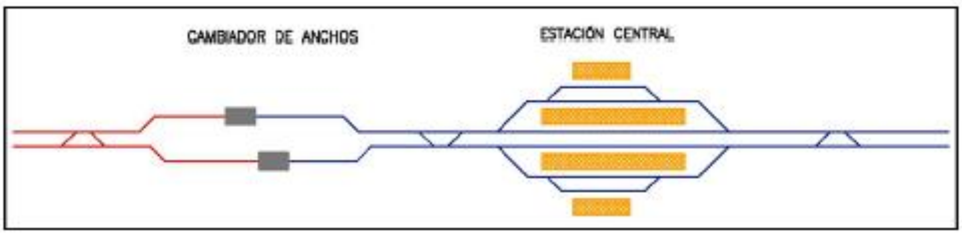


FIGURE 34 ESTACIÓ CENTRAL LAYOUT

The switch and crossings in this section are divided in:

- Hospitalet de l'infant: 12 devices

- Mont-Roig: 10 devices

- Cambrils: 4 devices

SPEED AND TRAFFIC

Nowadays, the maximum speed in this section with a single track is 160 km/h. The international gauge implementation will allow reaching a maximum speed of 220 km/h in the main tracks (8).

With the construction of this new infrastructure, all the actual traffic in this section will run through this track. Nowadays, the circulations are following a different path, which is listed in the following table. The values are the mean weekly traffic in this tracks classified by typology of train (2016)(2)

Table 15 Real traffic 2016 (weekly mean) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Vandellòs	Cambrils	390	186	149	0	49	5
Cambrils	Salou	403	186	167	0	49	1
Salou	Port Aventura	426	186	191	0	49	1
Port Aventura	AG.CLAS. KM 272	440	186	204	0	49	1
AG.CLAS. KM 272	Tarragona	427	186	204	0	36	1

NUS DE VILASECA – ST. VICENÇ DE CALDERS

This section is divided in two sub-sections, from Nus Vilaseca to Tarragona (9km) and from Tarragona to St. Vicenç de Calders (24.1 km)

The section has a double track with Iberian gauge. There is a one-way track to access one of the logistics centers of Tarragona's harbor (Tres Camins) that may be interesting while transporting freight trains. The forecast is to implement mixed gauge along the whole section by 2020.

FIGURE 35 PROJECTED SOLUTION FOR THE SECTION VILASECA – ST. VICENÇ DE CALDERS (9)

This section needs 109 switch and crossing devices, of which 17 have Iberian gauge and 92 mixed or standard gauge.

RAILWAY STATIONS AND SIDINGS:

The configuration of the whole section is:

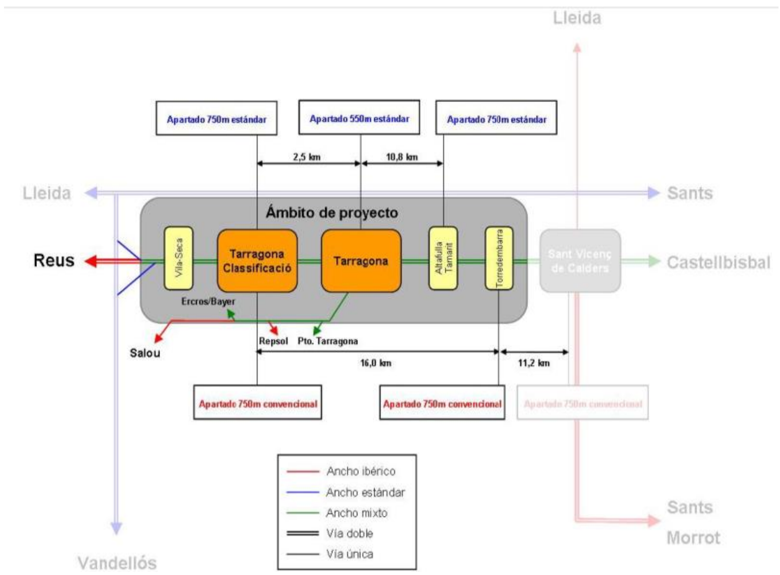


FIGURE 36 LAYOUT OF THE CONFIGURATION (9)

Now, all the stations are listed and sidings and switches and crossings detailed.

- Torredembarra:

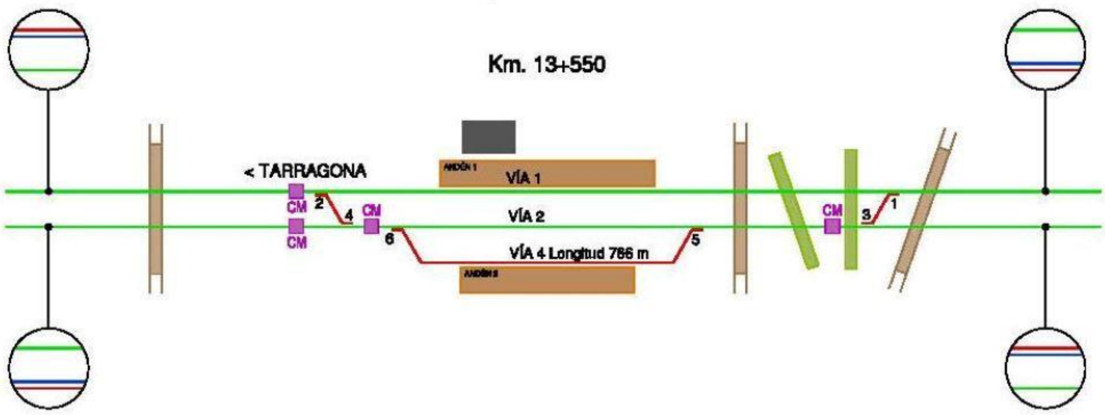


FIGURE 37 TORREDEMBARRA STATION(9)

- Altafulla – Tamarit:

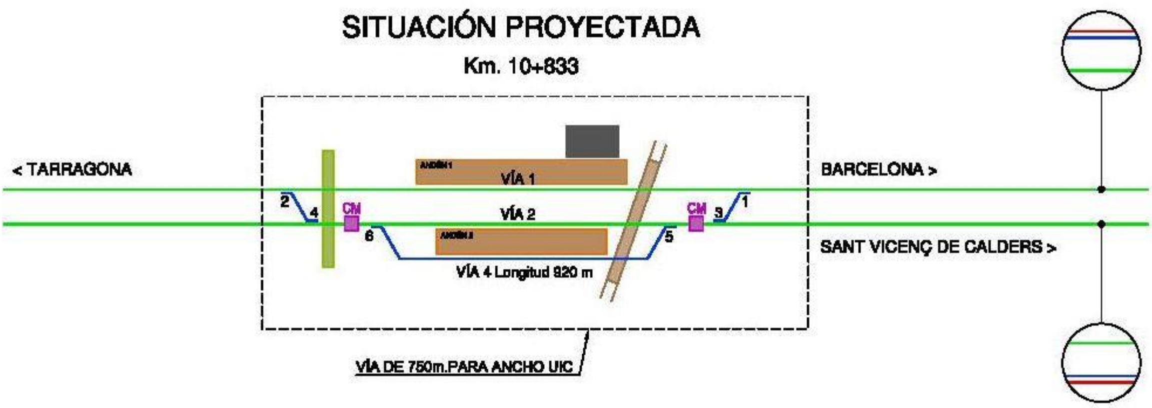


FIGURE 38 ALTAFULLA - TAMARIT STATION (9)

- Tarragona:

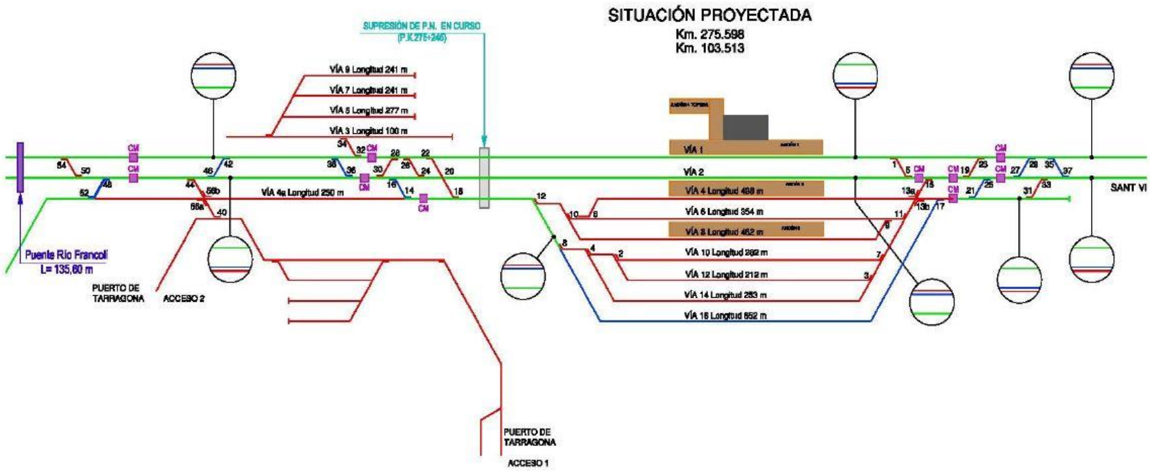


FIGURE 39 TARRAGONA STATION (9)

- Vila – Seca

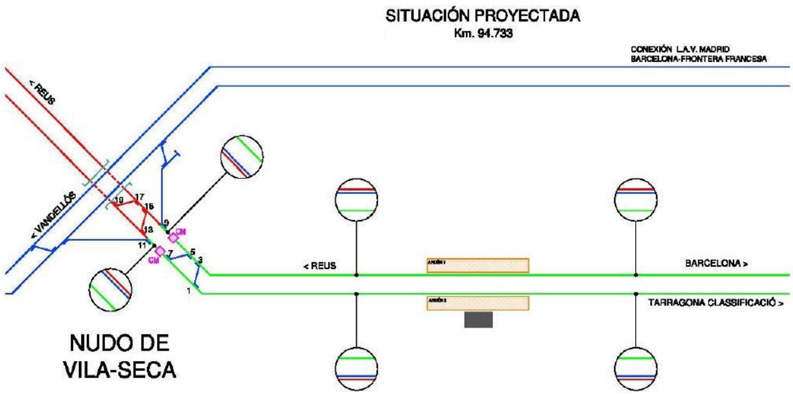


FIGURE 40 VILA-SECA STATION (9)

- Tarragona Classificació: This station is a logistical node that links the Mediterranean Corridor with the Tarragona harbor.

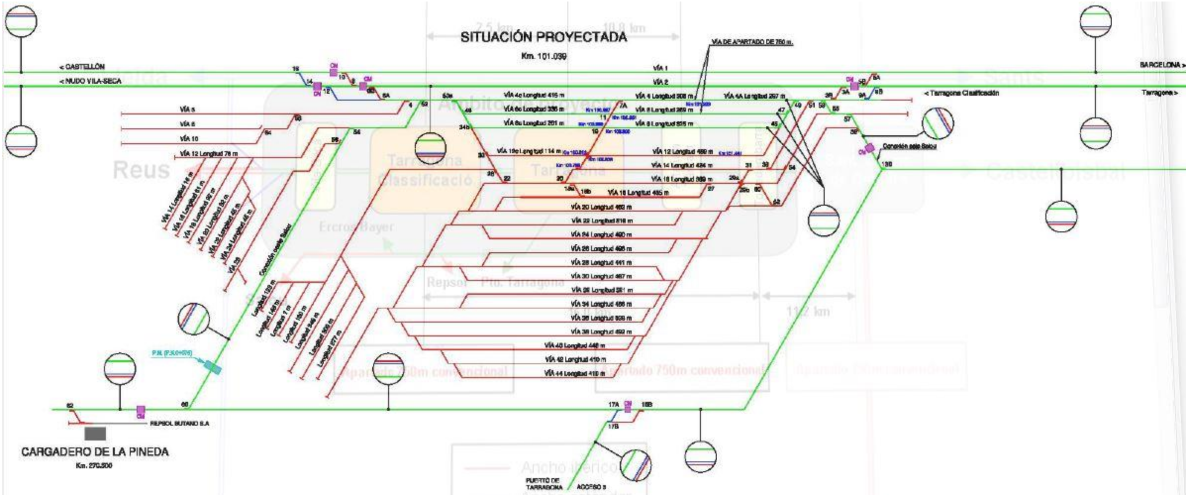


FIGURE 41 TARRAGONA CLASSIFICACIÓ STATION (9)

SPEED AND TRAFFIC

The maximum speed of the section is 160 km/h and cannot be reached in the whole track. Some parts of the track have speed limitations of 55 km/h.

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2011) (10).

TABLE 16 REAL TRAFFIC 2011 (WEEKLY MEAN) (10)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Vila-Seca	Tarragona Classif.	508	14	228	0	260	6
Tarragona Classif.	Tarragona	460	14	228	0	212	6
Tarragona	St. Vicenç Calders	791	205	347	0	232	7

St. Vicenç de Calders – Martorell

The section has a double track with Iberian gauge. The forecast is to implement mixed gauge along the whole section by 2020. The total length is 85 km.

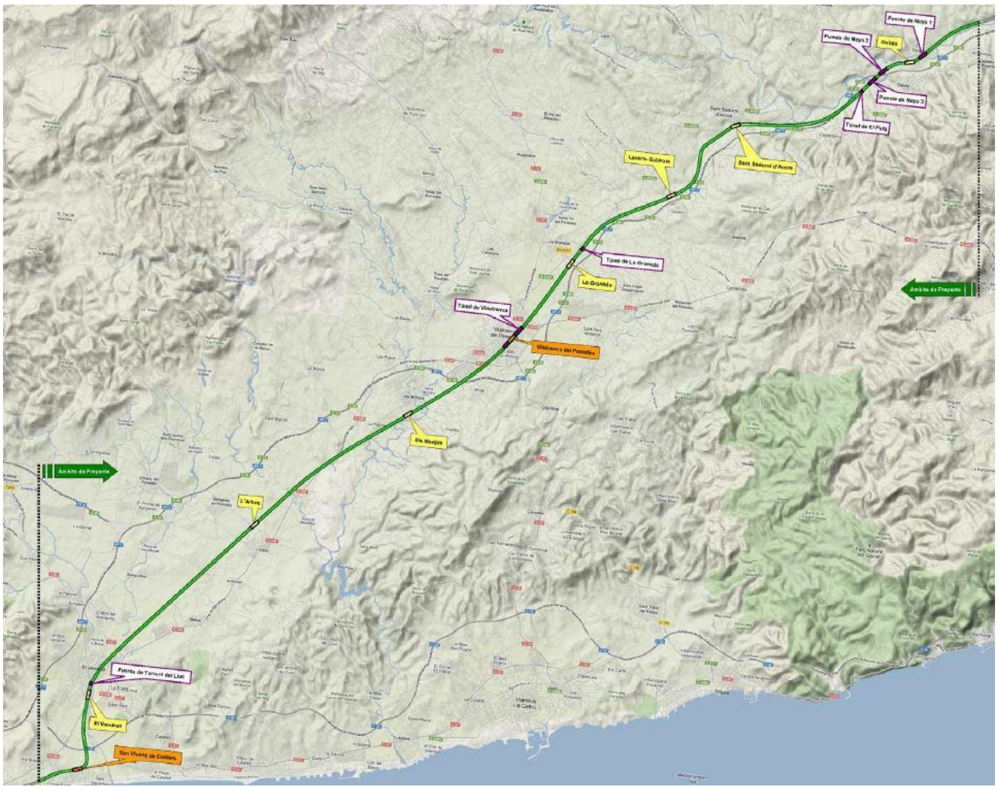


Figure 42 Projected solution for the section St. Vicenç de Calders – Martorell (11)

This section needs 95 switch and crossing devices, of which 30 have Iberian gauge and 65 mixed or standard gauge.

Stations and sidings

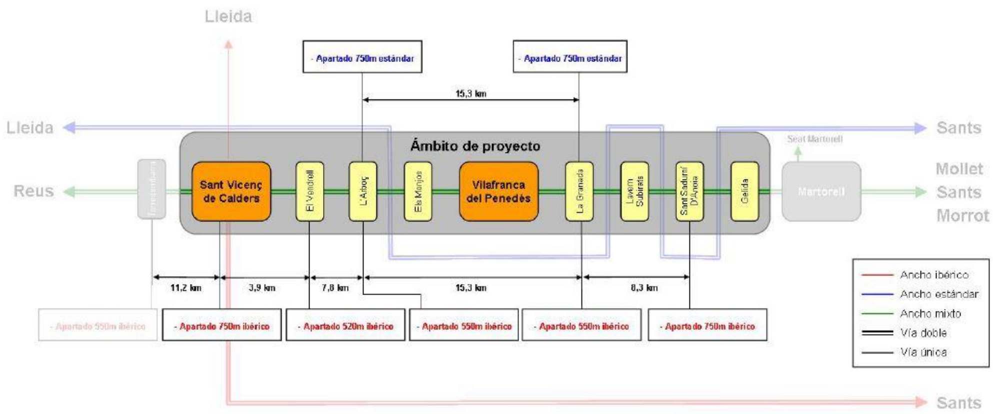


Figure 37. Layout of the section (11)

Now, all the stations are listed and sidings and switches and crossings detailed.

- Gélida: No sidings. Double-way track with mixed gauge.

- Sant Sadurní d'Anoia:

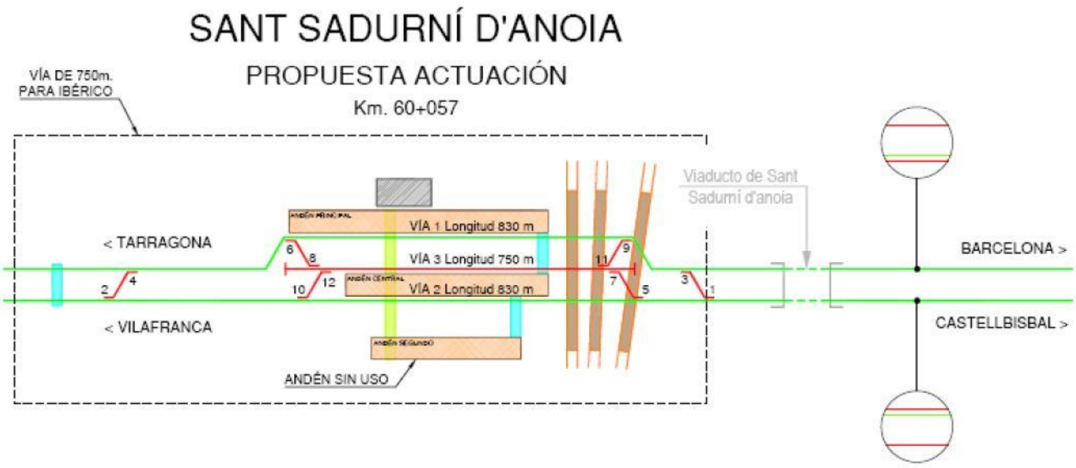


FIGURE 43 SANT SADURNI D'ANOIA STATION (11)

-Lavernt – Subirats: No sidings. Double-way track with mixed gauge.

- La Granada:

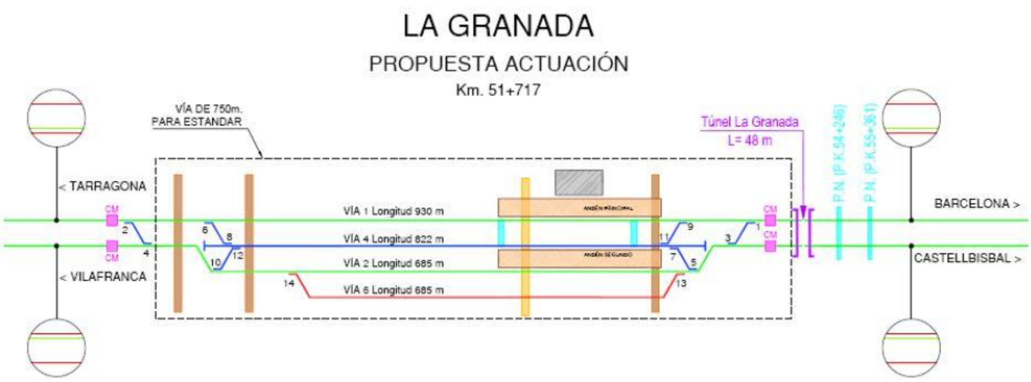


FIGURE 44 LA GRANADA STATION (11)

- Vilafranca del Penedés:

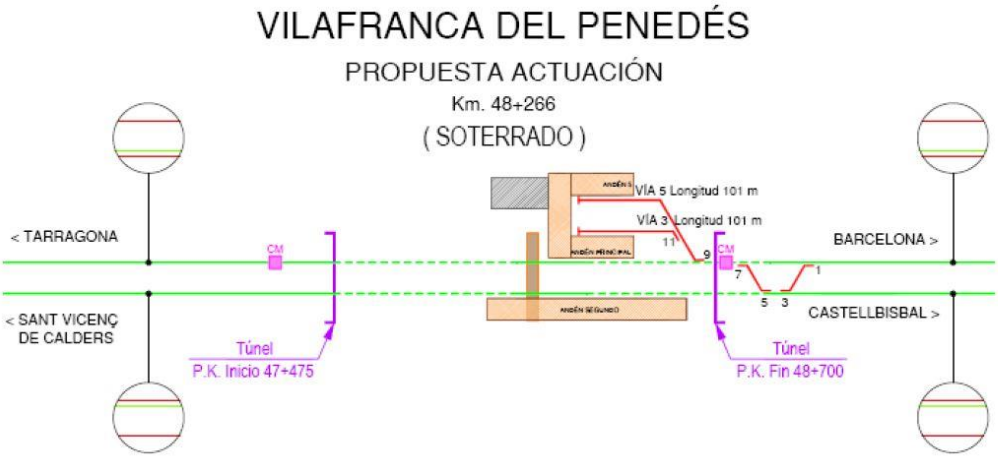


FIGURE 45 VILAFRANCA DEL PENEDES STATION (11)

- Els Monjos:

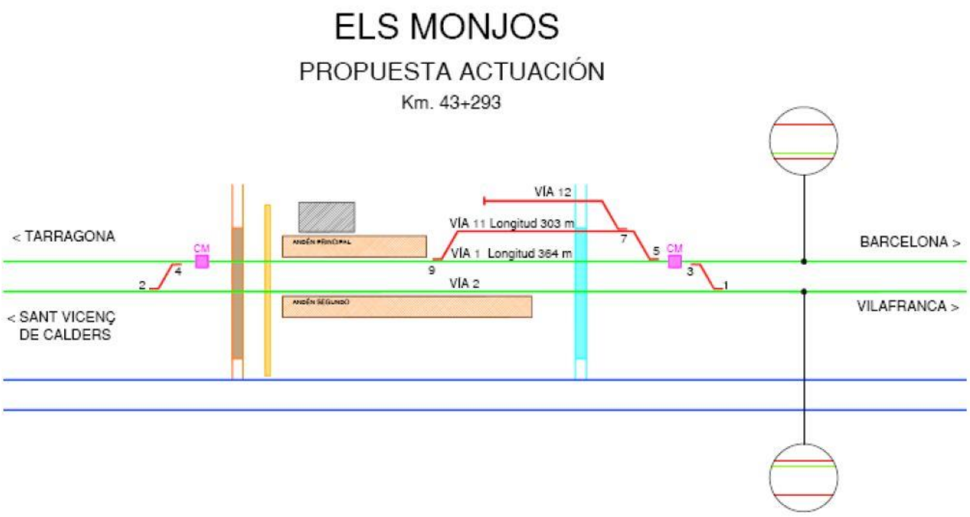


FIGURE 46 ELS MONJOS STATION (11)

- L'Arboç:

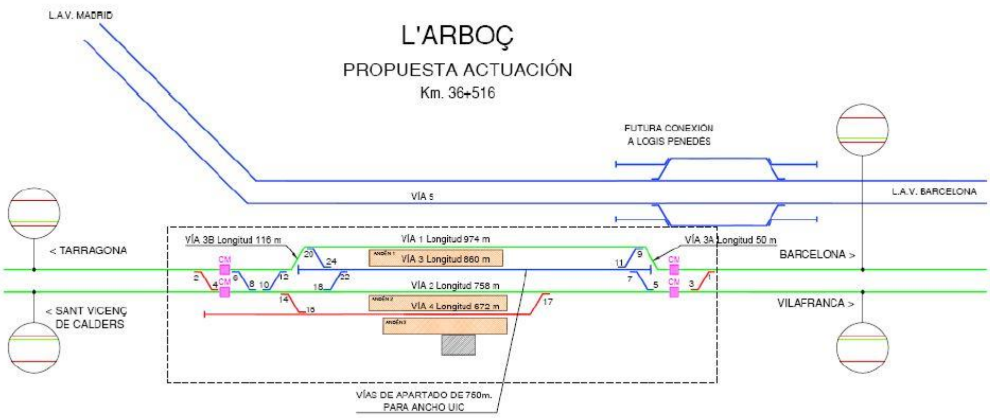


FIGURE 47 L'ARBOÇ STATION (11)

- El Vendrell:

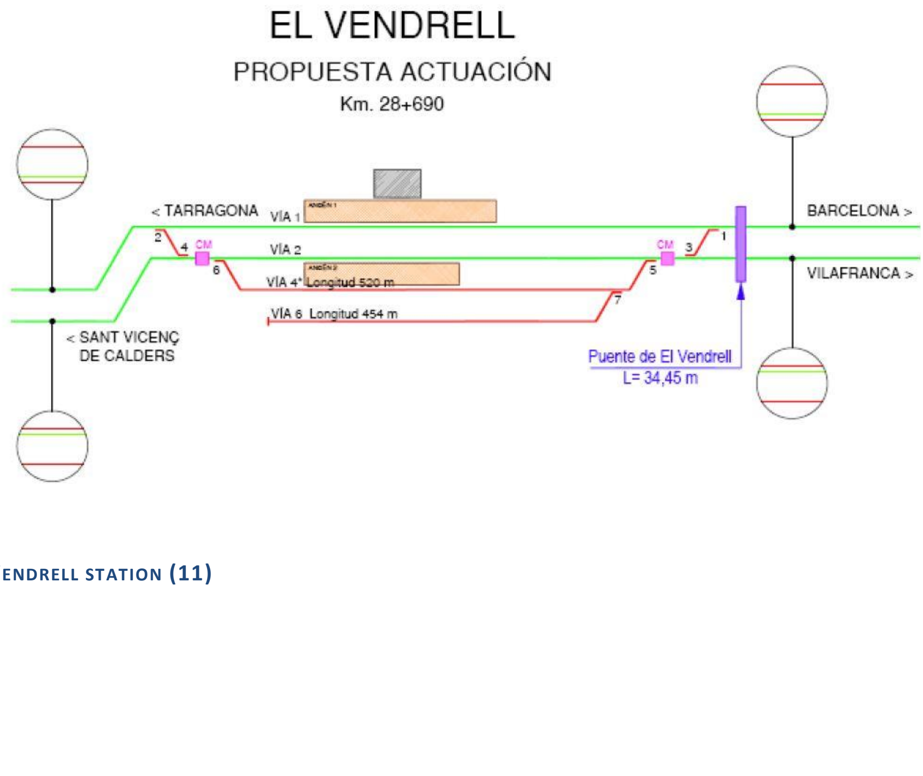


FIGURE 48 EL VENDRELL STATION (11)

- Sant Vicenç de Calders: It is an important node, with a huge daily circulation of trains.

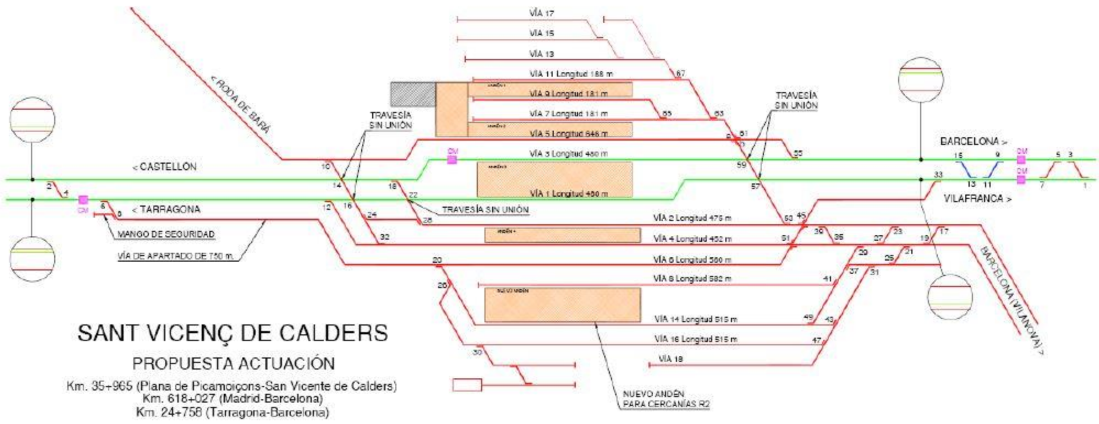


Figure 49 St Vicenç de Calders station (11)

Speed and traffic

The maximum speed of this section is 140 km/h.

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2).

Table 17 Real traffic 2016 (weekly mean) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
St. Vicenç Calders	L'Arboç	599	1	58	290	247	3
L'Arboç	Vilafranca Penedés	680	1	2	429	247	2
Vilafranca Penedés	S. Sadurní	750	1	2	498	245	4
S. Sadurní	Aguja Km.70,5	751	1	2	498	246	4
Aguja Km.70,5	Aguja Km. 71,185	746	1	2	498	241	4
Aguja Km. 71,185	Martorell	820	1	2	498	315	5

MARTORELL – CASTELLBISBAL

This section is already constructed and has double-way track with mixed gauge.

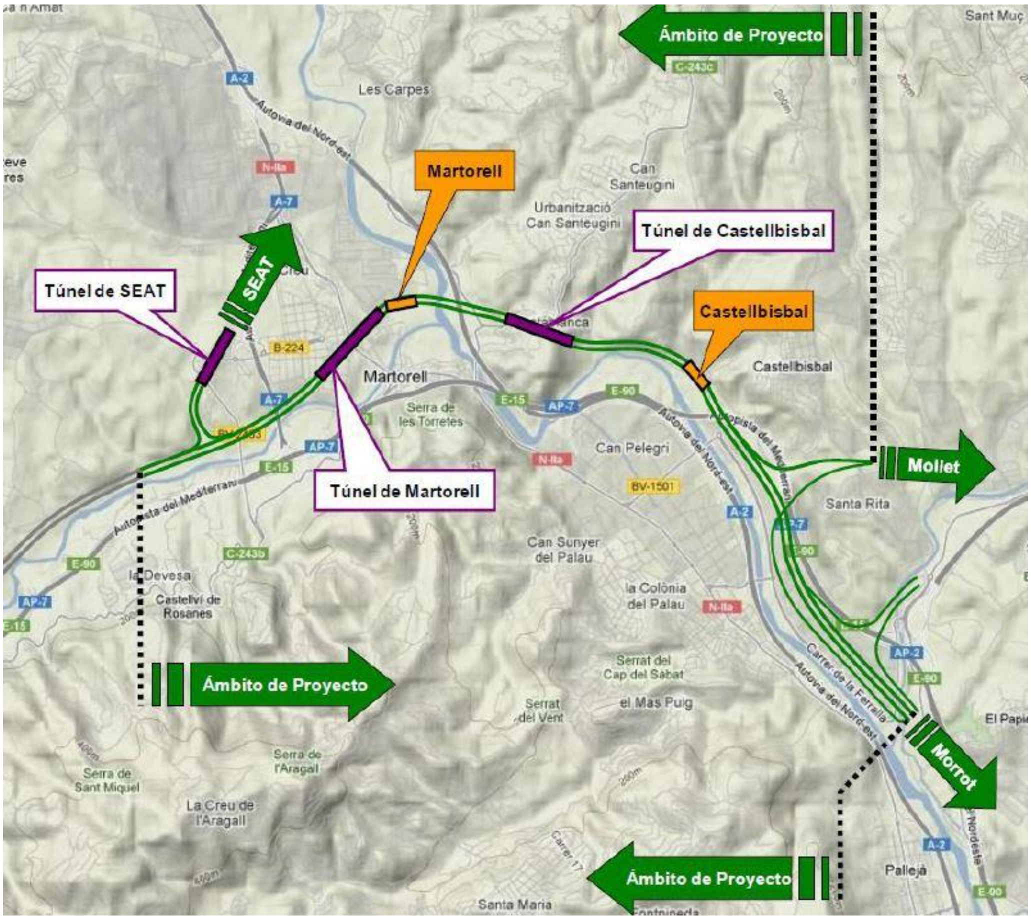


FIGURE 50 SITUATION OF THE SECTION MARTORELL – CASTELLBISBAL (12)

This section needs 95 switches and crossing devices, of which 6 have Iberian gauge and 89 mixed gauge.

STATIONS AND SIDINGS

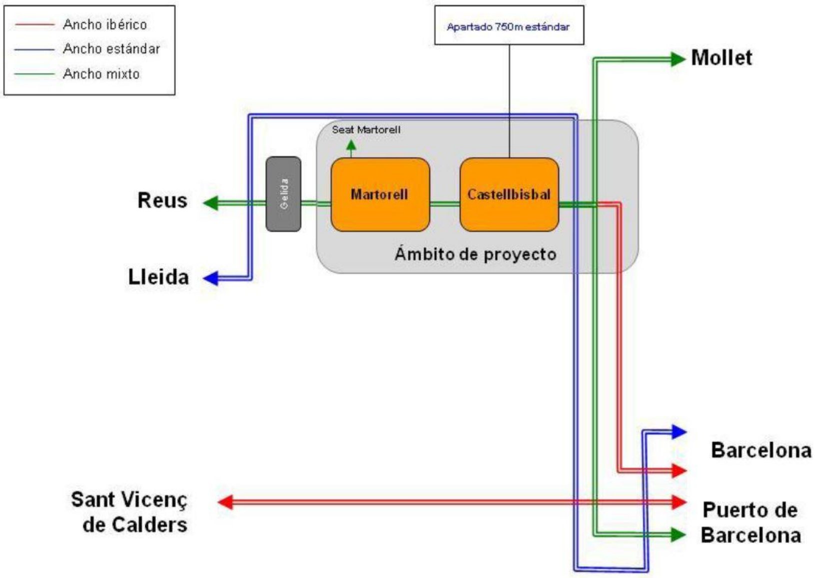


FIGURE 51 LAYOUT OF THE SECTION (12)

Now, all the stations are listed and sidings and switches and crossings detailed.

- Castellbisbal:

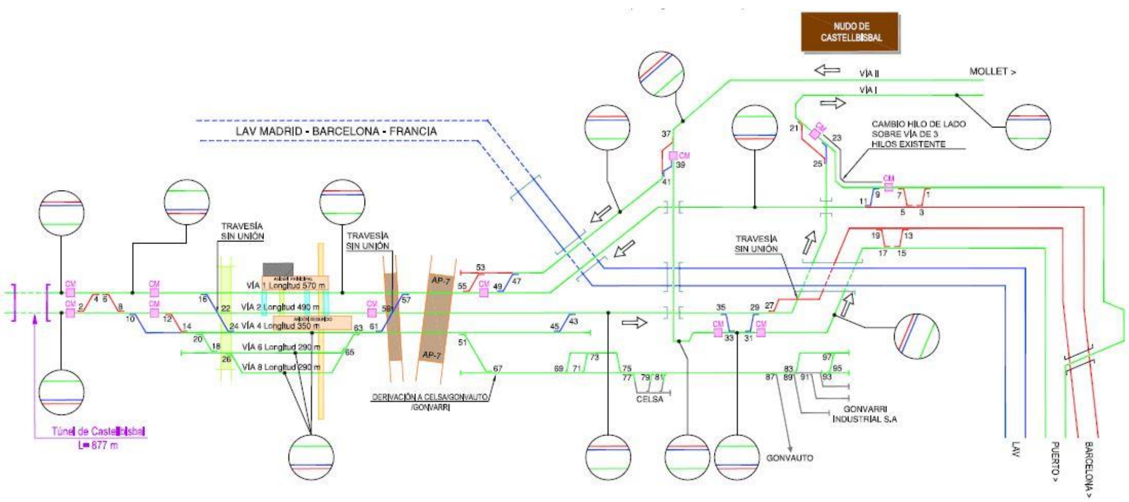


FIGURE 52 CASTELLBISBAL STATION (12)

- <u>Martorell:</u>

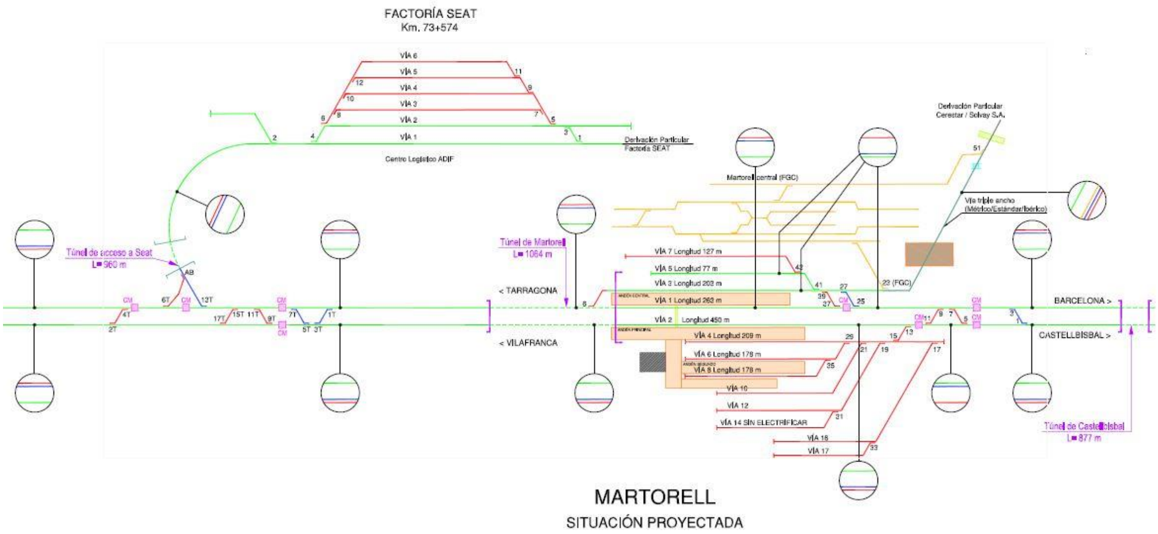


FIGURE 53 MARTORELL STATION (12)

SPEED AND TRAFFIC

The following table summarizes the mean weekly traffic in this track classified by typology of train (2016) (2).

TABLE 18 REAL TRAFFIC 2016 (WEEKLY MEAN) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Martorell	Castellbisbal	1,460	1	2	1,125	326	6

Castellbisbal - Port Barcelona

In this section the third rail is already implemented. Therefore, a double track with mixed gauge is used. The total length of the section is 17.5 km and the trains can have a maximum length of 750 m.

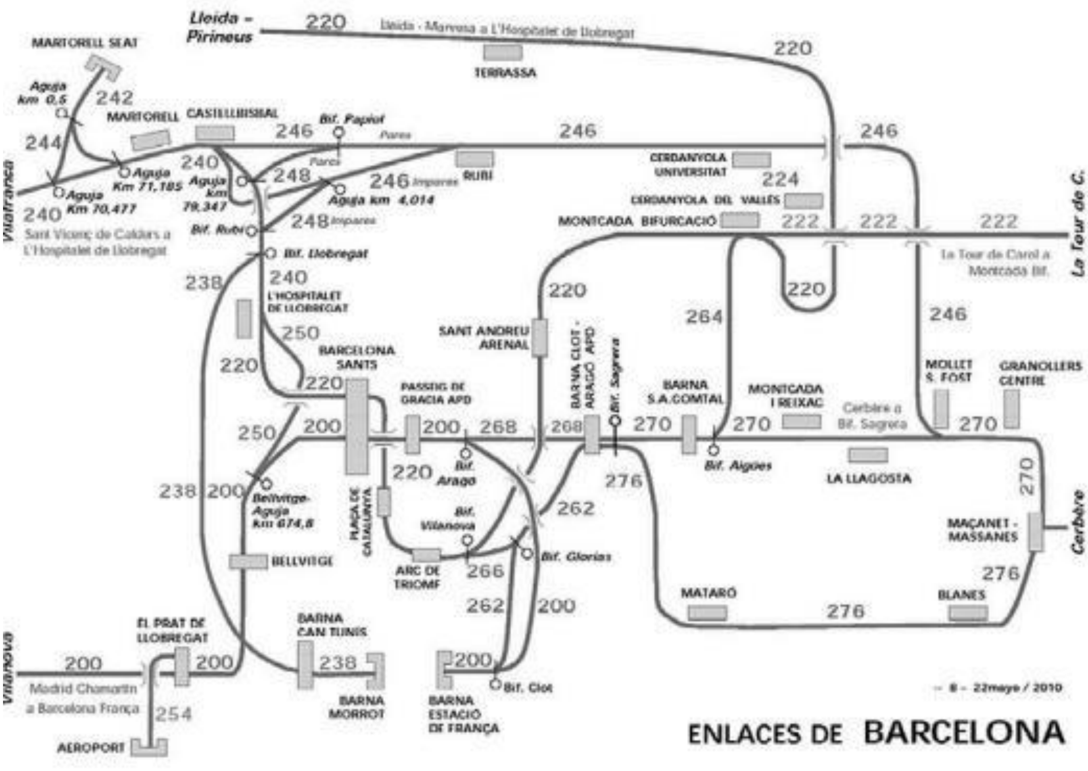


Figure 54 Layout of lines and stations (13)

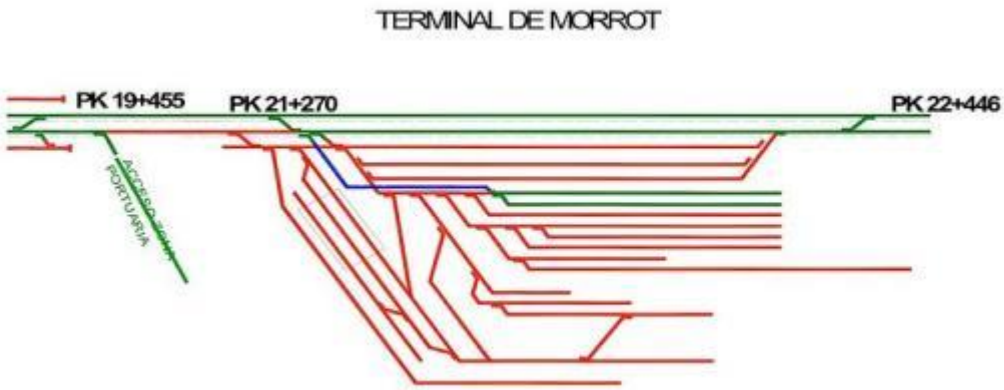


Figure 55 Terminal de Morrot layout (14)

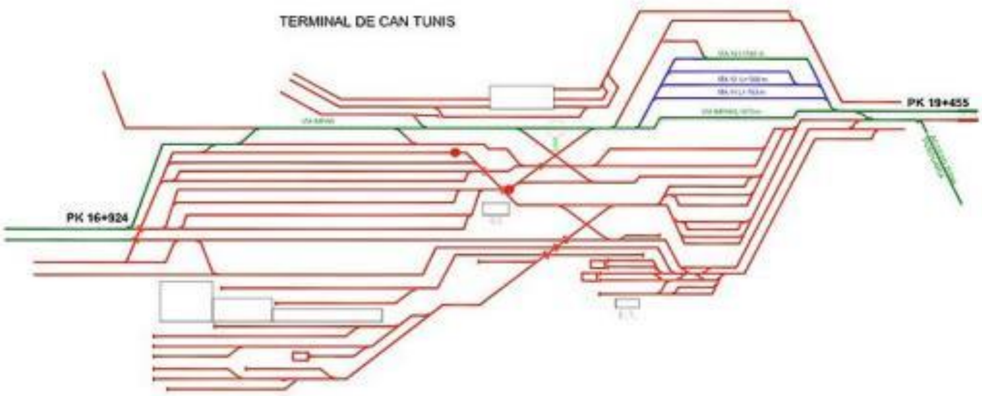
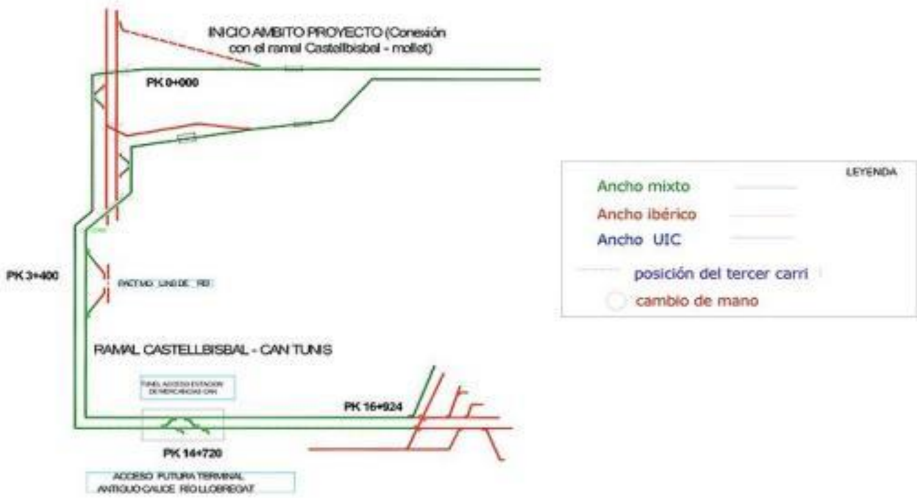


FIGURE 56 CAN TUNIS STATION



SPEED AND TRAFFIC

The maximum speed of this section is 140 km/h.

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2).

Table 19 Real traffic 2016 (weekly mean) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Castellbisbal	Cast – AGS Rubí	1,450	1	2	1,126	316	6
Cast – AGS Rubí	Cast – AGS Molins	1,136	1	2	901	228	4
Cast – AGS Molins	Riu Llobregat	287	22	-	-	262	3
Riu Llobregat	Barna – Can Tunis	286	22	-	-	262	3
Barna – Can Tunis	Barna - Morrot	66	-	-	-	66	0

The statistics of Barcelona's harbor summarize the total number of trains in a year classified by gauge. Moreover, the monthly evolution of the railway traffic is also detailed in the following tables. (15)

Table 20 Traffic circulations (15)

Gauge	2015	2016	%	% over the total 2016
Iberian (1.6678 m)	6,321	6,459	2.2%	72.1%
UIC (1.435 m)	304	253	-16.8%	2.8%
FGC (1.000 m)	2,582	2,250	-12.9%	25.1%
TOTAL	9,207	8,962	-2.7%	100%

Table 21 Monthly evolution of the railway traffic (15)

Evolución del tráfico ferroviario mensual	Toneladas 2015			Toneladas 2016			%	
	Sólidos	Líquidos	Total	Sólidos	Líquidos	Total	mensual	acumulado
Enero	34.602	10.868	**45.470**	35.415	12.324	**47.739**	5,0%	5,0%
Febrero	46.906	9.523	**56.429**	33.021	8.300	**41.321**	-26,8%	-12,6%
Marzo	48.552	12.053	**60.605**	36.762	4.688	**41.450**	-31,6%	-19,7%
Abril	44.081	11.567	**55.648**	36.879	7.604	**44.483**	-20,1%	-19,8%
Mayo	38.534	5.828	**44.362**	38.841	4.951	**43.792**	-1,3%	-16,7%
Junio	42.531	9.319	**51.850**	37.449	5.245	**42.694**	-17,7%	-16,8%
Julio	39.823	12.836	**52.659**	26.574	7.039	**33.613**	-36,2%	-19,6%
Agosto	40.427	4.126	**44.553**	29.677	6.345	**36.022**	-19,1%	-19,5%
Septiembre	40.176	7.505	**47.681**	32.986	6.248	**39.234**	-17,7%	-19,4%
Octubre	42.289	5.396	**47.685**	36.127	5.359	**41.486**	-13,0%	-18,8%
Noviembre	42.159	6.002	**48.161**	36.845	4.842	**41.687**	-13,4%	-18,3%
Diciembre	34.565	5.948	**40.513**	36.297	4.974	**41.271**	1,9%	-16,9%
Total	**494.645**	**100.971**	**595.616**	**416.873**	**77.919**	**494.792**		

Castellbisbal – Mollet

Nowadays, this section has double track with third rail implemented. (Between PK 25+915 and PK67+345)

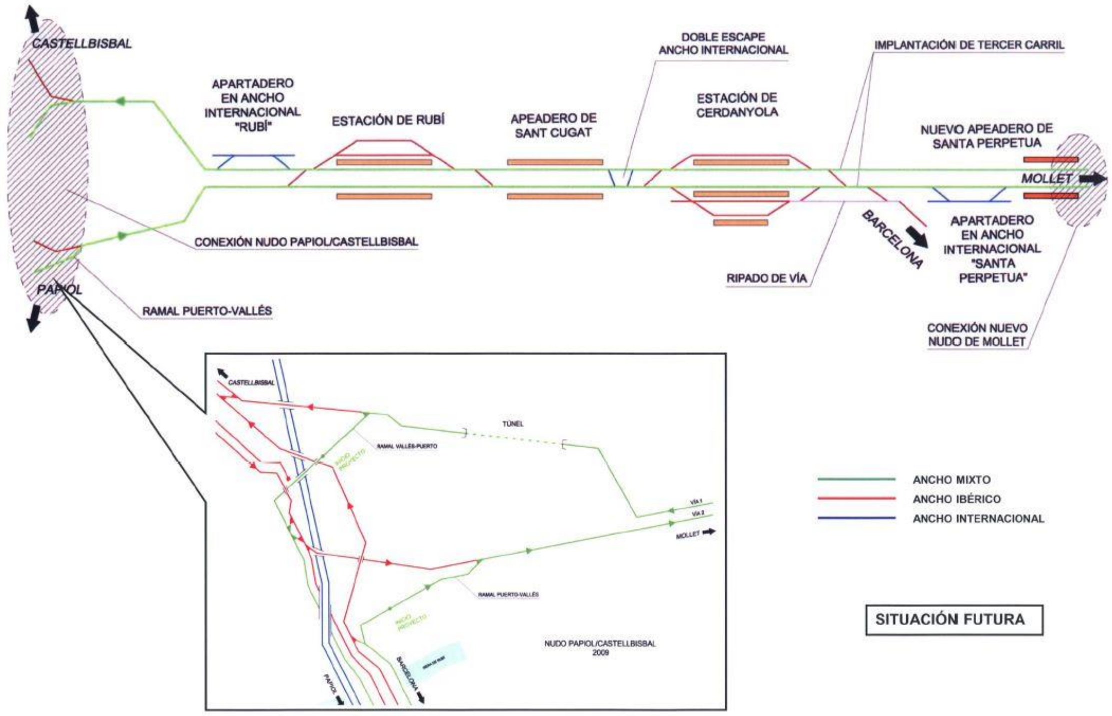


Figure 57 Situation of the section Castellbisbal – Mollet (16)

The section needs 30 switches and crossing devices, of which 7 are in Rubi station, 4 in Sant Cugat, 11 in Cerdanyola, 4 in Rubi siding and 4 in St. Perpetua siding. (16)

Railway stations and sidings

- Rubí siding: 750 m of useful length (PK 6+464.73 to PK 7+440.95 + 25 m in each side)

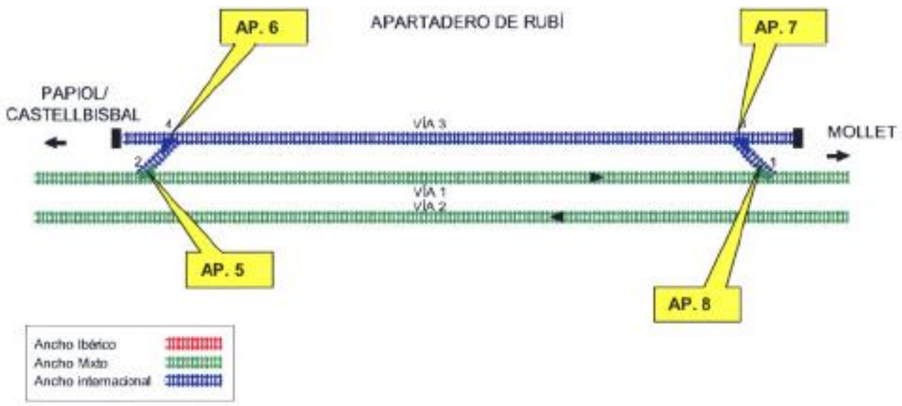


Figure 58 Rubi siding (16)

- Rubí station:

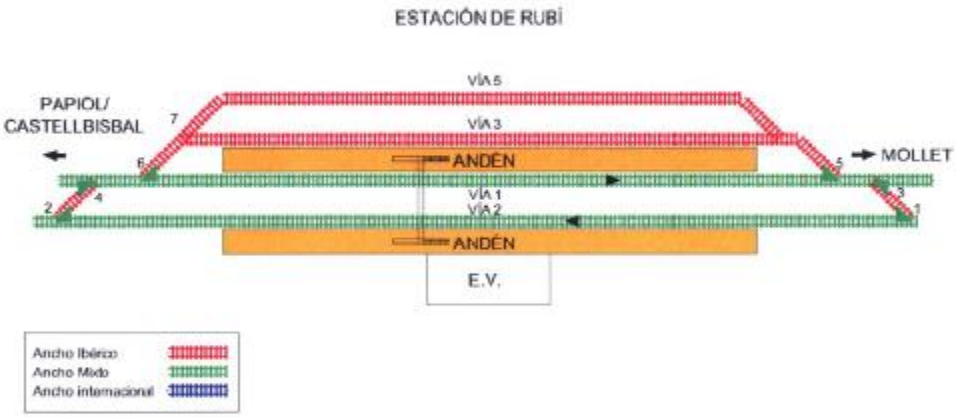


FIGURE 59 RUBI STATION (16)

- Sant Cugat:

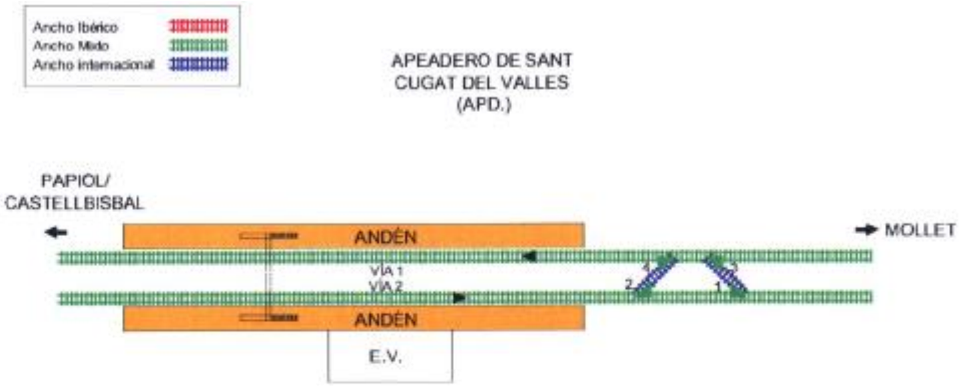


FIGURE 60 ST. CUGAT DEL VALLES SIDING (16)

- Cerdanyola:

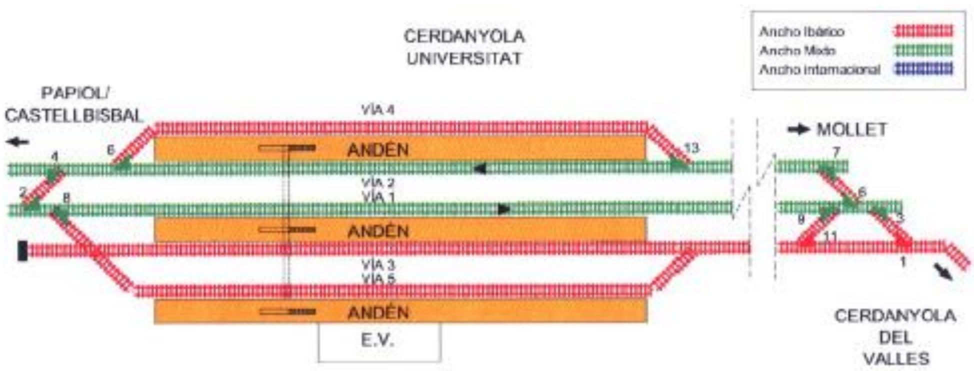


FIGURE 61 CERDANYOLA STATION (16)

- Santa Perpetua siding: 750 m of useful length (PK 21+240.71 of track 2 to PK 22+217.66 + 25 m in each side)

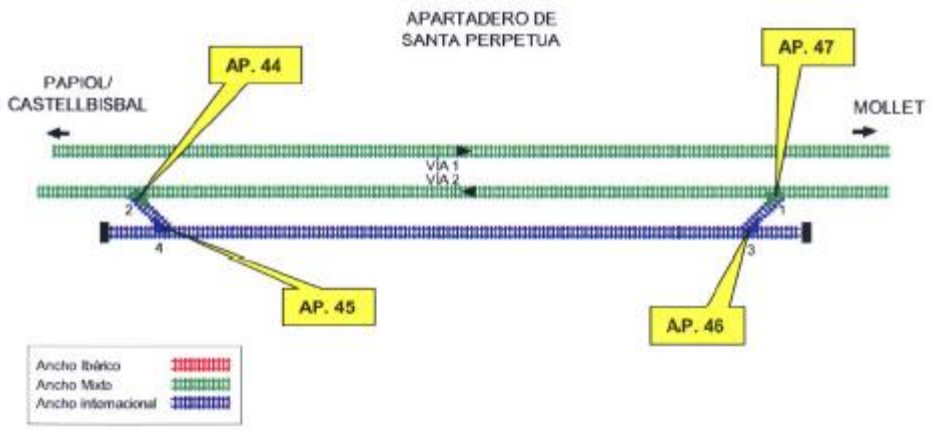


Figure 62 Santa Perpetua siding (16)

- Santa Perpetua:

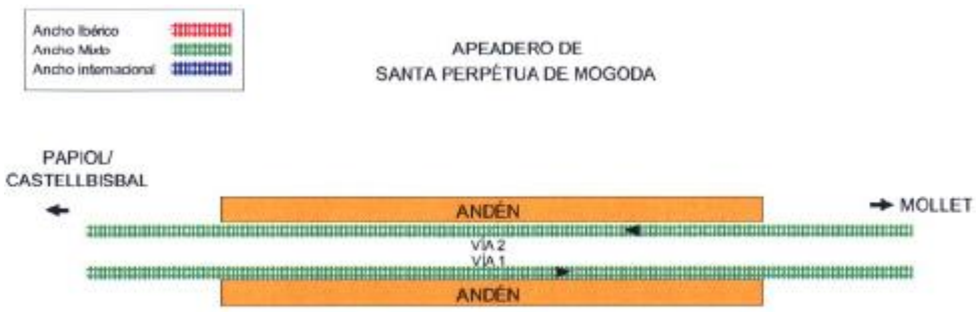


Figure 63 Santa Perpetua station (16)

Speed and Traffic

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016)(2).

Table 22 Real traffic 2016 (weekly mean) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Castellbisbal	Cast – AGS Rubí	1,450	1	2	1,126	316	6
Cast – AGS Rubí	Cast – AGS Llobreg	320	0	0	228	88	4
Cast – AGS Llobreg	Cerdanyola Univ.	376	21	0	228	121	5
Cerdanyola Univ.	Bif. Nudo Mollet	326	-	0	212	111	2
Bif. Nudo Mollet	Mollet – Sant Frost	292	-	0	212	78	2

Mollet – Girona – Figueres – French border (HS line, International gauge)

The high speed line between Mollet and Figueres started their operations in 2013 with a double-way track and UIC gauge. It is a mixed line with passengers and freight traffic.

Mollet - Figueres

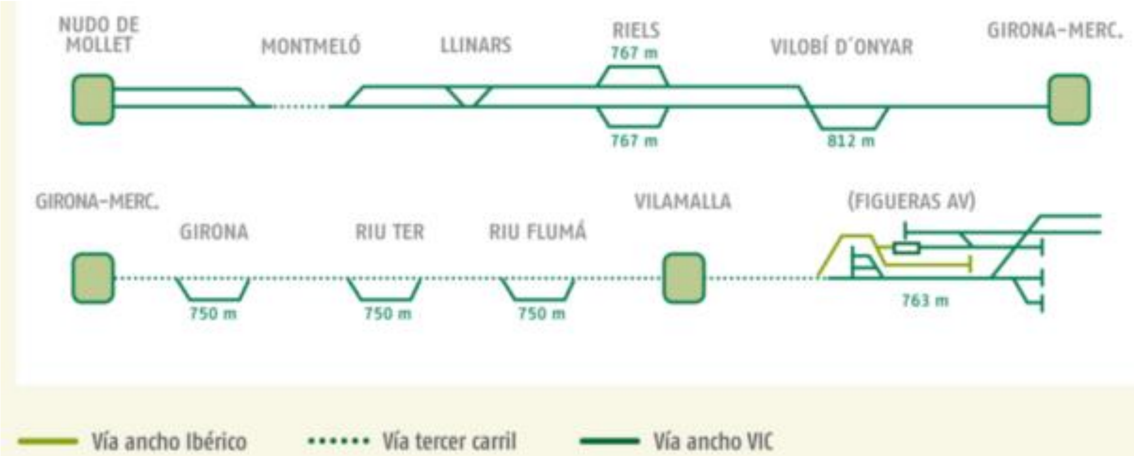


Figure 64 Mollet - Figueres layout

Maximum speed of the section is 200 – 250 km/h. Only the passenger's trains are entering Girona city, freight trains can follow a different path without visiting Girona station.

In the following tables are detailed the main design parameters of the line.

LÍNEA DE ALTA VELOCIDAD. PARÁMETROS TRAZADO EN PLANTA

VELOCIDAD MÁXIMA DE PROYECTO:			**$200 \leq V_{Máx}$ (km/h) < 250**	
TRAZADO EN PLANTA - IGP-2004			**Normal**	**Excepc.**
PERALTE MÁXIMO		D_{Max} (mm)	140	160
MÁXIMA INSUFICIENCIA DEL PERALTE		I_{Max} (mm)	80	100
MÁXIMA ACELERACIÓN SIN COMPENSAR		$a_{q\ Max}$ (m/s²)	0,52	0,65
MÁXIMO EXCESO DE PERALTE ($V_{Mín}$ DE TRENES LENTOS)		E_{Max} (mm)	80	100
MÁXIMA VAR. DEL PERALTE CON EL TIEMPO		$[dD/dt]_{Max}$ (mm/s)	40	60
MÁXIMA VAR. DEL ÁNGULO DE GIRO DE LA VÍA		$[d\theta/dt]_{Max}$ (rad/s)	0,027	0,040
MÁXIMA VAR. DE LA INSUFICIENCIA CON EL TIEMPO		$[dI/dt]_{Max}$ (mm/s)	50	75
MÁXIMA VAR. DE AC. NO COMPENSADA CON EL TIEMPO		$[da_q/dt]_{Max}$ (m/s³)	0,33	0,49
MÁXIMA VARIACIÓN DE PERALTE RESPECTO DE LA LONGITUD (Pendiente del diagrama d peraltes)		$[dD/dl]_{Max}$ (mm/m)	0,7	2,0
LONGITUD MÍNIMA DE ALINEACIONES DE CURVATURA CONSTANTE (M)	CURVA CIRCULAR		$\geq V_{Máx}/2$	
	RECTA ENTRE CURVAS DE IGUAL SIGNO DE CURVATURA		$\geq V_{Máx}/2$	
	RECTA ENTRE CURVAS DE DISTINTO SIGNO DE CURVATURA		$\geq V_{Máx}/2$ ó 0	

FIGURE 65 DESIGN PARAMETERS MOLLET - FIGUERES (HS LINE) (17)

LÍNEA DE ALTA VELOCIDAD. PARÁMETROS TRAZADO EN ALZADO:

VELOCIDAD MÁXIMA DE PROYECTO:			**$200 \leq V_{Máx}$ (km/h) < 250**	
TRAZADO EN ALZADO - IGP-2004			**Normal**	**Excepc.**
MÁXIMA ACELERACIÓN VERTICAL		$a_{v\ Max}$ (m/s²)	0,22	0,35
PENDIENTE LONGITUDINAL MÁXIMA	iMáx (‰)	En vía general con tráfico de viajeros	25	30
		En vía general con tráfico mixto	15	18
		En apartaderos	2	2
MÁXIMA ACELERACIÓN VERTICAL		$a_{v\ Max}$ (m/s²)	0,22	0,35
PENDIENTE LONG. MÍNIMA EN TÚNELES Y TRINCHERAS		$i_{Mín}$ (‰)	5	2
LONGITUD MÍNIMA DE ACUERDOS VERTICALES		(m)	$\geq V_{Máx}/2$	
LONGITUD MÍNIMA DE RASANTE UNIFORME ENTRE ACUERDOS		(m)	$\geq V_{Máx}/2$	
LONGITUD MÁXIMA DE RASANTE CON LA PENDIENTE MÁXIMA (*)		(m)	3000	

(*) Para pendientes inferiores a la máxima admisible justificar que la pérdida de velocidad supera el 10% de las velocidades máxima y mínima de circulación

FIGURE 66 DESIGN PARAMETERS MOLLET - FIGUERES (HS LINE) (17)

The number of switches and crossing are:

- La Roca - Riudellots: 27 devices

- Girona - Figueres: 27 devices

Figueres – French border

This section is managed by TP Ferro with double-way track with international gauge. It is used for high- speed passenger trains and freight trains.

The maximum length of the trains is:

- Freight trains: 750 m. A pilot test was performed and determined the possibility of having 850 meters trains if needed.

- Passenger trains: 400 m

The capacity of the line is slightly superior to 100 trains per day

LAV Perpignan - Figueres	
Longitud	44,4 km (26,4 km en Francia y 19,8 km en España)
Via / ancho	Via doble en ancho UIC
Electrificación	25kV CA
Sistema de Comunicaciones	GSMR
Sistema de Señalización	ETCS
Sistema de Bloqueo	Bloqueo de control automático (bloqueo automático banalizado específico de las LAV)
Tipo de tráficos	Línea diseñada para **tráfico mixto.**
Rampa característica	18‰
Velocidad máxima	350 km/h

Figure 67 Parameters Figueres - French Border (HS)

Mollet – Girona – Figueres – Portbou - Cerbère (Conventional line, Iberian gauge)

This section is a double track in Iberian gauge and run approximately parallel to the International gauge track from Mollet to Girona. The section Girona- Figueres is longer than the AVE track due to the large number of stations it serves. In the last section, between Figueres and the French border, the track reaches the coast and goes to Portbou and Cerbère.

The maximum length of the trains is 500 m and mixed traffic is running through this line.

The section between Girona and Figueres has implemented third rail. The implementation in the rest of the line is not yet foreseen, as there is UIC gauge between Mollet and France by HS Line. Actually, the third rail was implemented between Girona and Figueres as a demand of TPFerro when the HS line was constructed from Barcelona to Girona and not yet to Figueres.

Stations and sidings

- Granollers:

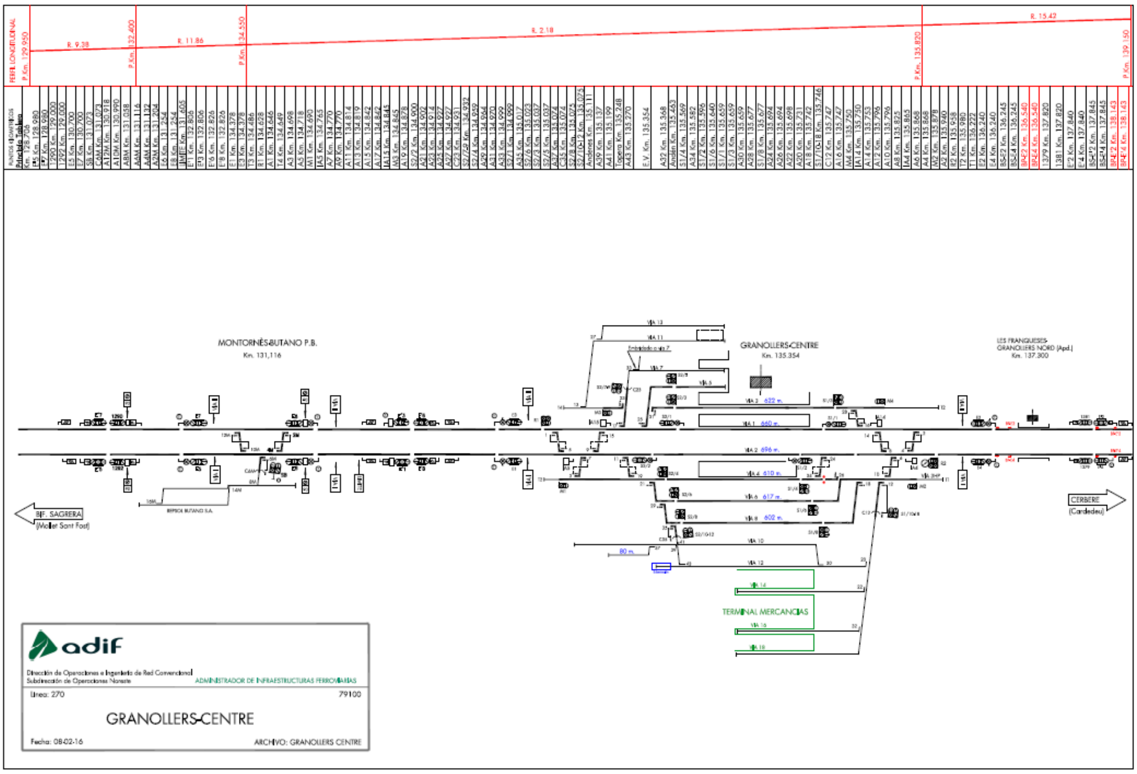


Figure 68 Granollers station

- Sant Celoni:

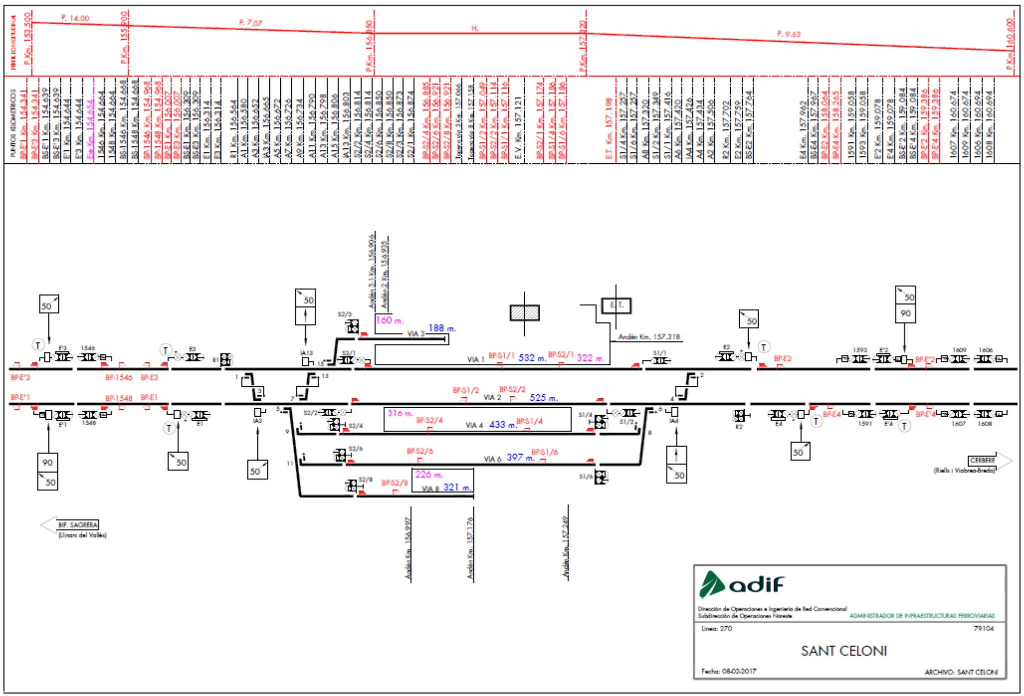


FIGURE 69 SANT CELONI STATION

- Riells i Viabrea:

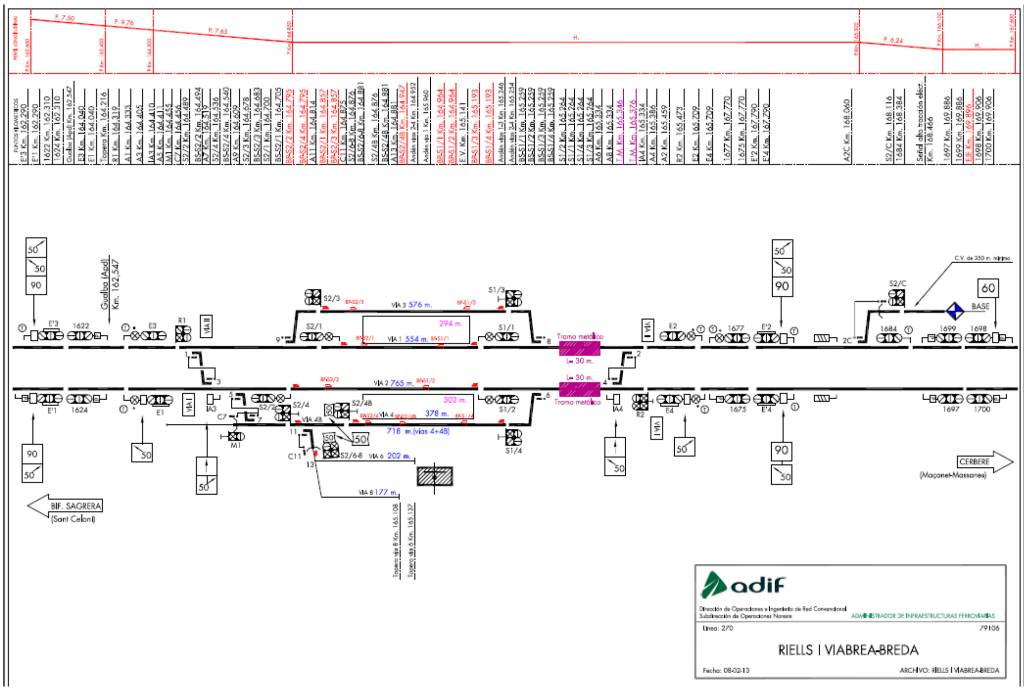


FIGURE 70 RIELLS I VIABREA STATION

- Maçanet – Massanes:

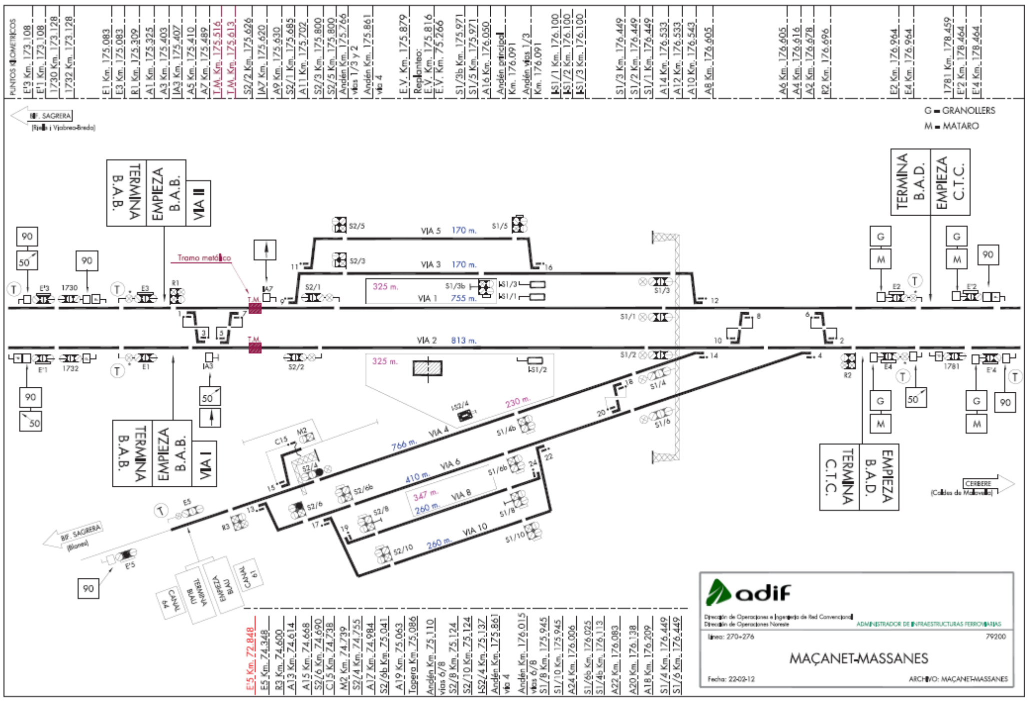


FIGURE 71 MAÇANET - MASSANES STATION

- Girona (Mercaderies):

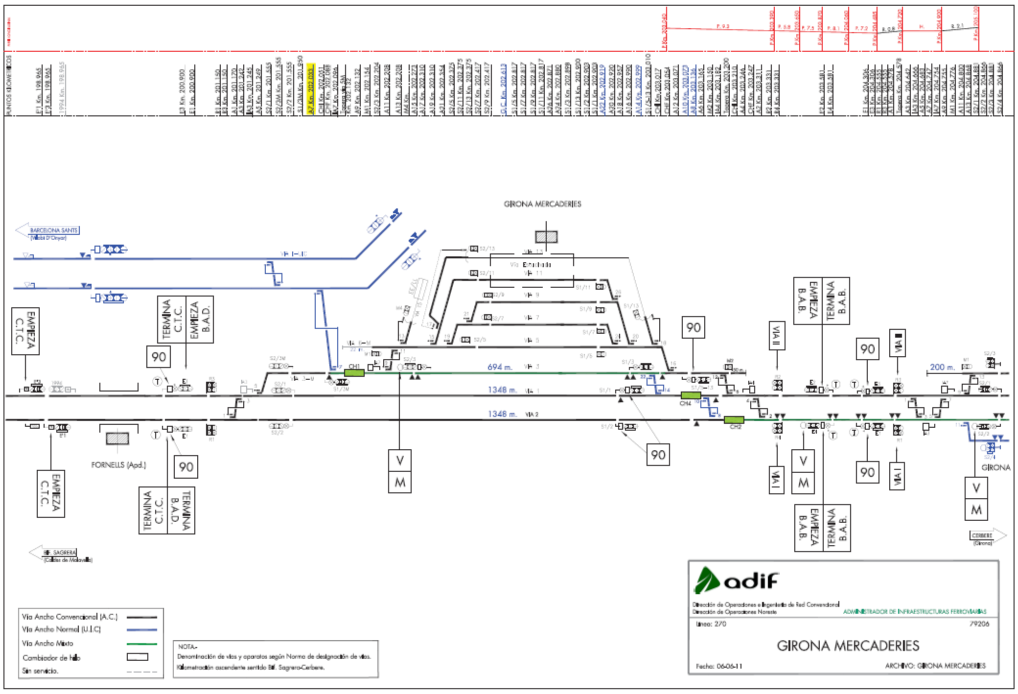


FIGURE 72 GIRONA (MERCADERIES) STATION

- Flaçà:

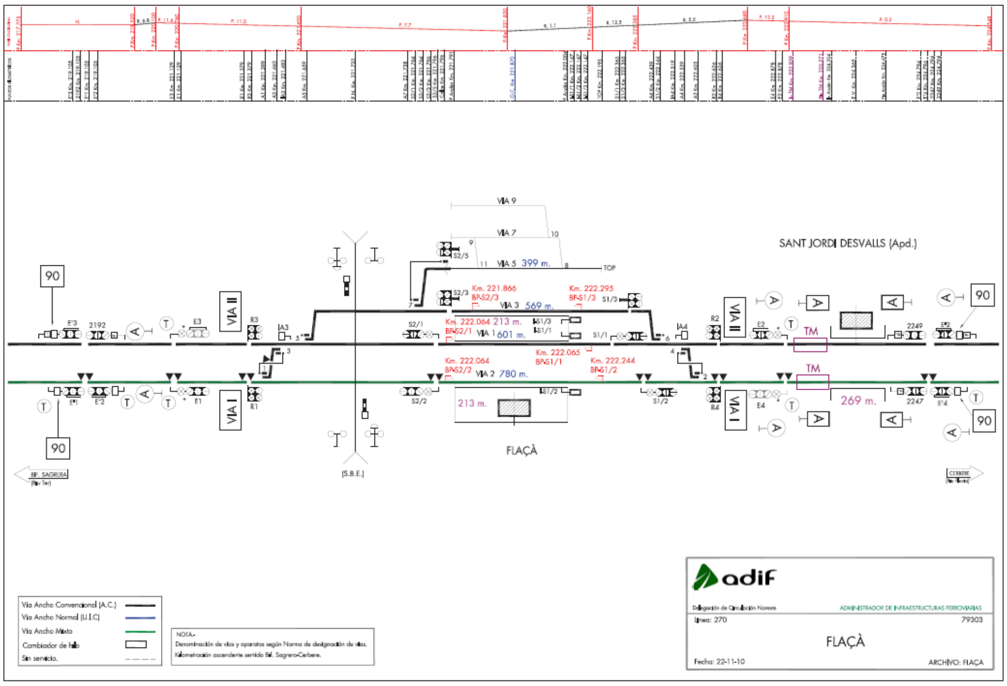


FIGURE 73 FLAÇA STATION

- Figueres:

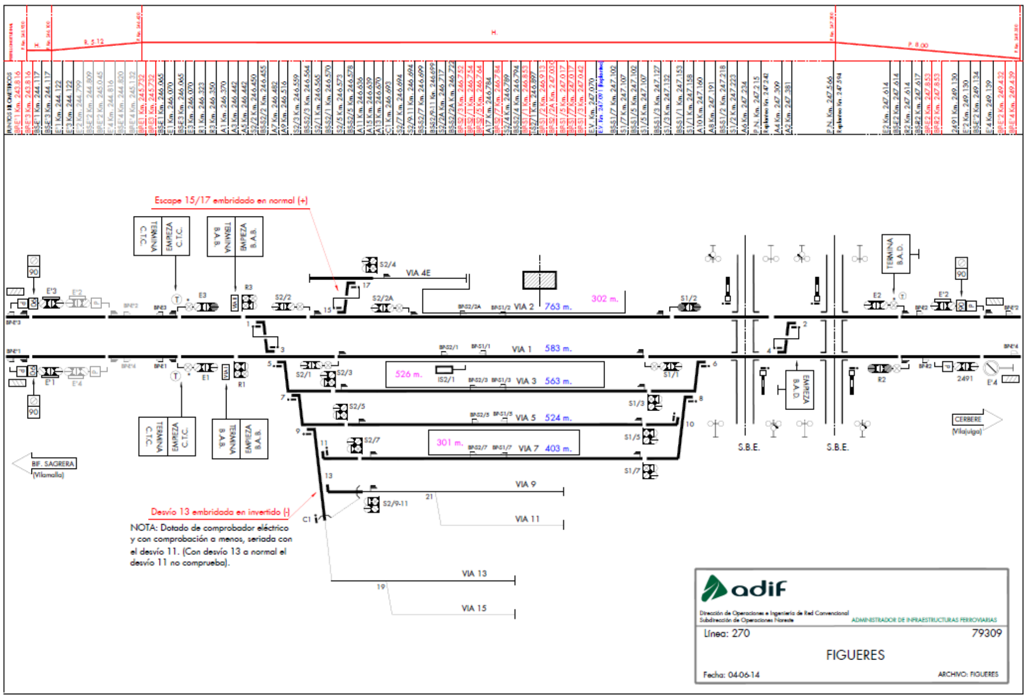


FIGURE 74 FIGUERES STATION

- Portbou:

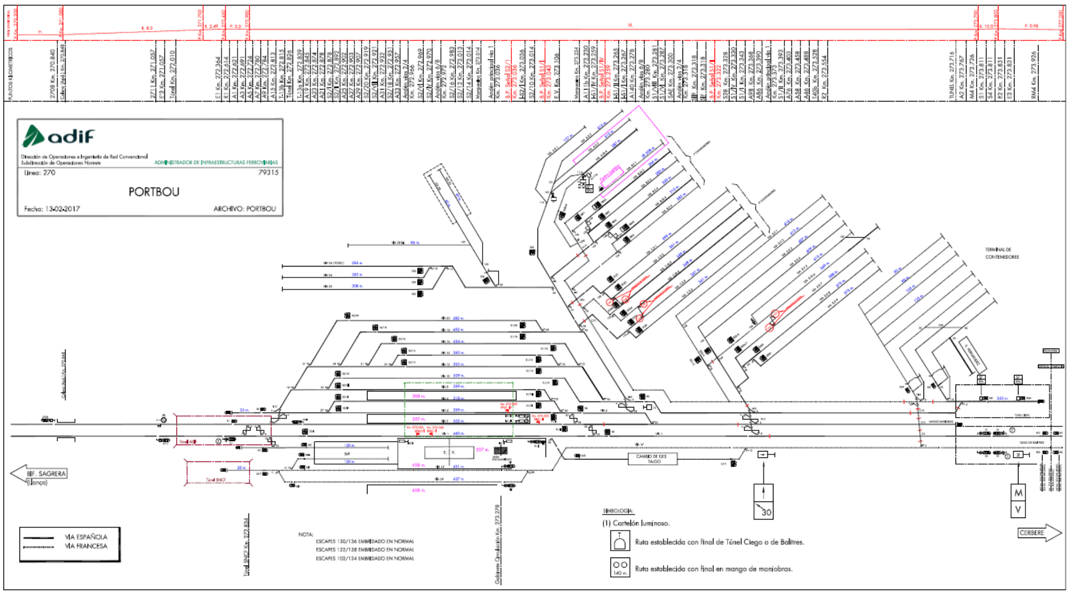


FIGURE 75 PORTBOU STATION

- Cerbère:

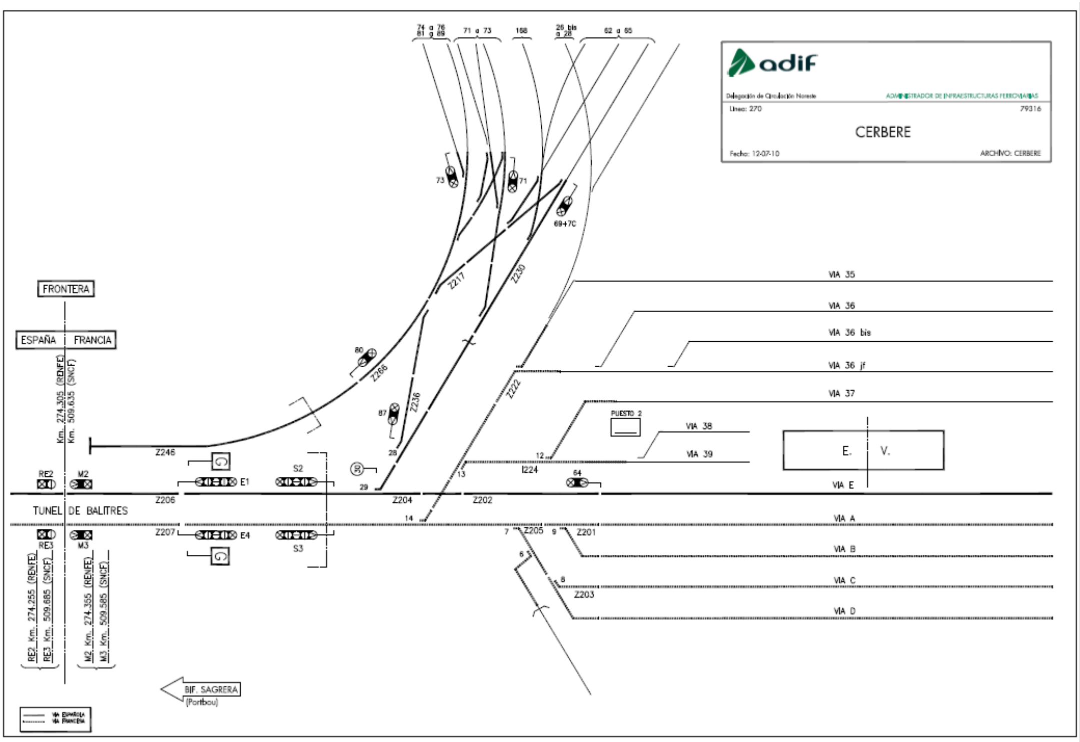


FIGURE 76 CERBÈRE STATION

Besides, there are two PAET (Puesto de Adelantamiento y Estacionamiento de Trenes) (18), which are created to allow the overtaking of trains.

- PAET Ter:

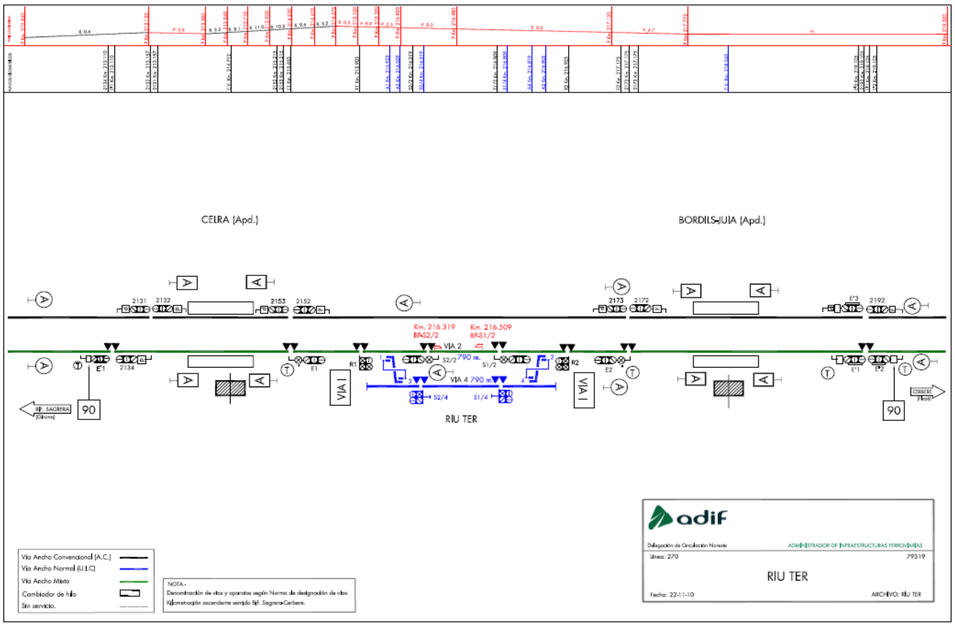


FIGURE 77 PAET TER

- PAET Fluvià:

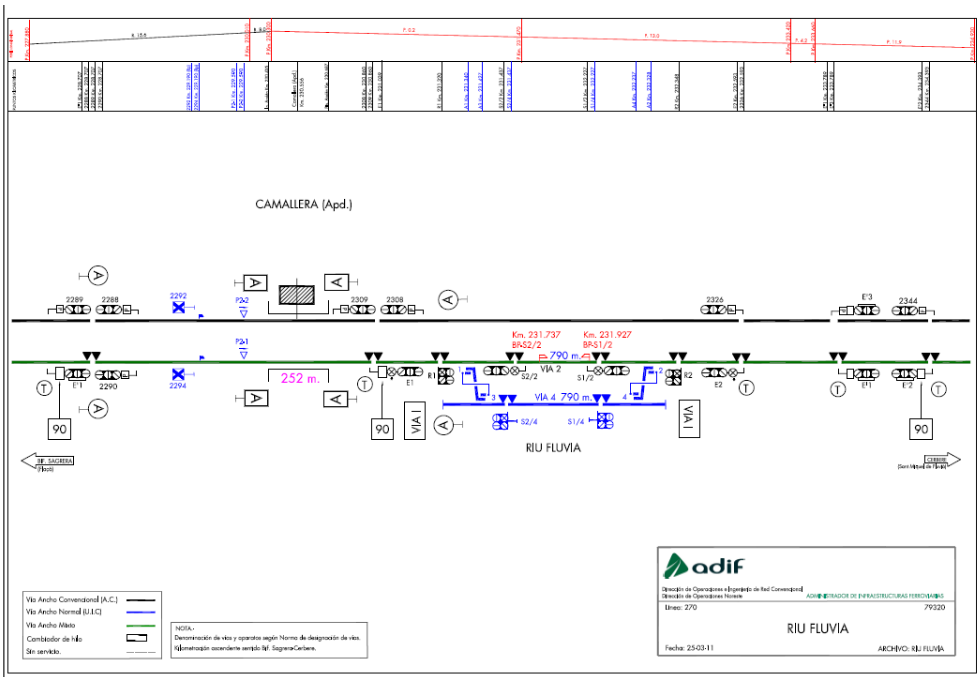


FIGURE 78 PAET FLUVIÀ

SPEED AND TRAFFIC

Maximum speed: 140 km/h – 160 km/h (only between Girona and Maçanet)

The following table summarizes the mean weekly traffic in this tracks classified by typology of train (2016) (2).

TABLE 23 REAL TRAFFIC 2016 (WEEKLY MEAN) (2)

Origin	Destination	Total	Long distance	Regional	Regular local	Freight	Service
Mollet Sant Frost	Montornes –Butano	1,356	-	295	971	84	6
Montornes –Butano	Granollers – Centre	1,357	-	295	971	84	7
Granollers – Centre	Sant Celoni	870	-	295	487	83	6
Sant Celoni	Gualba	433	-	295	52	83	3
Gualba	Maçanet –Massanes	433	-	295	52	83	3
Maçanet –Massanes	Fornells	458	-	374	0	83	2
Fornells	Girona – Mercader	458	-	374	0	83	2
Girona – Mercader	Girona	455	-	374	0	78	3
Girona	Vilamalla	441	-	360	0	78	3
Vilamalla	Figueres	441	-	360	0	78	3
Figueres	Portbou	299	-	213	6	78	1
Portbou	PK 274.305 (FRA)	150	-	84	-	65	1
PK 274.305 (FRA)	Cervere	150	-	84	-	65	1

FREIGHT VEHICLES

The freight vehicles are divided in 4 typologies (19):

1. Intermodal (containers): 45 feet, 60 feet, 90 feet platforms.
2. Siderurgic y (reel holders): They can be flat, long or pipelines.
3. Multiproduct: Bulk, mineral, wood and petrochemical products (chemical tanks)
4. Automotive: car transporters.

Info on all trains operated by RENFE: "*http://www.renfe.com/viajeros/nuestros_trenes/*"

Locomotives

There are four series of locomotives currently used in Spain for freight transport: S252, S253, S333 and S335.

All of them have Iberian gauge except S252, which accepts also UIC gauge.

S252

"http://www.ferropedia.es/wiki/Renfe_Serie_252"

"https://es.wikipedia.org/wiki/Serie_252_de_Renfe"

S253

Exclusive for freight transport. It has Iberian gauge. Although UIC gauge bogies could be installed, this locomotive cannot circulate through HS lines, as it works only at 3kV DC. Maximum speed of 140 km/h.

"https://es.wikipedia.org/wiki/Serie_253_de_Renfe"

S333

"https://en.wikipedia.org/wiki/RENFE_Class_333"

S335

"https://es.wikipedia.org/wiki/Serie_335"

MAXIMUM SPEEDS

Source: page 12 "*http://www.adif.es/es_ES/conoceradif/doc/CA_DRed_Anexos_mapas.pdf*"

MAXIMUM FREIGHT TRAIN LENGTHS

(Source: page 18 *"http://www.adif.es/es_ES/conoceradif/doc/CA_DRed_Anexos_mapas.pdf"*)

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APPENDIX 6 ANALYSIS OF MEDITERRANEAN CORRIDOR

INTRODUCTION

Given its nature, the Mediterranean corridor is expected to become a major European corridor, linking South-Western and Eastern EU countries.

In particular, it represents a key access gateway to Ukraine and therefore has a high potential in diverting part of the Western Europe-Asia traffic flows, which presently are ensured by the road mode.

Therefore the traffic development along this corridor has to be interpreted also in terms of significant potential increase in the rail market share and consequent reduction of environmental externalities in terms of reduction of gas emissions and reduction of roads and highways congestion.

It has to be taken into account that Mediterranean Corridor, as it is defined in the Core Network, has some common sections with other corridors: Baltic-Adriatic, Atlantic and North Sea-Mediterranean.

Most of the traffics of the Mediterranean Corridor are concentrated in the common section with North Sea-Mediterranean Corridor, since an important part of them flow to the North of France, Benelux and Germany. It has also two links between Ljubljana and Budapest, a direct one and the other through Zagreb with a connection to Rijeka. It has two branches in the Iberian Peninsula. From Tarragona a branch follows more or less all the coast (or coastal provinces), and the second one moves inwards through Ebro River valley until Zaragoza and from there to Madrid and Andalucia.

It is very important to keep in mind that the Iberian coastal branch is clearly disadvantaged compared to interior branch because of endemic delayed investments. The interior branch has double line in almost all the way, while coastal one has mostly one single line (with only one track for many km). There are even zones with no line at all (Murcia – Almeria). Further, the lay out in Southern sector is inconsistent given that it is necessary to make a considerable detour to arrive in Algeciras.

Main branches can be identified at this RFC, these are:

- Algeciras – Bobadilla – Madrid – Zaragoza – Tarragona
- Murcia– Valencia – Tarragona
- Tarragona – Barcelona – Perpignan – Marseille/Lyon – Torino – Novara – Milano – Verona – Padova – Venezia – Ravenna/Trieste/Koper - Ljubljana – Budapest
- Ljubljana/Rijeka – Zagreb – Budapest – Zahony (UA border)

Figure 79 Map of Corridor

RFC 6 has a big potential due to the large amount of Mediterranean and Adriatic ports that are linked through this corridor. Moreover, it has several connections with other RFC due to the fact that it is a horizontal RFC while most of them are vertical ones. The connections with other RFC are the following:

- Algeciras – Madrid section is shared with RFC 4
- Lyon and Ambérieu-en-Bugej with RFC 2
- Alessandria and Tortona, with RFC 1
- Verona with RFC 3
- Venezia – Cervignano – Villa Opicina/Trieste- sections in Italy and Trieste/Koper – Ljubljana – Zidani Most – Pragersko sections in Slovenia are shared with RFC5
- Győr and Budapest with RFC 7

Traffic development along this corridor has to be interpreted also in terms of **significant potential increase in the rail market share and consequent reduction of environmental externalities** in terms of reduction of gas emissions and reduction of roads and highways congestion (source: RFC6 Implementation plan, 2013).

According to the EU document "Appendix 1 – corridor description", the main missing links are related to:

- New cross border rail links between France and Italy ("Lyon-Turin") and between Italy and Slovenia ("Trieste-Divača");
- Multimodal connections with the ports in Spain that have to be developed and, in general along the corridor ,the lack of interoperable multimodal centres able to attract private operators and generate additional demand;

- Spanish railway connection between Murcia and Almería.

Moreover, concerning rail interoperability, some barriers have to be overcome:

- Coexistence of two gauges
- Exploitation difficulties for mixed rail
- Different electrifications systems
- Lack of electrification
- Different standards with regards to train length and axle loads
- Different safety systems
- Important gradients

On the other hand, some success stories can be highlighted such us:

- The Madrid-Barcelona high-speed line that reduced the journey time between the two cities attracting millions of passengers from air and road transport because of the standards of comfort and a seamless city to city connection;
- The connection of the Spanish and French high speed networks (Barcelona-Perpignan – under construction) that has been constructed with UIC gauge and that is available also for freight. However, it has not accomplished the expectative as a high capacity link for freight.
- The improved rail accessibility which will take place in Milan Malpensa airport (located in the intersection between two different Ten-t corridors) with the foreseen linkage between terminal 1 and 2 as part of the Ten-t project called “Accessibility to Malpensa airport from the North”. This is an extremely important investment which will provide easier connections to airport passengers. It’s important to specify that Malpensa T2 is constantly increasing its flight traffic reaching 6 million passengers in 2013.

Corridor analysis

The total length of the railway network belonging to the Mediterranean corridor is about 8.611 kilometres, half of which located in Spain, with Slovenia and Croatia covering just a little portion of the overall corridor.

Table 24 shows the compliance to the European requirements established by Regulation (UE) 1315/2013, in particular:

- Speed limits for freight trains (93%)
- Electrification (91%)
- Axle load (85%)
- Track gauge (71%)
- Train length (26%)

Speed limits

Four countries are nearly full compliant (ES, FR, IT and HU), while in Slovenia only 2/3 of sections are compliant and in Croatia 1/3. In both cases these physical bottlenecks concern the connections to ports of Koper and Rijeka respectively.

Interventions are expected in order to overcome these speed limitations along Slovenian rail sections; also in Croatia, upgrades of the existing rail lines and new lines to increase freight train speed are foreseen.

Electrification

Four countries are fully compliant (FR, IT, HR and HU). Spain and Slovenia foresee interventions (e.g. Murcia-Lorca section and Pragersko –Hodos for Slovenia). In Spain's south there is a lack of electrification between Alicante-Murcia-Cartagena-Lorca and Almería (Huéneja Dolar)-Granada-Bobadilla-Algeciras and Bobadilla-Sevilla.

Axle load

All countries are compliant with the European requirement except for Hungary and Slovenia; it is important to mention that in France some sections have axle load of 17 tonnes but they are used for passenger services only. In Hungary and Slovenia, several interventions on rail sections aiming to solve physical bottlenecks are foreseen.

Track gauge

It is almost full compliant to the European requirements less for Spain that adopts the 1668 mm standard for the existing conventional lines; the recently built HS lines has the UIC gauge (thus ensuring full interoperability on these lines).

TRAIN LENGTH

This parameter has low rate of compliance (26%), except France; the remaining countries foresee projects to standardize their sections to the European target. As examples: in Italy Bologna- Ravenna section (intervention foreseen); Slovenia (Pragersko- Hodos); Croatia (Goljak – Skradnik); Spain (Conventional rail line Madrid-Córdoba-Algeciras: Castillejo-Villasequilla and Alcázar de San Juan-Santa Cruz de Mudela and Santa Cruz de Mudela-Algeciras).

TRAFFIC MANAGEMENT SYSTEM

Despite the lowest compliance shown in the table, it is important to mention that all countries foresee great effort to adopt the new European signalling system (ERTMS) along the corridor sections in order to ensure the highest train interoperability.

TABLE 24: EUROPEAN STANDARDS ACCOMPLISHMENT BY PARAMETER AND COUNTRY

Rail technical parameters								
Parameter	Requirement	Spain	France	Italy	Slovenia	Croatia	Hungary	TOT
Length of all sections	Km	4045	1418	1026	631	361	1130	8611
Electrification:	Core network to be electrified by 2030 (including sidings where necessary)	84%	100%	100%	76%	100%	100%	91%
Track gauge:	New lines to be built in UIC standard gauge (1435mm), except in certain circumstances	38%	100%	100%	100%	100%	100%	71%
Traffic management system	(target: ERTMS level 1)	25%	2%	13%	0%	0%	0%	13%
Train length	(target: 740 m)	9%	86%	0%	10%	0%	58%	26%
Axle load	(target: 22,5 t)	100%	68%	100%	95%	100%	27%	85%
Speed limits	(target: 100 km/h for freight)	100%	98%	99%	68%	35%	90%	93%

Country analysis

Spain

Spain's biggest problem is the well-known Iberian gauge (1668mm). Recently, big efforts have been done to introduce UIC gauge, but still being a problem. For the moment only high-speed railways (HSR) are using it. The **lack of standard gauge** in most of the Spanish sections prevents from dispatching international direct rail freight trains, and forces to car load changing manoeuvres, which penalizes rail transportation competitiveness and increases costs, due to:

- The necessity of transhipping the cargo from an Iberian train to an UIC train at Portbou terminal
- Using the axles changer at Cèrbère, and the two single tracks (UIC + Iberian) between Portbou and Cerbère

With the arrival of HSR from Barcelona to French border Barcelona's port, that has a big traffic potential, can use a UIC railway to ship freight to Europe. The remaining HSR network is not being used for mixed traffic. Works are being done to adapt coast's railway to UIC, but it is a slow issue. When it is finished, Valencia's port would also be able to ship to Europe without the gauge handicap.

The other big problem Spain is facing is the lack of sidings where to park or prepare long trains (750m), limiting train length between 550 and 600m. Moreover, train weight is usually limited too.

Spanish orography is pretty complicated, it is usual to see conventional lines including sections with >15‰ characteristic gradient, what leads to the three different situations:

- Reduction of the maximum load of the freight trains
- Need of two locomotives
- Reinforced couplings

Although different choices can be taken, the same result is obtained: cost increase (€/tonne).

Electrification is another big issue in Spain. However it seems to be focused only in the south of the country. It requires hybrid locomotives and it may also require double traction in hilly tracks, both consequences raise the transport cost. Apart from this, disparity of the power supply (3kV in mixed gauges and 25kV in HSR) require locomotives with up to three different electrification standards (because in France its used 1,5kV), which are much more expensive.

With regard to traffic management system, Spain is world leader in ERTMS implementation. Nevertheless, it is only found at the HSR (UIC gauge), whereas freight is mainly transported through conventional lines, with ASFA system. Additionally, France uses KVB, which leads to the same situation as with electrification: expensive triple standard locomotives.

Heavy commuter train traffic penalizes freight trains, limiting its potential development because the few available windows cannot host competitive paths. This happens at Barcelona access (i.e. Martorell-Castellbisbal) and also in access to Barcelona's port.

Single track sections also represent an important infrastructure limitation, affecting its potential development, the available capacity and/or few conditioning timetabling.

FRANCE

The avant-garde of the railway sector in Europe. Probably the best prepared country of the RFC 6. The main problem that can be found is the lack of ERTMS management system, what can cause difficulties for border crossing if RTMS is installed on the other side. No prevision of implementing ERTMS has been found.

It is also true that the axial load standard is not accomplished in the whole length, locally it can be reduced to 20 tonnes/axel. These local issues affect the loading limit for the whole route of the trains passing through them.

France orography is not as complicated as Spanish one; it is a pretty flat country. By contrast, all the difficulties are concentrated in the south zone, where Pyrenees and Alps are located. Despite the achieved low gradients on the Pyrenees railway, high gradients are found on the proximities of the Italian border, as well as single track from Lyon to Chambéry.

Frequently big cities have problem due to heavy traffic, Lyon is not an exception. Trains are suffering daily delays because of intensive and mixed use of the infrastructure. Lyon is the connection with RFC 2, becoming one of the most important railway hubs of Europe.

Marseille port suffers from insufficient standards and complexity which affect the productivity of freight trains and the port demand.

ITALY

As France, Italy is a well prepared country with regard to European standards. It only has two generalised problems. One if the lack of sidings for long trains. There is not any siding for >740m trains. This is a big limitation for the central part of the RFC 6. Additionally, as many other counties, the European traffic management system is poorly implemented.

As happens in the French side of the Alps, the current standards of the Lyon-Turin railway penalise especially they freight trains in terms of productivity.

Loading gauge is also a relevant issue in Italian railways. The western part of the corridor is limited to PC45 whereas the eastern sections have an available loading gauge up to PC80, this does not permit to exploit rolling motorways.

Trieste is on the zones with poorest standards. Performance is affected for freight due to the limiting train length and passengers are also affected because of the low speed. Besides, its port railway infrastructure has shown a lack of capacity.

Finally, there are important urban nodes in the north (**Venezia, Torino, and Milano) which** are characterized by a high promiscuity of rail traffic due to overlapping of metropolitan, regional, long distance and freight traffic.

The careful planning and renewal of infrastructure (including a rationalization of traffic management for Milano and the deployment of new lines to separate passenger from freight traffic by limiting as much as possible interference in case of Milano Lambrate or Venezia Mestre “linea dei bivi”) is aiming to solve such issue.

Concerning the node of Torino, the main critical issue is the infrastructural organisation of the node, which hampers the capacity of the node and the smooth functioning of rail freight transport.

SLOVENIA

Slovenia knows about its limitations in the railway network and about its importance, that why it is orientating the development of the rail transport especially for cargo, with the scope of reducing environmental impacts. The idea is to attract freight from road to railway to avoid unacceptable occupation and emission levels on the roads.

The main limitations of its network are the low speed, between 70 and 80 kmh for an important part of the corridor, and the lack of capacity. On top of that, electrification and train length are well-known problems that should also be solved.

Thus, removal of existing bottlenecks for upgrading of existing infrastructure concerns: Divača – Koper (second track); Divača – Trieste (in progress); Divača – Ljubljana (upgrade of the current infrastructure); Ljubljana node (short-term solution: track deepening, Tivoli arc); Zidani Most – Celje (increase in capacity); Pragersko – Hodoš; Pragersko – Hungarian board (project in progress, electric traction); Šentilj –Maribor (upgrade of the existing track).

As far as passenger transport is concerned, only 5% of the population is using rail service as a mean of transport. It should be pointed out that adequate infrastructure and good rail connections are of great importance to attract foreigners to Slovenia, in particular tourists during the summer period. There is a relatively poor connection with Italy and apparently limited interests to improve it.

Croatia

The main drawback on Croatia's railway is the low maximum operation speed in most of the corridor. However it is not the only improvement point. Train lengths are very limited, between 400m and 700m, and there is only double track in the section Dugo Selo-Zagreb. Additionally, ERTMS is not equipped anywhere.

Hungary

Before moving to the detailed description of the critical issues, it is important to underline that Hungarian State Railways (MAV) plans to eliminate bottlenecks on several sections belonging to the corridor. The related investments are under preparation and cover:

- Track alignment (lifting slow-down signs);
- Energy supply system of catenary (sub-stations and catenary);
- Renewal of old bridges;
- Station reconstruction, in particular the renewal of the three Budapest head-stations;
- Intermodal investments in Kaposvár and Debrecen in order to increase the quality of services as detailed below.
    - Debrecen plays an important role in its Euro-region and the Eastern part of the country. Its integration into transport systems should be developed accordingly. Part of the efforts is the creation of an intermodal node serving the city's population and its visitors. The main railway station in the centre of the town will be reconstructed.
    - Kaposvár sees the following investments: interconnection of the railway station, the local and inter-city bus terminals, PR, BR, joint platforms, information system, passenger facilities and other functions; two-level separation of roads and railways, separation of pedestrian movement and bike traffic. The related feasibility study is completed

With this, several sections will be reconstructed with the main objectives or increasing the operating speed and the maximum axle load, which was one of the worst parameters that Hungarian railway had.

Other issues affecting the Hungarian railways infrastructure are the high number of stations and the out-dated telecommunications systems in use, despite it is under preparation EMRTS level 2.

More problems are also faced by Hungarian railways:

- Insufficient integration among transport modes: Unjustified competition between state-owned Volan bus companies and state-owned passenger services. It has also been found a Deteriorating aptitude of the Budapest urban and suburban transport system to adapt to changing settlement development and mobility patterns; growing split between the city and its suburbs; public mass transport losing terrain to individual modes of transport
- Environmental risk: It is needed to reduce the noise levels. All development projects include this issue.
- Slow implementation of action and projects: Inefficient management of tracks and that of railway transport companies, resulting in a weak international market position of HU railways, negative impact on the economy of peripheral regions and that of the whole country.

Railway liberalisation does not necessarily bring advantages due to small country size, small population and low level of effective demand.

Lack of sufficient domestic financial means within the rail sector for further infrastructure development (such as extension of double-tracks, extension of electrified lines, introduction of high-speed traffic, timely construction of train movement control systems, lifting speed limitations, increasing 225 kN network, decreasing number of rail-road level crossings, reconstruction of rail bridges, reducing the average age of rolling stock). The only important financial resources are the EU programmes.

SECTION ANALYSIS

A detailed section analysis will be carried out next for the whole corridor. The RFC 6 is divided into small and smaller zones so it is easier to understand. The division has been made based on the main branches, and it is the following:

- Algeciras – Tarragona
- Murcia – Tarragona
- Tarragona – Budapest
- Ljubljana/Rijeka – Zagreb – Budapest
- Budapest – Zahony (Hungarian-Ukranian border)

ALGECIRAS – TARRAGONA

There are two connections between the south of Spain with Tarragona, trough Madrid;

- Conventional line
- High speed line

As explained before, conventional line uses Iberian gauge (1668mm) while HS uses UIC gauge. However, HS line is used exclusively for passengers (at this route).

A section analysis will be done from south (Algeciras) to north (Tarragona) for the conventional line. Most of the sections have the same low technical standards.

ALGECIRAS-BOBADILLA

This section connects the Core port of Algeciras to the national railway network, nevertheless this part of the Med Corridor suffers from low technical standards, penalizing the freight flows departing from or arriving to the Port, such as in particular:

- Section with a non-electrified line over 176 km
- Section with a 305.3 km single-track line, (potential bottleneck)
- Maximum admissible train length for freight trains: 500m.; (this constraint concern all the conventional sections up to Madrid).
- Different traffic management systems than ERTMS exists, which limit the operation of some tracks. Section equipped with Land Train, no GSM-R. No ERTMS (BT type signalling system is available)
- There are a significant load limitations with values ranging between 920 - 960 t / train connected to grades with 24 ‰

BOBADILLA - CORDOBA

- Single track
- High gradient:17%
- Gross load hauled ranging between 920 and 1,980 t, with a
- Single electric locomotive class 253
- Existing limitation to train length for freight: 500m.
- No ERTMS (ASFA is the available signalling system)

SEVILLA-CORDOBA-LINARES- SANTA CRUZ DE MUDELA

- Single track: except for few elementary sections
- Existing limitation to train length for freight: 500-550m.
- High gradient: on elementary sections such as: Linares-Santa Cruz de Mudela (16%)
- No ERTMS (ASFA is the available signalling system)

Santa Cruz de Mudela-Alcazar de San Juan-Madrid

- Existing limitation to train length for freight: 500m except form Alcázar de San Juan – Madrid which allows 740 m.
- Iberian gauge (1,668 mm) so change in width is necessary to provide continuity to the tours
- No ERTMS (ASFA is the available signalling system)

Madrid-Casetas-Zaragoza

- Single track in a short section between Calatayud and Ricla (potential bottleneck)
- Existing limitation to train length for freight (500 m)
- High gradient (Guadalajara Torralba 14‰)
- No ERTMS (ASFA is the available signalling system)

The upgrade of the Madrid-Zaragoza-Tarragona conventional line is not yet defined and planned. Delays in the development of ERTMS have also been registered.

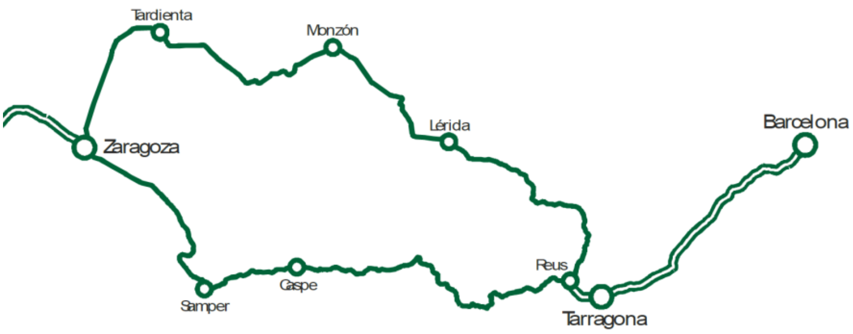
Zaragoza-Reus-Tarragona

- Single track: this section has two single-track lines working as double track one, which serve to different territories. It would be desirable to adapt both lines to UIC gauge in the future.
- Existing limitation to train length for freight (500 m)
- High gradient 19‰
- No ERTMS (ASFA is the available signalling system)

Zaragoza-Reus

This crucial section, connecting the two main cities of Spain, Madrid and Barcelona is single tracked between Zaragoza and Reus, while the remaining part of the line between Madrid and Barcelona is double tracked.

Nevertheless, these cities are connected by two different railway routes (both single-tracked) as shown in the following map:



In order to maximise the running capacity, these routes are used as a single double tracked railway line (forming an integrated system); which means that on each route trains run on a single direction (trough Caspe for trains coming from Barcelona, and through Lerida for trains coming from Barcelona). Furthermore, it should be underlined that these routes are used mainly by freight operators while passengers use the HS line (for medium and long distance). Said that, the Mediterranean corridor alignment follows only one of these two sections (the one which goes through Caspe); this choice should be changed; because it would be more efficient to include also the second one (as requested by the Ministry).

Congestion can be found at some sections of these single tracks:

- Zaragoza-Tardienta: Saturation level over 50% at Tardienta.
- Huesca-Lleida (Monzón): Lack of suitable slots for freight due to maintenance operations.
- Lleida-Reus: Freight traffic limitations due to regional passenger trains between Lleida and rest of Catalonia.
- Saturation level over 60% in the stretch Zaragoza -Reus (South).
- Potential bottleneck at the southern bypass at the Zaragoza node (Information study projected to increase capacity, eliminate the current 19 ‰ gradient and improve PLAZA access).

BOTTLENECK OVERVIEW

Technical standards are very far away from the European targets, what will not allow European trains to arrive there. The most important limitation is the different gauge. Despite the technical limitations that are specialty found in Andalucía area there is not a really bottleneck as all surrounding tracks have the same low standards. Train length limitation is also important, but as far as the standards are the same for the whole region (or even country), it does not represent a bottleneck in the south.

Metropolitan area of Madrid has high commuter traffic which produced delays for freight trains. UIC gauge should arrive at least to Madrid, so Spanish capital can receive trains directly from Europe. It is required to construct the 3rd rail that would allow both gauges trains. Indeed it is connected with Barcelona with UIC gauge but it is only a HSR for passengers as it was not designed for mixed traffic.

Zaragoza – Reus connection has saturations levels higher than 50% for the south branch and at a punctual section in the north one.

Murcia – Tarragona

This branch is known as the Spanish Mediterranean Corridor. It has numerous single track zones and high gradients due to the fact that crosses some mountainous regions. From several years ago it is being renewed but works are very slow and investments are usually late. At some zones they are constructing a new HSR (with 3rd rail) so freight can utilise the whole capacity of the conventional line, and also some of the HSR if needed. The 3rd rail is being implemented for the whole corridor, but works have not finished, so it still Iberian gauge at most sections.

Almeria - Murcia

Link between Algeciras port and the Eastern Part of the corridor is restrained also by this missing section; there is no direct link between Murcia and Almeria, forcing the journey to Alcazar de San Juan, in Castilla la Mancha. HS line is already planned.

Cartagena-Murcia-Alicante

- Single track
- Existing limitation to train length (500 m)
- Not electrified (electrification of the line has been already planned)
- No ERTMS (ASFA is the available signalling system)

Alicante - La Encima

- Single track
- Existing limitation to train length (< 450 m)
- High gradient (17 ‰)
- No ERTMS (ASFA is the available signalling system)

It is planned to be built a third track with the UIC gauge.

La Encima-Xativa-Valencia

- No ERTMS

Valencia port- conventional line problems: freight traffic flows run on the Iberian gauge, interventions for mixed gauges are needed.

Tarragona-Valencia

- Single track between Vandellos and Tarragona (45km).
- Existing limitation to train length (500 m)

Bottleneck overview

From these sections it is necessary to highlight the limitations that the 45km of single track produce, being the only section without double track for Valencia-Barcelona connection, one of the strongest links in Spain. These 45km represent the most important bottleneck for this branch. Single track it is also found in the south, but demand is not the same.

TARRAGONA – BUDAPEST

This is the central and main branch of the corridor. Several bottlenecks are found along the railway. The study will be carried out dividing the whole length by sectors.

TARRAGONA – BARCELONA – PERPIGNAN

This section has a HS line and also a conventional one.

HS section has double track, UIC gauge and 25kV electrification. In order to foster Barcelona's port this line was designed for mixed traffic from Mollet (near Barcelona) until the French border. With the 3rd rail help from the port to Mollet Barcelona's port can connect without the usual trouble because the different gauge at the border. Rail access to the Port of Barcelona is heavily congested (more than 75% of traffic at street number 4).

Conventional line is the same that was coming from Valencia, originally with Iberian gauge but with works for 3rd rail implementation. There is no connection from the previous lines with this one, but it is planned to do it due to the short distance between them (10km).

Despite having double-track, between Tarragona and Sant Vicenç de Calders there is one of the busiest sections of the Spanish Mediterranean corridor. Heavy traffic due to local, regional, long distance and freight trains going to Barcelona from the rest of Spain join here. Different traffic management systems than ERTMS exist, which limit the operation of some tracks. Improvement in traffic management is required to minimize delays and maintenance, resulting into a larger capacity.

Barcelona area is very congested due to heavy traffic. It is specialty notable from Martorell to Castellbisbal (small distance, about 7km) where very high commuter traffic is combined with heavy flow of freight trains (connection with Barcelona's Port and SEAT factory). There is no 3rd rail in the section, but it is planned (from Castellbisbal to Sant Vicenç de Calders) to do it to increase the traffic keeping the same capacity.

From Tarragona to Barcelona there is a lack of access from cargo terminal and private factories to UIC railway. Railway traffic represents only the 3.5% of the quota for land transport due to problems of capacity, interoperability and intermodality. Although the gauge problem has been solved with the new HS line, which offers capacity, fluidity and safety, it still underutilized due to further problems at the border.

SPAIN-FRANCE BORDER

As it has been mentioned before, power supply and signalling systems at the border is a critical issue that results into expensive locomotives and a cost increase. Detailed information about it is provided next:

- Different power supply:
  - **1,5 kV dc** from France to the freight yard close to Le Soler (included)
  - **25 kV ac** from the exit of the freight yard to Mollet Junction (close to BCN) -112 km
  - **3 kV dc** from Mollet Junction to Barcelona Port (end of the line) - 45km

- Different signalling systems:
  - **RFF/SNCF existing KVB system** and French radio sol train (Mesa 23) from France to the freight trains yard close to Le Soler (included)

- **ERTMS level 1 and 2 with GSM-R** from the exit of the freight yard to Figueres (international section,- 45 km)
- Both **ERTMS and the Spanish ASFA system**, **with GSM-R** from Figueres to Mollet junction - 108,5 km
- Only Spanish ASFA system, with Spanish "tren-tierra" radio system from Mollet Junction to Barcelona Port -45,0 km

Currently, **there are three options to cross the rail border**:

- Transhipping the cargo between UIC and Iberian trains at Portbou terminal
- Using the axle's changer for freight trains at Cerbère, and the two single tracks (UIC + Iberian) between Portbou and Cerbère
- Using the UIC connection through the Le Perthus Tunnel (only from/to Barcelona), which includes a 18‰ gradient and a toll.

Variable gauge axles are developed for passenger trains only, but this technology is not available for freight trains yet.

Consequently, in order to run on the line, **all freight locomotives need to be equipped with at least three different power supply voltages and three different signalling systems**.

Nevertheless, **this problem does not affect passenger trains** (10 trains per day on the peak season) as all the French and Spanish TGVs running on the line have the 1,5 kV and the 25 kV needed and are fitted with ERTMS (running over 200 km/h).

BOTTLENECK OVERVIEW

In this section important bottleneck are found, mainly related with the border cross and the Barcelona area.

Catalonia's capital capacity problems are pretty focused. Martorell-Castellbisbal is the biggest issue despite the fact that it is a short distance. Doubling the tracks or building a new alternative for freight could be a solution.

High saturation it is also found at the Port. However, it is concentrated. If some freight redistribution is possible, it would help to solve that.

The border is an important bottleneck for the existence of different standards that have been seen. Additionally, the track between Le Soler and Perpignan only allows 20tonnes per axle, which jeopardise the whole railway axle load for train crossing trough Le Perthus Tunnel. Moreover, there is a slightly higher gradient in the border.

Another relevant issue is related with capacity and train length. There is diversity in the standards from France and Spain. France railways allow running trains up to 850m, but not Spain, so cross-border trains can be only 500m. This results into a larger number of trains for the same freight quantity, saturating French railways.

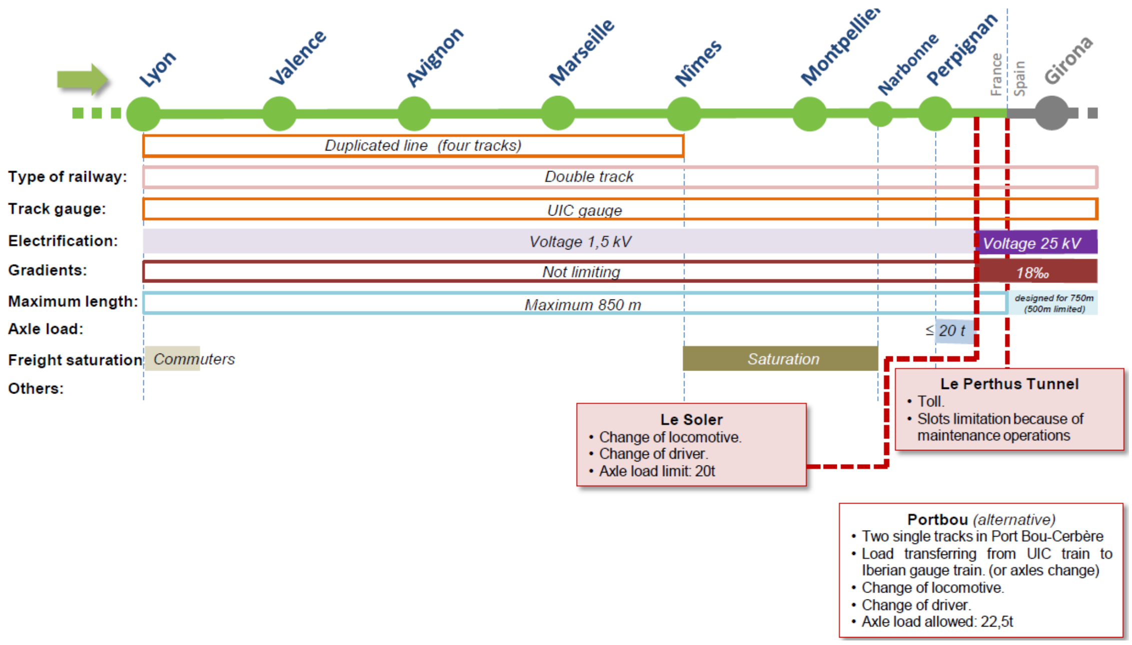


Figure 80: Track detail for Girona – Lyon (Source: CLYMA project)

Perpignan – Marseille – Lyon – Torino

Perpignan – Marseille – Lyon

Once the border is crossed, European standards are much more accomplished than before:

- Double track for all section (and four between Nîmes and Lyon)
- UIC gauge
- No gradients problems
- Maximum train length is 850m

Even though, some section show problems, mainly related with capacity:

- Axle load limit (20t) between Le Soler and Perpignan
- Weather vulnerability between Perpignan and Narbonne. This section is close to sea level and it can be affected by weather conditions (winds mainly).
- Very high traffic between the border and Avignon: Conventional railway between the border and Nîmes suffers from mixed traffic and insufficient capacity in particular urban nodes such as Montpellier and Perpignan. Currently there is a new HSL line under construction between Nîmes and Montpellier, designed also for freight traffic.
- Lyon bottleneck: Lyon is combining the attractiveness of a major city, regional capital, with a central position in connecting north-south and east-west long distance flows, which makes a Lyon one of the most important railway hub in Europe. Today, the railway infrastructure of this node is clearly identified as insufficient to ensure good service quality and allow further development of the traffic. Three sections in particular are raising the most serious capacity constraints:
    - The St-Clair – Guillotière section passing through the city centre and receiving almost all train traffic on four tracks only.

- The St-Fons – Grenay section (connecting Lyon to the East) with only two tracks and a complex connection with the North-South axis.
- The Lyon Part-Dieu station with a complex track system and insufficient number of platforms.

The first idea to relieve this bottleneck was to build a new freight line outside Lyon to allow freight traffic to avoid passing through the city centre and connect directly to the future Lyon – Turin line (CFAL project, which northern part has been declared of public utility in 2011) because Valence-Grenoble-Chambéry line has been recently upgraded and Lyon-Marseille has been connected with a new HSL, what allows considering it as an alternative for Marseille-Turin without passing through Lyon. However its capacity still limited due to single-track sections and heavy regional traffic around Grenoble.

However, it has become recently clear that a global approach is necessary, combining short, medium and long term works to improve the whole system. The long-term project foresees two more tracks from St-Clair to Grenay, which may be underground between St-Clair and Guillotière inside Lyon.

Lyon – Torino (France-Italy border)

In addition to difficulties found at the cross-border link that will be explained at the end of this point(very high gradient, train length and loading gauge limitations affecting international freight trains productivity), other major bottlenecks exist on the French section, thus underlining the necessity of a new access line from Lyon.

The Chambery – Montmélian section is the most critical section in terms of capacity, because all traffics in the North-South and West-East directions are crossing here, with intense regional train traffic.

In addition, passenger trains use a slow, single-track line between St-André le Gas and Chambéry, with strong technical and environmental issues that prevents its on-site doubling. This single-track section is causing uncompetitive travel time and frequent delays for international, long-distance and regional trains between Lyon and Chambéry.

The first and second phase of the new access line (Lyon – Chambéry – St-Jean-de-Maurienne) have been recently declared of public utility, thus authorizing expropriations and works to be done. However, the decision is still undergoing legal actions and financing is still uncertain. The “Mobilité 21” commission has declared this project of “second priority”, meaning that completing this work could be postponed after 2030. Nevertheless, this position is said to be reviewed in light of the progress of the international section.

The current technological standards penalise especially the freight traffic at the border.

The steep gradient impose the double pushing locomotives in case of trains composed by 20-25 wagons otherwise the maximum admissible weight (with single loco) is around 600 – 650 t.

In addition the available sidings, passing tracks and extra tracks length are not capable to accommodate longer trains.

Despite the wide debate on this infrastructure, no total consensus about the realisation of the infrastructures has been yet achieved.

Bottleneck overview

High saturation levels are found on France. It is expected to be reduced with a new HSR, which will attract passengers from the conventional lines.

Lyon node is a serious bottleneck and a serious approach is necessary. Doubling tracks around Grenoble could increase its capacity and be used as a bypass from Marseille to Torino.

Chambery – Montmélian is a critical section and its capacity needs to be improved. With Grenoble bypass traffic would be diminished on this section, as well as at St-André le Gas – Chambery.

The French-Italian border is another bottleneck. Several alternatives have been thought and studies have been performed, but for the moment nothing is happening.

Torino –Trieste

As an urban node Torino has heavy traffic and its exploitation cannot be taken to its potential because of the current infrastructural organisation. After quadruplication of Porta Susa – Stura this issue had been partially solved.

The section between Milan and Venice has an increasing foreseen traffic, which combined to its lack of capacity will affect the whole line, especially on Treviglio-Brescia section. A possible solution is to build a new HSR along the north of the country. However, currently there is a lack of funding for that project.

Venice urban node capacity is also limited. It is planned to upgrade sections around Venice and the signalling system. Nevertheless, several issues are affecting this project such as: constructive interference with a new highway, lack of funding or trouble with environmental evaluation.

Lack of funding seems to be the main cause for not developing the northern Italian railway. It does not seem a major issue as it has a bottleneck in the French border and also technical standards on the eastern countries.

Trieste – Ljubljana – Budapest

Triesta-Divaca (Italy-Slovenia border)

The possible shorting of capacity between Trieste and Divača has leaded to develop possible further alignments. Studies, possible solution and preliminary design have been done, but for the moment have been postponed. The actual section only allows a maximum admissible operation speed of 75kmh and an inferior length the 740m standard.

Koper-Divaca

In the existing operation schedule on the mountainous (severe gradient) single track Divača – Koper section preference was given (based on energy consumption consideration) to the upstream trains against the downstream trains. That means, the downstream running trains have to wait until the upstream running train have passed. There are 3 side-tracks on the whole line where the trains can pass. This limits railway capacity in this 48 km section, so that the existing 80 trains (in both directions) are near the maximum capacity of this section. This operation schedule decreases the speed of the freight trains. From the designed speed of 80 km/h the speed of the running trains is 34 km/h. Compared with that, speed of passenger trains is about 60 km/h.

Problems summary:

- Lack of capacity with a congestion rate of about 92%
- Speed limitations (70km/h)

- Train length limitation

Divaca-Ljubljana

Problems summary:

- Speed limitation (80kmh): At Divaca-Pivka and Gornje Ležeče – Pivka
- Lack of capacity on the section Pivka-Ljubliana with a congestion rate of about 87%
- Train length limitations
- **Ljubljana node**: an intervention of traffic diversion is needed. According to the traffic data, 30% of journeys on railway section Primorska continue its path, or come from, railway section Gorenjska. Since there is no direct rail line connection between them, all train compositions must be directed to the train station in Ljubljana, stop and change the direction and continue on the other section (in the program plan a proposal of 30% traffic diversion to arc of Tivoli is proposed as a temporary solution).

Ljubljana - Zidani Most

- Speed limitations (80km/h)
- Train length limitations

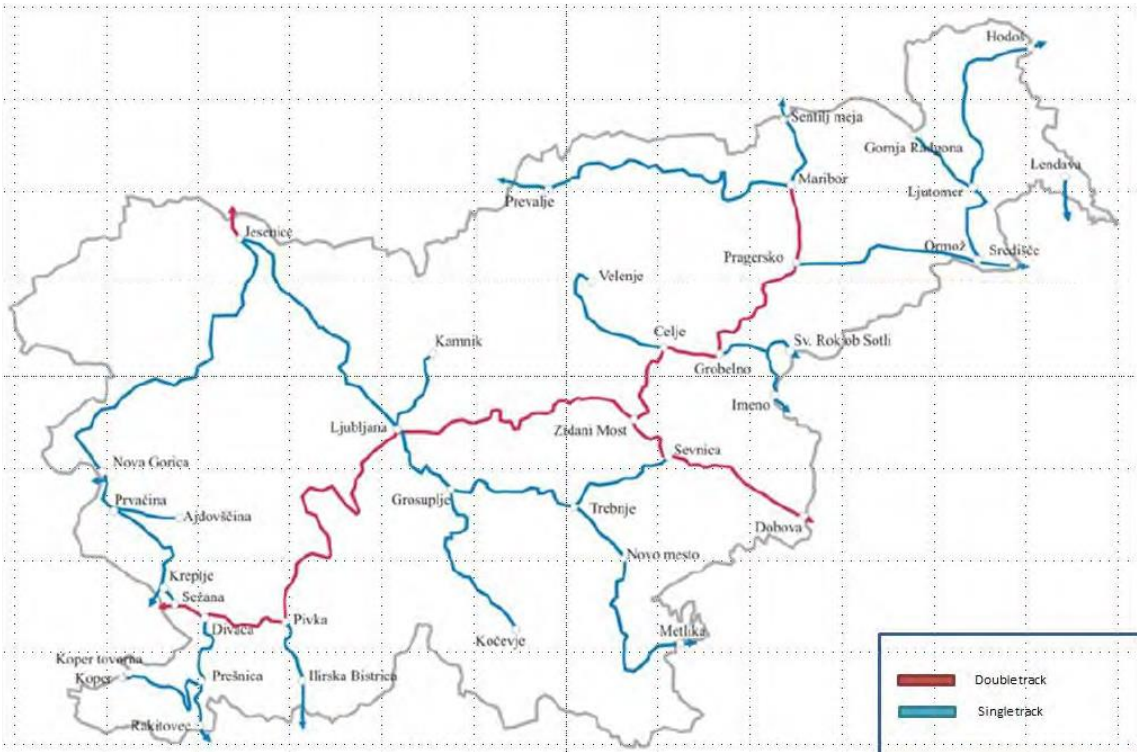
Zidani Most – Pragersko

- Axle load limitation (20 tonnes) at Zidani Most-Celje
- Speed limitation (maximum admissible operating speed 80km/h)
- Lack of capacity with a congestion rate of about 65%

Pragersko- Hodos (Slovenia-Hungary border)

- Single track line
- Lack of electrification
- Lack of capacity with a congestion rate of about 65%
- Axle loads and train weight limitations on the following sections:
    - Cirkovice Pragersko (20 tonnes)
    - Cirkovice-Ormoz (20 tonnes)
    - Ormoz-Puconci (20 tonnes)
    - Puconci Hodos (20 tonnes)

Neverthless works are on-going and will be completed in 2015 (in order to solve axle load limitations)



Once the border has been crossed, as explained the axle load is one of the main issues for Hungarian railways. Several reconstructions are being carried or are planned:

- Boba-Székesfehérvár: Section reconstruction is aimed for achieving 22,5t of axle load, an operating speed around 150kmh, ERTMS level 2, 740m long trains and partial double track.
- Kelenföld-Százhalombatta: Section development to achieve 22,5t/axle and 120kmh.
- Százhalombatta-Pusztaszabolcs: Section development to achieve 22,5t/axle and 160kmh.
- Pusztaszabolcs-Budapest: Section reconstruction plans have been completed.
- Székesfehérvár - Budapest Ferencváros "C": installation of ERTMS of 2nd level is planned and contracts for it have been signed.
- Szajol – Püspökladány: reconstruction is needed. No details about the future speed have been found neither for the axle load. This last one can be supposed as 22,5t/axle.
- Szolnok-Szajol: Szolnok railway junction needs a complete reconstruction, which has been already planned. The section is currently being intervened for reconstruction. Heavy mixed traffic on an out-dated section made it real necessary.
- Budapest-Szajol-Debrecen-Nyiregyhàza: It is mainly a passenger traffic section. The main goal of the reconstruction is to achieve 160kmh. ERTMS , double track and electrification will also be implemented.

Bottleneck overview

Train length limitation does not represent any bottleneck for international freight running through these sections as it is also limited on surrounding countries.

Low maximum speed and 20 tonnes axle load do represent a problem for capacity.

As explained in the Spanish-French border overview, a little section with low maximum axle load affects the whole railway, so it is important to solve it all of them, if possible.

Several bottlenecks and congestion zones are can be found in this region. Koper-Divaca is probably the one with worst performance. Double track, more siding or a different schedule is needed to improve traffic conditions. Other congested zones such as Zidani Most – Hodos are also observed. Lack of electrification at the Slovenia-Hungarian border requires Hybrid locomotive, what increases the transport cost.

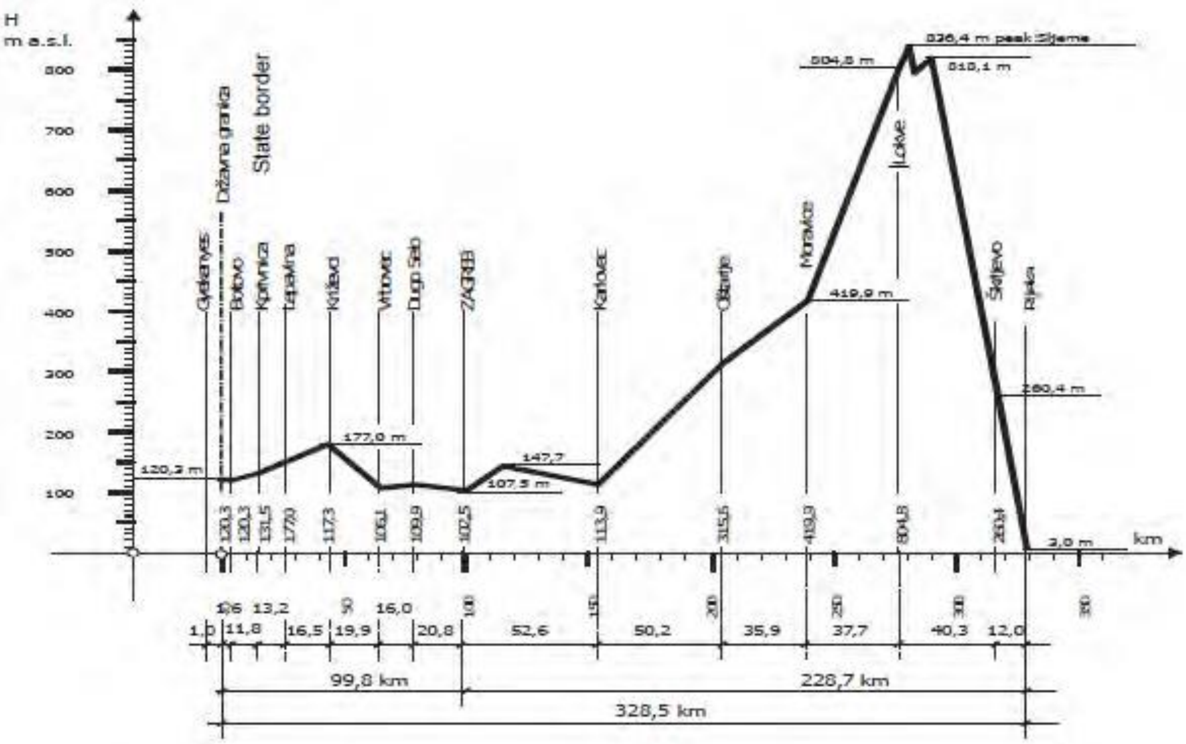
The Hungarian railways show the same issues as the Slovenian, low maximum speed and limited axle load with regard to European standard. When all the works are finished, Hungary will have an adequate network for freight.

LJUBLJANA/RIJEKA – ZAGREB – BUDAPEST

Connection between Slovenia and Croatia is made through Dobova. This section presents the following limitations: train speed (<100kmh) and length (400-500m).

RIJEKA-ZAGREB

As it has been explained, this RFC connects several ports from the Mediterranean, such as Rijeka's Port. The line between Rijeka and Zagreb present several difficulties due associated to the fact that was built 135 years ago. It has unfavourable route, completely contrary to the modern traffic requirements. Karlovac-Rijeka section is probably the most complicated, with a 70% of its length is in curves.



Construction length of the railway is 228km. Longitudinal grade on individual sections of the railway line is as follows: In Zagreb Main station – Moravice section, up to 8 ‰, in Moravice – Lokve section, up to 17 ‰ and in

Lokve – Rijeka section, up to 26 ‰. Besides some shorter railway line sections, design geometry in Karlovac - Rijeka section, and especially in Moravice - Rijeka section, is very unfavourable. It consists of a lot of consecutive curves with radius of 240 to 400 m and opposite directions with no intermediate straights, curves with shortened transition curves and sets of points located in parts of the railway line with a greater longitudinal grade or at alignment breaks. Horizontal geometric properties allow the following design speeds for conventional trains: 80 km/h between Zagreb Main Station and Remetinec, 160 km/h in Remetinec – Karlovac section with speed limited in individual curves to 85 - 120 km/h, between 70 and 90 km/h in Karlovac – Moravice section and 70 km/h in Moravice – Rijeka section.

In railway line sections which have been upgraded, in the last ten years, passenger trains with tilting mechanisms applied in curves may achieve speeds 10 to 20% greater than those specified for conventional trains.

Problems summary:

- Single rail track
- Train speed limitations for freight (<100kmh)
- Train length limitations (400-500m)
- High gradients (up to 26 ‰)

As consequence, the maximum weight of freight trains in Moravice – Lokve section and especially in Lokve - Rijeka railway line section is limited due to large longitudinal grade and specific resistance due to the grades and small curve radius. Throughput and transport capacity of the railway varies by section and equals 72 to 99 trains per day.

Construction of the second track and reconstruction of the railway line within the existing route, which would conform to requirements of interoperability demanded from combined traffic railways of the Trans-European conventional railway system, is virtually impossible, with an exception of section between Zagreb Main railway station and Karlovac. From the above, it follows that lasting improvements are only possible if the railway line is relocated.

Dobova – Zagreb (Slovenia-Croatia border)

- Double rail track
- Train speed limitations for freight (<100km/h)
- Train length limitations (400-500m)

Zagreb node

In Zagreb railway node system there are 15 existing railway lines and railway line sections, including connecting and linking sections, with an overall length of 192.6 km. They are all classified as railways of international significance. The mainstay of the railway node consists of the following railway lines: M101 state border - Savski Marof – Zagreb Main railway station and M102 Zagreb Main railway station – Dugo Selo, which are double track railways, as well as railway line sections: Hrvatski Leskovac - Zagreb Main railway station, Velika Gorica - Zagreb Main railway station and the eastern bypass section: Velika Gorica - Sesvete (consisting of M401 Sesvete – Sava and M407 Sava – Velika Gorica railways).

The node also contains a number of shorter, connecting railways. In principle, it may be said that the railway infrastructure is well blended with urban structure of the city of Zagreb. The main railway lines run through the central area of the city thereby providing a large number of residents with good communications using railway transportation. That particularly pertains to Dugo Selo – Zagreb – Zaprešić railway line, which is nearly ideally positioned relative to city and suburban passenger transport demands.

Zagreb railway node is located within an area delimited by Dugo Selo, Velika Gorica, Hrvatski Leskovac and Zaprešić railway stations. Transport activities are performed in 14 stations within Zagreb node, all of them handling cargo, while arrival and departure of passengers is performed in 8 of the stations. 10 stops are available for passenger transport. Passenger transport in the node is organized to have all passenger trains originate/terminate at Zagreb Main railway station or transit through the station. Zagreb Main railway station is the central station of the node in terms of passenger transport. It is point of origin or destination for trains travelling on domestic and international lines, while a portion of the international trains transit through the station following a stopover for embarkation and alighting of passengers. On March 10, 2013, at Zagreb Central Station, a new electronic security signalling device was released. Therefore Zagreb Central Station completely fits in the modern system of traffic management.

Critical bottleneck: lack of capacity in the short-medium run (by pass for freight trains needed):

Zagreb is the city with the heaviest traffic of Croatia, the most intensive long-distance cargo and passenger transport takes place along this sector, it is also the most intensive suburban area. Hence a bottleneck is generated.

Barring any large and radical efforts, Zagreb railway node shall not have sufficient capabilities to receive planned increased railway transport (inner suburban passenger transport and local cargo transport, inbound or outbound long distance passenger and cargo transport, transit passenger and cargo transport). There are requests regarding increase of frequency and volume of suburban passenger transport in Zagreb area, and needs shall continue to grow. That said, in order to accommodate all those demands and allow transit of the expected volume of transport through Zagreb railway node, it is necessary to expand the existing and build new facilities to match construction and expansion of the corridor railways connecting to the node. Interventions are needed within Zagreb railway node, passenger transport on the state border – Botovo – Zagreb – Rijeka railway corridor should be carried out along a four-track Dugo Selo – Sesvete – Zagreb main railway station section and further on via a double track Zagreb Main railway station – Hrvatski Leskovac – Horvati railway section, while cargo transport shall be routed to Dugo Selo railway station bypass and further on via double track Dugo Selo – Zaprešić railway until it reaches Horvati junction. A new marshalling yard is expected to be constructed on that section.

Zagreb – Dugo Selo

This is the most intensive passenger transport section for international, inter-city and city-suburban transport.

In terms of passenger transport, the Mediterranean corridor runs through Zagreb node following a route from Rijeka and Karlovac through Hrvatski Leskovac, Zagreb Main railway station and Dugo Selo, where one branch of the railway diverges towards Koprivnica and Botovo (state border with Hungary), and another one towards Novska.

The cargo traffic originates from this node to Rijeka and Karlovac, passing through Hrvatski Leskovac, Remetinec, branching to Zagreb Klara and entering Zagreb marshalling yard. Following processing within marshalling yard (shunting or transit – change of locomotive, partial rearrangement of trains), the route leads on through Zagreb

Žitnjak, Zagreb Resnik and Sesvete railway stations to Dugo Selo railway station, and further on towards Botovo (and state border with Hungary).

Mixed traffic is running along this section, except for Zagreb Main railway station – Zagreb Borongaj section, which is mostly used for passenger transport. Sesvete – Dugo Selo railway section carries the largest volume of transport in entire Croatia today.

Average daily volume of transport on that section comprised 159 passenger trains, including 114 city transport trains which run to Dugo Selo as the node boundary railway station and 30 suburban trains with service extending to larger cities in vicinity of Zagreb, towards the node boundary stations) and 31 freight trains.

Finally, this is a double track section which permits to run trains with max axle load 22,5 ton and loading gauge of PC 80 (UIC GB, GC) (compliant to TEN-T requirements).

The fact that mixed traffic is run generates a potential bottleneck in case of a future freight traffic.

The existing problems for this section are:

- Train speed limitations for freight (<100km/h)
- Train length limitations (400-500m)

Dugo Selo – Botovo (Croatia – Hungary border)

- Single rail track
- Train speed limitations for freight (<100km/h)
- Train length limitations (400-500m)

Bottleneck overview

Rijeka railway it is a real problem for freight rail transport. Very high gradients are on the way from the Port to Zagreb, limiting the weight of the trains. An alternative route should be constructed in order to solve it.

Speed limitation (<100kmh) is constant for the whole railway, it does not suppose a local bottleneck. Neither train length limitation, as surrounding countries still in the same condition.

The most critical bottleneck of Croatia is Zagreb and its connection with Dugo Selo. For Zagreb node an extension of the facilities is required to increase its capacity. The track from Zagreb to Dugo Selo is the most congested zone due to high commuter traffic mixed with freight. With today's infrastructure, an increase in freight volume could generate overlapping and hence a bottleneck.

BUDAPEST – ZAHONY (HUNGARIAN-UKRAINIAN BORDER)

Worsening international market position of Zahony (HU-UA) trans-loading terminal. “Zahony is a meeting point between the European standard and the Eastern (UA, RF) wide gauges and plays an important role in goods transport, marshalling and logistics (road-rail) for all types of cargo. It is the terminal station of the Mediterranean Corridor as a link to the wide gauge network of almost 10 thousand kilometres reaching UA, BY, RF, Baltic States, Central Asia and China. Hungary government considers Zahony (total surface of the terminal: 80km2) as a priority for further developments. The wide gauge network of the station has been renewed in the last couple of years, thus access to trans-loading points is easy”.

Bottleneck summary

BOTTLENECKS BY CATEGORY
AXLE LOAD
Le Soler - Perpignan (France)
Zidani Most - Celje (Slovenia)
Slovenia - Hungary border
Hungary
SATURATION
Zaragoza - Reus (Spain)
Vandellos - Tarragona (Spain)
Martorell - Castellbisbal (Spain)
Perpignan - Avignon (France)
Koper - Divaca (Slovenia)
Zadani Most - Pragersko (Slovenia)
Slovenia - Hungary border
Potential bottlenecks
Algeciras - Bobadilla (Spain)
Calatayud - Ricla (Spain)
Zaragoza southern bypass (Spain)
Zagreb - Dugo Selo (Croatia)
DIFFERENT STANDARDS
Spain - French border
HIGH GRADIENT
Spain - French border (through Le Perthus)

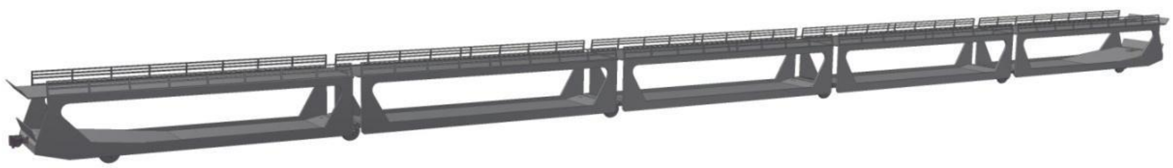
France - Italy border
Koper - Divaca (Slovenia)
Rijeka - Zagreb (Croatia)
URBAN NODE
Madrid (Spain)
Barcelona (Spain)
Lyon (France)
Torino (Italy)
Zagreb (Croatia)
WEATHER
Perpignan - Narbonne (France)

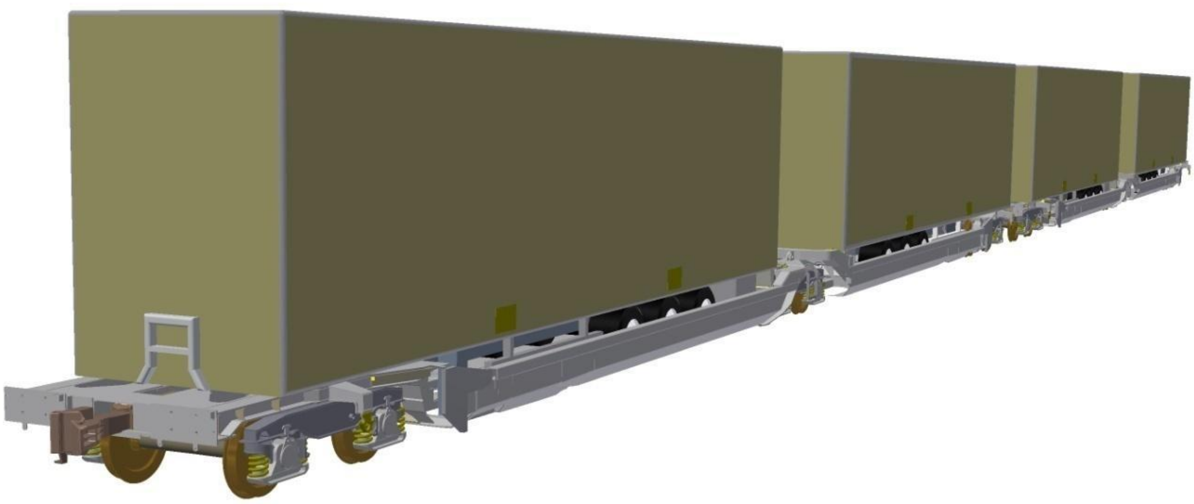
APPENDIX 7 SP2 INNOVATIONS IN RAIL FREIGHT

Innovative freight wagons

Innovation 1

6 axle car design for transport of light automotive and heavy intermodal freight (maximising usable length) – using articulated bogies or shared wheel sets between wagons





- Principles behind the design is to reduce numbers of axles and minimise non-freight carrying length
- Disadvantages – not able to couple and decouple so reduced flexibility to take wagons out of service if not required or there are maintenance issues – need maintaining more as a train rather than individual wagons

Innovation 2

Increase flexibility of wagons to carry different containers by extending carrying capability over the buffers between wagons allowing carrying of 45’ as well as 40’ containers

Innovation 3

Improved braking to reduce maintenance costs – Electrically controlled braking valve on each wagon to ensure simultaneous braking leading to ability to have longer and heavier trains and reduced maintenance costs

Innovative freight terminals

Possible innovations

- Linear traffic (siding – pulls in and loads/unloads returns to mainline)
- Horizontal + parallel loading – allowing loading under OHL reduce need for diesel shunting locos
- Fast transtainers???
- Automated gates
- Automatic couplings and automatic ITU
- Vehicle control
- Data exchange
- Duo locomotives
- Linear train system rather than node system
- Full automation of marshalling yards

Scenarios – road-rail terminals and rail-sea

Innovation Scenarios

Munich Riem

Rail - Road terminal Munich Riem					
Scenario 1		**Scenario 2**		**Consolidated Scenario**	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Faster and fully direct handling Automatic ITU and vehicles control and data exchange No locomotive change Long train (1500 m) H24 working time	Automated fast transtainer Intermodal complex spreader Duo loco Fast automated gate	Horizontal and parallel handling Faster and fully direct handling Automatic ITU and vehicles control and data exchange No locomotive change Long train (1500 m) H24 working time	Automatic systems for horizontal parallel handling Duo loco Fast automated gate	Automatic ITU and vehicles control and data exchange Partial and fast locomotive change Long train (670m) H24 working time	Fast transtainer (+30-40% RMG performances) Fast Automated gate Automatic coupling loco

Rail - Road terminal Antwerp Combinant		Rail - Road terminal Antwerp Zomerweg		Rail - Road terminal Antwerp HUPAC	
Consolidated Scenario		**Consolidated Scenario**		**Consolidated Scenario**	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Automatic ITU and vehicles control and data exchange Partial and fast loco change Long train (670 m) H24 working time	Fast transtainer Duo propulsion loco Automatic coupling loco Automated gate (based on OCR and RFID)	Partial automatic ITU and vehicles control and data exchange Fast loco change Long train (670m) H24 working time	Partial Automated gate (based on RFID and manual procedure) Automatic coupling loco Long train (670 m) H24 working time	Automatic ITU and vehicles control and data exchange Fast loco change Long train (670 m) H24 working time	Automatic systems for horizontal parallel handling Automatic coupling loco Automated gate

Rail - Sea terminal Valencia Principe Felipe					
Scenario 1		Scenario 2		Consolidated Scenario	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Automatic ITU and Vehicle. control and data exchange No locomotive change Tracks operative length 1500 m H24 working time	Automated fast transtainer Intermodal complex spreader Duo propulsion loco Automated gate	Horizontal and parallel handling Automatic ITU and vehicles control and data exchange No locomotive change Long train H24 working time	Duo propulsion loco Automated gate	Automatic ITU and vehicles control and data exchange Long train (850-1000 m) H24 working time	Multi lift spreader handling Fast Automated gate Automatic coupling loco

Rail - Rail marshalling yard Hallsberg		
Scenario 1	Scenario 2	Consolidated Scenario
Innovative technologies	*Innovative technologies*	*Innovative technologies*
Automatic brakes on wagons Self-propelled wagons Automatic coupling and uncoupling Tracks operative length1500 m H24 working time Automatic wagon identification	Driverless loco Automatic brakes on wagons Duo propulsion loco Automatic coupling and uncoupling Tracks operative length 1500 m H24 working time Automatic wagon identification	Tracks operative length till 1500 m Multi Modal Marshalling (MMM): classification tracks accessible not only via hump Automatic wagon identification Automatic coupling and uncoupling Automatic brakes on wagons Self-propelled wagons Duo propulsion and driverless loco H24 working time

Key assessment criteria used in D23.2

Transit time hrs – have data for these scenarios

- Vehicles and ITUs

Equipment performance (Ep [ITUs/h])

Systems utilisation rate

For Hallsberg marshalling yard

Average wagon transit time

Tracks utilisation rate

Maximum flow through yard

Average number of wagons in the yard

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