# Synthesis of the study

# Feasibility of ERTMS implementation on the cross-border section Vitoria-Bordeaux



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## CONFIDENTIALITY

# 1 OBJECTIVES OF THE STUDY

The aim of this study is to provide to the Members States and the Infrastructure Managers of the Atlantic Corridor an analysis of the ERTMS implementation in the cross-border section Vitoria - Bordeaux. This analysis will provide the following results:

- Hypothesis and technical results of ERTMS implementation,
- Benefit for the customers and the infrastructure managers of the Atlantic Corridor.

The progression of the study is synthesized in the following scheme.

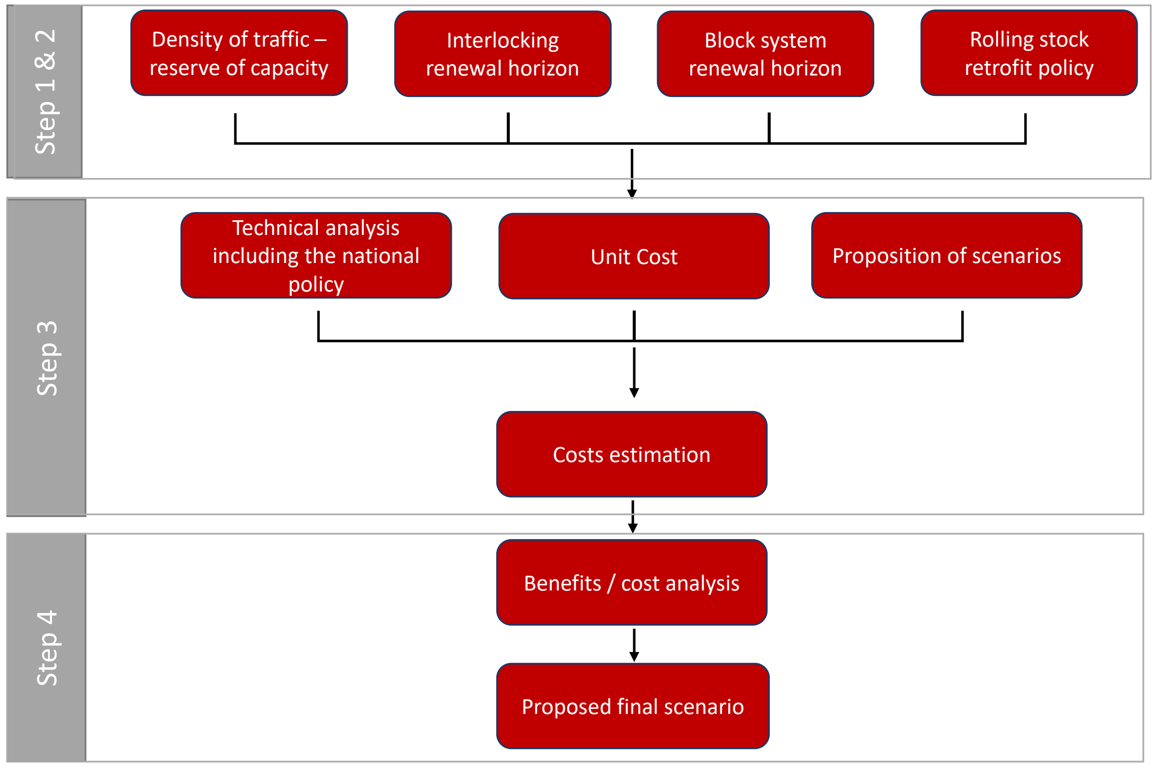



*Figure 1: Study organisation in four steps*

**Step 1.** On the basis of documents provided by the IMs and surveys made within the scope of this study, a detailed list of all trains running on the Bordeaux Vitoria section is made with a special focus on international or cross-border passengers and freight trains showing:

- The origin and destination of the train,
- The different type of rolling stocks (number, type electrified or diesel) used by railway undertakings for regional, national and international traffic.

The traffic concerned by an ERTMS deployment (types of passenger and freight missions and affected equipment) has been identified.

**Step 2.** On the basis of documents provided by ADIF and SNCF Réseau, step 2 establishes a detailed analysis of the infrastructures characteristics existing and planned, especially about the signaling system on the different sections concerned by this study; this detailed analysis shows:

- the location and characteristics of signaling boxes (age, type, operating section)
- the signaling system on tracks (age, type,) including "banalisation" system,
- the renewal program of the rail infrastructure (signal boxes, signaling system on track) expected by the infrastructure manager for these sections, where ERTMS is not implemented, planned or under construction yet.
- the estimated cost of renewal for the signal boxes and system on track in different situations

Step 2 focuses on the characteristics of the lines to be fitted with ERTMS within the perimeter of the study.

Step 3. The aims of the study of **step 3** are:

- The development plan to implement on the scope of the study.
- The main technical characteristics of the deployment that refers to the technical level of ETCS (1 or 2), those backup systems classified as national class B system, transition between systems, levels, and baselines …
- The deployment plan according to commitments developed in European and national programs.
- The pricing method to develop in step 4 and unit prices to use.
- The economic impacts of the ERTMS equipment on CAPEX and on OPEX to consider later in the step 4.

Regarding the analysis, it will provide the technical detail of the deployment considering signalling system as well as the signalling technology, looking for possible synergies regarding the renewal of block and signal boxes.

The unit costs for each unit will be accorded between Spain and France considering the European benchmark. The economic impacts of the ERTMS equipment for on board retrofit will be considered in step 4.

Step 3 also focus on the border section Hendaye/Irun, with its equipment and its special constraints that come from the operation rules under ERTMS between both countries.

**Step 4.** Aims to give a detailed economic analysis of the **CAPEX costs** with comparison between the reference (without ERTMS) and the project scenarios. All investment costs for deployment are valuated in step 4, based on unit costs obtained in step 3.

The analysis performed in step 1 allows to determine the number of on-board units that have to be updated with EVC ERTMS. This analysis will consider:

- The units already equipped in 2025
- The units that would be out of service during the next 10 years until 2035 (equipped or not)
- The residual units to be equipped

**OPEX costs** will be also estimated. The impact of a decrease or increase on maintenance costs is estimated.

Step 4 analyses the other impacts of the introduction of ERTMS on the following items:

- **Capacity of the line**
- **Punctuality**
- **Travel time reduction**
- **Reliability**
- **Operating costs of railway companies**: having locomotives with a single control and command system obviously allow to reduce costs.
  - possible capacity linked to cancelled operations at the border, especially Irún or Hendaye,
  - optimization of locomotives and drivers timeline for Railway Undertakings,
  - cost impact for Railway Undertakings (rolling stock equipment and drivers trainings)
- **Functional Safety**

# 2 STEP 1 - TRAFFIC ANALYSIS

To perform the traffic analysis of the French and Spanish sides, several hypotheses were established to understand which data sources were to be used, the time frame needed to analyse the data along with identifying specific characteristics of each side.

In order to prepare the cost-benefit analysis (CBA) of the ERTMS deployment, it is also important to know the total number of locomotives that is necessary to be equipped with considering on-board ETCS systems. Therefore, the analysis of the rolling stock that runs through this line, detailed in the second part of this section, will provide this datum.

## 2.1 Hypothesis

To perform a reliable and consistent rail traffic analysis, the external factors that might affect the integrity of the rolling stock circulation must be taken into consideration. Therefore, there are some circumstances affecting both French and Spanish sides that must be considered before starting the study:

- French strike since November 2019.
- Works in the Spanish tracks at Astigarraga - Irún section since October 2017, which aim to widen the tunnels clearance gauge and affect the traffic of long-distance trains. These routes are currently bypassed and operated using commuting trains instead of long-distance ones.

### 2.1.1 French hypothesis

The French data collected from the LERINS 2017 database,—shows the daily traffic by type of circulations. With a calculation base of 6 days a week, the data show the weekly average traffic. Considering the year 2017 as being the last official data, due to 2018 and 2019 are unavailable; there have been no significant changes since the year 2016.

The types of circulation are long distance, regional, freight, and service trains. The distribution is based on the origin-destination representing a section, which is the aggregation of several elementary sections (smallest section used by the maintenance service).


*Figure 2 Scope of the study - French side*

### 2.1.2 Spanish hypothesis

The Spanish data are collected from two databases:

- The CT (Traffic Control) database, which provides information about the traffic flow without disaggregating it by type of circulation,
- CIRTRA (circulations by section) database, which shows the traffic sorted by type of circulation and calculates the weekly average taking the annual data as calculation base. Hereafter, the data from CIRTRA are presented in a tabular format in order to ease their interpretation, are sorted by type of circulation in long distance, regional, commuting services, freight trains, and maintenance trains. These data are clustered using an origin-destination criterion.

The projected « Y Vasca » traffic data has been foreseen in several studies, whose traffic density is supposed to be higher than the currently existing. Nevertheless, it must be kept in mind that these data come from a forecasting model, although it can be taken as a proper estimation.

In this way, after consulting it with the infrastructure manager that is in charge of the works, and having consulted different studies of this line, the « Y Vasca », at least considering the Vitoria-Astigarraga (San Sebastián) branch, is expected to be fully operational in 2025. Therefore, the projected data cannot be taken from actual data, but from projected estimations.

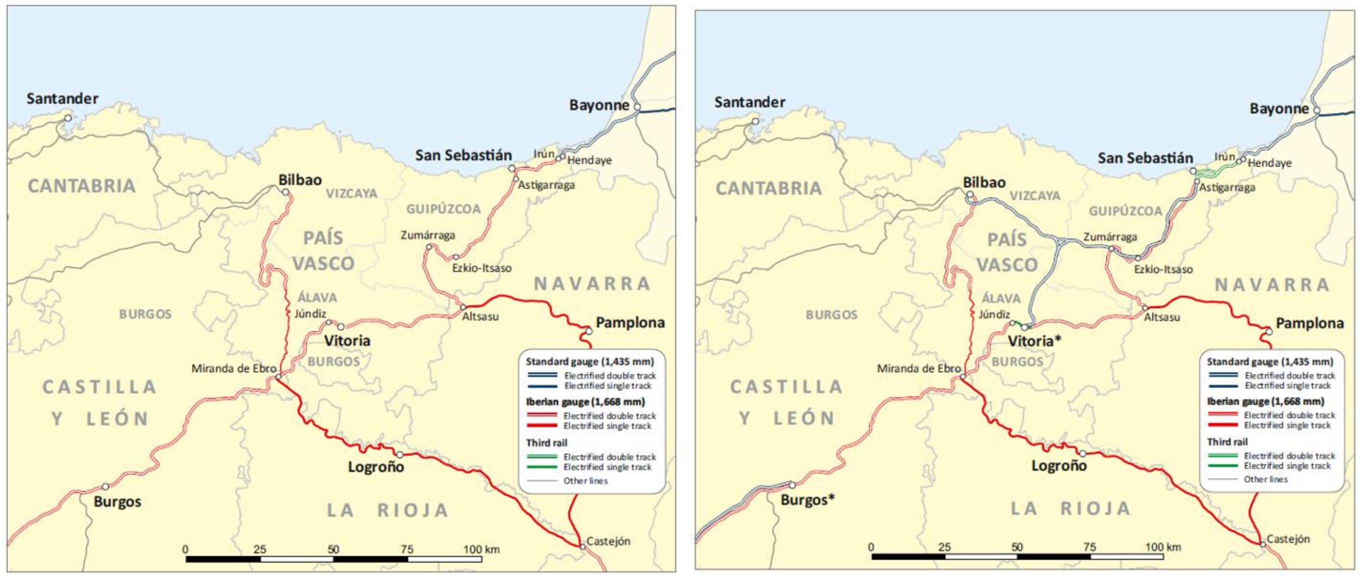



*Figure 3 Current and projected situation (left and right, respectively) of the Spanish side*

The analysis considers the following categories regarding passenger traffic, sorted by origin/destination:

- **Long-distance**: Barcelona, Madrid, Galicia and Portugal.
- **Medium-distance**: Madrid-Pamplona.
- **Commuting or suburban trains** operating within the area between San Sebastián and Irún.
- **High-speed trains** Madrid/Bilbao-France and Burdeaux-San Sebastián that are operating in the mid/short-time.

Regarding freight traffic on the Spanish side, the analysis has considered the following categories:

- Trains from/to San Sebastián that provide service to ITE.
- Trains dispatched from Irún to France or « Y Vasca », in the future, using UIC gauge.
- Trains dispatched from Hendaye to Irún using Iberian gauge.

## 2.2 RESULTS OF THE PROJECTED SITUATION

### 2.2.1 New line in Spain

The projected situation concerns the commissioning of the « Y Vasca », which has been fostered and is supposed to be fully operational around2028-2029. This new line will increase the capacity of the current traffic on both sides of the border and will allow high-speed trains and UIC gauge freight rolling stock to circulate between Vitoria, Astigarraga, and Bilbao.

This line is also supported by the installation of the third rail at Astigarraga-Irún and Vitoria-Júndiz, which enables the connection of the French lines and the high-speed line that comes from Madrid with the «Y Vasca».

The traffic data can only be obtained using simulation models that are extracted from studies such as the study performed by Arcadis & Idom[1].The following table projects the traffic that have been studied for both sides of the border.

| Origine - Destination | Vitoria Este | Bergara | Astigarraga |
|---|---|---|---|
| Bilbao-Paris | - | 1 | 1 |
| Madrid-Paris | 4 | 4 | 4 |
| San Sebastien-Bordeaux | - | - | - |
| Madrid-Bilbao | 10 | 10 | - |
| Madrid-San Sebastien | 7 | 7 | 7 |
| Barcelona-Bilbao | 4 | 4 | - |
| Barcelona-San Sebastien | 3 | 3 | 3 |
| Barcelona-Vitoria | - | - | - |
| Galicia-Bilbao | 1 | 1 | - |
| Galicia-San Sebastien | 1 | 1 | 1 |
| Vitoria-Bilbao | 14 | 14 | - |
| Vitoria-San Sebastian | 9 | 9 | 9 |
| Bilbao-San Sebastian | - | 12 | 12 |
| Vitoria-Pamplona | - | - | - |
| San Sebastien-Bayonne | - | - | - |
| Brinkola-Irun | - | - | - |
| Tolosa-Irun | - | - | - |
| Fret conventionnel & TC (UIC) | 18 | 18 | 18 |
| Autoroute ferroviaire Vitoria-Dourges | 8 | 8 | 8 |
| Fret conventionnel & TC (IBE) | - | - | - |
| | **79** | **92** | **63** |

*Table 1 Projected situation (Daily Trips each way) - Source: Electrical study on the Vitoria-Dax section by Arcadis/IDOM*

[1] Electrical study on the section Vitoria-Dax, performed by Arcadis & Idom.

### 2.2.2 Conventional line – both sides

The traffic data has been obtained using simulation models that are extracted from studies, for example the study performed by Arcadis & Idom "ARCIDOM Nota simulación_v3 230118". They are synthetised in the following tables, presenting the projected traffic on both sides of the border.

**Spanish side**

| Type | TRAFFIC CONVENTIONAL LINE | SPAIN | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Origin/Destination | Jundiz | Vitoria | *Vitoria Est* | *Bilbao* | Alsasua | Brinkola | Tolosa | *Astigarraga* | San Sebastian | Irun |
| LD | Bilbao-Paris (US) | - | - | - | 1 | - | - | - | 1 | 1 | 1 |
| | Madrid-Paris (US) | 4 | 4 | 4 | 4 | - | - | - | 4 | 4 | 4 |
| | San Sebastien-Bordeaux (US) | - | - | - | - | - | - | - | - | 3 | 3 |
| MD | Madrid-Bilbao (US) | 10 | 10 | 10 | 10 | - | - | - | - | - | - |
| | Madrid-San Sebastien-Irun | 7 | 7 | 7 | - | - | - | - | 7 | 7 | 7 |
| | Barcelona-Bilbao | - | - | 4 | 4 | 4 | - | - | - | - | - |
| | Barcelona-San Sebastien-Irun | - | - | 3 | - | 3 | - | - | 3 | 3 | 3 |
| | Barcelona-Vitoria | - | 1 | 1 | - | 1 | - | - | - | - | - |
| | Galicia-Bilbao | 1 | 1 | 1 | 1 | - | - | - | - | - | - |
| | Galicia-San Sebastien-Irun | 1 | 1 | 1 | - | - | - | - | 1 | 1 | 1 |
| Regional | Vitoria-Bilbao | | 14 | 14 | 14 | - | - | - | - | - | - |
| | Vitoria-San Sebastian | | 9 | 9 | - | - | - | - | 9 | 9 | - |
| | Bilbao-San Sebastian | - | - | - | 12 | - | - | - | 12 | 12 | - |
| | Vitoria-Pamplona | - | 3 | 3 | - | 3 | - | - | - | - | - |
| | San Sebastien-Bayonne | - | - | - | - | - | - | - | - | 16 | 16 |
| Cercanías | Brinkola-Irun | - | - | - | - | - | 23 | 23 | 23 | 23 | 13 |
| | Tolosa-Irun | - | - | - | - | - | - | 15 | 15 | 15 | 9 |
| Freight | Fret conventionnel & TC (UIC) | 18 | 18 | 18 | - | - | - | - | 18 | 18 | 18 |
| | Autoroute ferroviaire Vitoria-Dourges | 8 | 8 | 8 | - | - | - | - | 8 | 8 | 8 |
| | Fret conventionnel & TC (IBE) | 4 | 4 | 4 | - | 8 | 8 | 8 | 8 | 8 | 8 |
| | | **53** | **80** | **87** | 46 | **19** | **31** | **46** | **109** | **128** | **91** |

**French side**

Due to the lack of data on the section Bordeaux-connection to HSL SEA and the section Bordeaux-Dax[2], the assumption is that the long distance passenger traffic and some regional traffics on these sections are the same as the reference. Regarding the traffic of freight, the assumption is that the "fret conventional & TC (UIC)" concerns also the traffic in the North of Dax.

| Type | TRAFFIC CONVENTIONAL LINE | FRANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Origin/Destination | Hendaye | Bayonne | Dax | *Laluque* | *Talence-Médoquine* | Bordeaux | Cenon | La Gorp |
| LD | Bordeaux-San Sebastian (US) | 3 | 3 | 3 | - | - | 3 | - | - |
| | Paris-Hendaye-Bilbao (UM) | 1 | 1 | 1 | - | - | 1 | - | - |
| | Paris-Hendaye-Madrid (UM) | 4 | 4 | 4 | - | - | 4 | - | - |
| | Bordeaux-St-Jean – Poitiers* | - | - | - | - | - | 3 | 3 | 3 |
| | TER Bordeaux-St-Jean – Tourcoing* | - | - | - | - | - | 1 | 1 | 1 |
| | Bordeaux-St-Jean - Lille Flandres* | - | - | - | - | - | 1 | 1 | 1 |
| | Bordeaux-St-Jean - Roissy-Aéroport-CDG 2* | - | - | - | - | - | 1 | 1 | 1 |
| | Bordeaux-St-Jean - Paris-Montparnasse* | - | - | - | - | - | 11 | 11 | 11 |
| | Bordeaux-St-Jean - Strasbourg-Ville* | - | - | - | - | - | 1 | 1 | 1 |
| | Paris-Montparnasse – Arcachon* | - | - | - | 4 | 4 | 4 | 4 | 4 |
| | Paris-Montparnasse – Agen * | - | - | - | - | - | 1 | 1 | 1 |
| | Toulouse Matabiau - Paris-Montparnasse* | - | - | - | - | - | 6 | 6 | 6 |
| MD | IC Hendaye-Toulouse via Pau | 2 | 2 | - | - | - | - | - | - |
| | IC Bordeaux-Hendaye | 1 | 1 | 1 | - | 1 | 1 | - | - |
| Regional | TER Bordeaux-Hendaye | 13 | 13 | 13 | - | 13 | 13 | - | - |
| | TER Dax-Hendaye | 15 | 15 | 15 | - | - | - | - | - |
| | TER Bayonne-Hendaye | 9 | 9 | - | - | - | - | - | - |
| | TER Bordeaux – Arcachon | - | - | - | 44 | 44 | 44 | - | - |
| | Lesparre - Bordeaux-St-Jean | - | - | - | - | 4 | 4 | - | - |
| | Bordeaux-St-Jean - La Pointe-de-Grave | - | - | - | - | 10 | 10 | - | - |
| | Le Verdon - Bordeaux-St-Jean | - | - | - | - | 4 | 4 | - | - |
| | Macau - Bordeaux-St-Jean | - | - | - | - | 1 | 1 | - | - |
| | TER Bordeaux – Mont-de-Marsan | - | - | - | 14 | 14 | 14 | - | - |
| | TER Bordeaux-St-Jean – Coutras* | - | - | - | - | - | 9 | 9 | 9 |
| | TER Bordeaux-St-Jean – Libourne* | - | - | - | - | - | 17 | 17 | 17 |
| | TER Bordeaux-St-Jean - Limoges-Bénédictins* | - | - | - | - | - | 6 | 6 | 6 |
| | TER Bordeaux-St-Jean - Montluçon* | - | - | - | - | - | 2 | 2 | 2 |
| | TER Bordeaux-St-Jean – Périgueux* | - | - | - | - | - | 14 | 14 | 14 |
| | TER Bordeaux-St-Jean – Tulle* | - | - | - | - | - | 2 | 2 | 2 |
| | TER Bordeaux-St-Jean – Angoulême* | - | - | - | - | - | 9 | 9 | 9 |
| | TER Bordeaux-St-Jean – Brive-la-Gaillarde* | - | - | - | - | - | 1 | 1 | 1 |
| | Bayonne - San Sebastien | 16 | 16 | - | - | - | - | - | - |
| Freight | Fret conventionnel & TC (UIC) | 18 | 18 | 18 | 18 | 18 | 18 | - | - |
| | Autoroute ferroviaire Vitoria-Dourges | 8 | 8 | 8 | 8 | 8 | 8 | - | - |
| | Fret conventionnel & TC (UIC) | 8 | 12 | 12 | 12 | 12 | 12 | - | - |

*Table 2 Daily forecasted traffic in 2025 - Source: Electrical study on the Vitoria-Dax section by Arcadis/IDOM*

*Traffic from the reference data.

[2] The scope of the electrical study of Arcadis-Idom is only Vitoria-Dax

# 3 STEP 2 – SIGNALLING INFRASTRUCTURE ANALYSIS

## 3.1 Hypothesis

According to the official maps of the status of the works on the "Y Vasca" and regarding the actual progress on the area:

- The area of the future Bilbao station (2) is still under studying, and the entrance section is not yet finished (1).
- The bypass line in the Irún-San Sebastián branch is not definitive (3), being the Lezo-French Border section frozen (blue) and the San Sebastián by-pass under study (green).
- The section from Júndiz to Vitoria is partially defined if we take the old-line signalling layout (4).

Even if the track facility is not already built, the block diagrams and the official data of the signalling is available. These data have been taken as the main basis for the study.

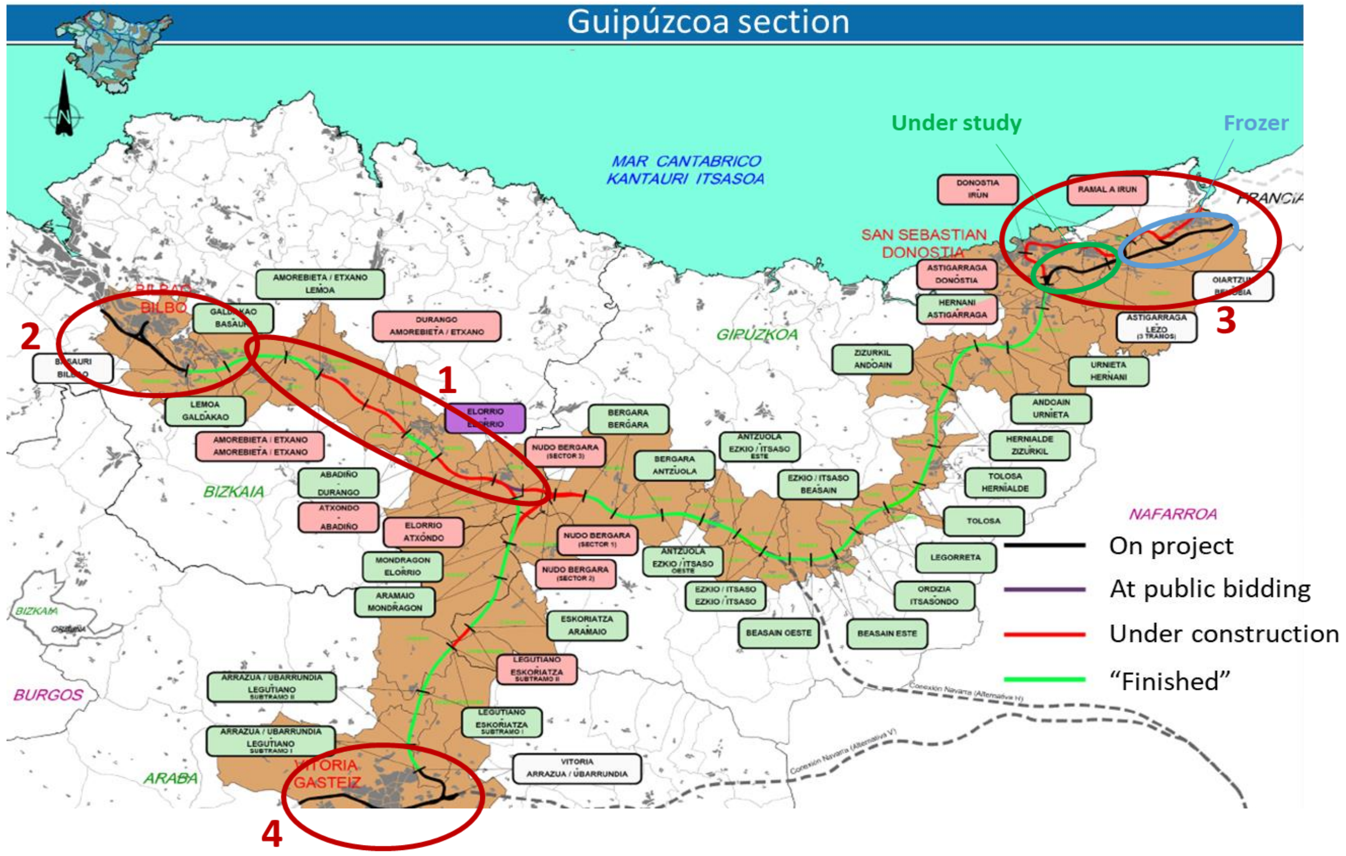



*Figure 4 Satus of works on the "Y Vasca"[3]*

It is important to notice that the status "finished" does not correspond to the real situation of the line, since only the platform is already built. Nevertheless, the future signalling plan to be implemented is available.

[3]ETS and Gobierno Vasco (2020). Nueva red ferroviaria del país vasco en el territorio historico de gipuzkoa (bergara-lezo). Informe trimestral de obras.

## 3.2 Strategy for the ERTMS deployment

As the aim of the project that is under study is to deploy ERTMS L2 in the line Vitoria-Bordeaux, , it is important to describe the deployment strategies that were set by each EU member and gathered by the TEN-T ERTMS department.

### 3.2.1 Spanish strategy[4]

The Spanish strategy for the ERTMS deployment is set in the NIP-CSS document, where Adif and Adif AV, the Spanish IM, are in charge of the infrastructure management. This strategy is divided into technical terms and, on the other hand, financial parameters.

**Technical side**

As it has been explained in the latter sections, the Spanish railway infrastructure has three different types of gauge track: narrow (1000 mm), International (1435 mm) and Iberian (1668 mm). Nevertheless, according to TSI 2016/919 section 1.2, narrow gauge is not part of the ERTMS deployment national plan aim. This plan regards ERTMS (L0 + Class B system, NTC, L1 and L2), LZB, EBICAB and ASFA as signalling systems.

In order to perform an analysis of the necessity in terms of ERTMS installation regarding both infrastructure and rolling stock, it is mandatory to gather the total number of kilometres that are equipped with this system. In Spanish case, the total length of the network equipped with this type of signalling amounts to 2415.3 km.

Below is a map showing the state of the Spanish network in relation to the signalling systems installed on the different lines.

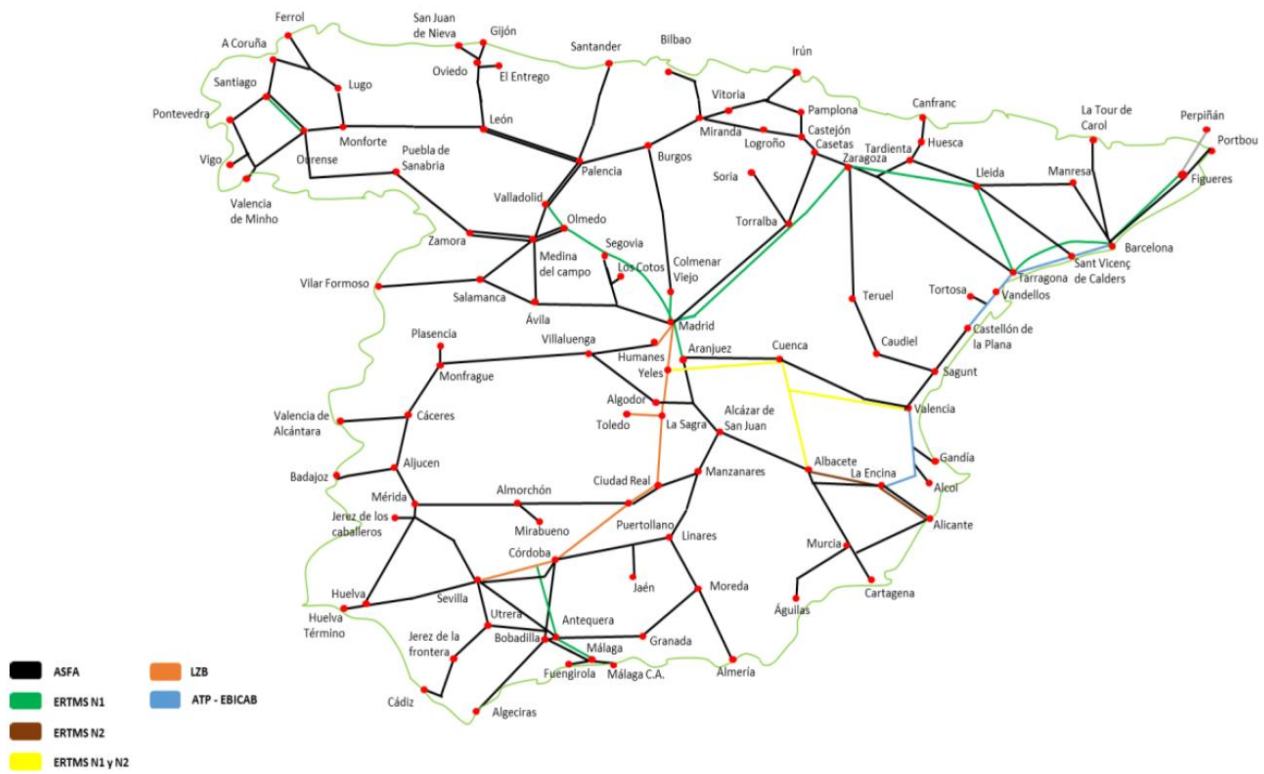



*Figure 5. Map of signalling systems in Spain (2017) (EBICAB is currently dismantled)[5]*

[4] Ministerio de Fomento (2017). Plan de Implementación Nacional del sistema ERTMS

[5] Ministerio de Fomento (2017). Plan de Implementación Nacional del sistema ERTMS

This plan also gathers the total number of rolling stock that is operating within the Spanish railway infrastructure and the signalling system that they are equipped with.

| Data | | Number of |
|---|---|---|
| **Cercanías fleet in Madrid** | Without ERTMS | 270 trains |
| **Rodalíes (commuting) in Cataluña** | Without ERTMS | 271 trains |
| **Cercanías fleet** | With ERTMS | 112 trains |
| **Long-distance and regional trains** | Without ERTMS | 249 trains |
| **Long-distance and regional trains** | With ERTMS | 230 trains |
| **Freights locomotives** | Without ERTMS | 269 locomotives |
| **Freights locomotives** | With ERTMS | 9 locomotives |
| **Total number of rolling stock with ERTMS** | | 351 |
| **Total number of rolling stock to be equipped with ERTMS** | | 436 (late 2020) |

In terms of compatibility between the signalling system in the track and the rolling stock side, we have the following:

| Trackside CCS | Rolling stock CSS |
|---|---|
| **ASFA** | Mandatory to have ASFA on-board |
| **ETCS** | Mandatory to have ETCS on-board |
| **LZB** | Mandatory to have LZB on-board |
| **ASFA + LZB** | Mandatory to have LZB on-board |
| **ASFA + ETCS** | Mandatory to have ETCS on-board, ASFA is optional |
| **LZB + ETCS** | Mandatory to have ETCS on-board, LZB is optional |

With regard to the baseline of deployed ERTMS so far, it is important to underline that the reference version is 2.3.0.d, which is supposed to be the one that will work with any future version of ERTMS. As it has been done with the total number of kilometres and rolling stock that are installed with ERTMS, it is also important to be aware of the baseline version that infrastructure and rolling stock are equipped with. This information allows to get the big picture of the ERTMS deployment both trackside and on board in Spain.

| Line | Contracted version at the beginning | | Current version | | Manufacturer | Length |
|---|---|---|---|---|---|---|
| | ETCS level | Version | ETCS level | Version | | |
| Madrid- Albacete-Valencia | 1+2 | 2.3.0d | 1** | 2.3.0.d | -Siemens | 239 km |
| Albacete Junction -Alicante | 2 | 2.3.0d | 2 | 2.3.0.d | Alstom | 239.1 km |
| Madrid-Zaragoza-Lleida | 1+2 | 2.2.2+ | 1*** | 2.3.0d | Ansaldo - Hitachi), Alcatel (Thales) | 442.1 km |
| Lleida-Barcelona | 1+2 | 2.2.2+ | 1* | 2.3.0.d | Thales and Siemens (Eurobalises) | 179.2 km |
| Barcelona-French border | 1+2 | 2.2.2+ | 1* | 2.3.0.d | Ansaldo - Hitachi), Alcatel (Thales) | 194 km |
| Córdoba - Málaga | 1+2 | 2.2.2+ | 1+2 | 2.3.0.d | Dimetronic (Siemens) | 155 km |
| Antequera S. Ana Junction – Granada | | | 2 | 2.3.0.d | Siemens | 109 km |
| Madrid - Valladolid | 1+2 | 2.2.2+ | 1+2 | 2.3.0.d | Alcatel (Thales) | 184 km |
| Valladolid – Palencia - León | - | - | 2 | 2.3.0.d | Alstom | 166 km |
| Medina Junction -Zamora - Pedralba de la Pradería | - | - | 2 | 2.3.0.d | Thales | 205.88 km |
| Vandellós-Camp de Tarragona | - | - | 1 | 2.3.0.d | -CAF Signalling | 47.44 km |
| Santiago - Ourense | 1+2 | 2.30d | 1* | 2.3.0.d | -Thales | 85 km |
| Murcia Junction – Beniel | - | - | 2 | 2.3.0.d | -Hitachi / CAF | 51.97 km |
| Cercanías Madrid (Parla – Colmenar / Alcobendas / San Sebastián de los Reyes | 1+2 | 2.3.0d | 1* | 2.3.0d | Dimetronic (Siemens) / Thales | 62,2 km |

*Level 2 under construction

** Level 2 disconnected due to interoperability issues at the transition point

*** Level 2 2.2.2+ being migrated to 2.3.0d

*Table 3 ERTMS trackside baseline(Adif Network statement)*

| Rolling stock series | Current version | | Aimed version | | Manufacturer | Number of trains |
|---|---|---|---|---|---|---|
| | ETCS level | Version | ETCS level | Version | | |
| **S-102/112** | 1+2 | 2.2.2+ | 1+2 | 2.3.0.d | Siemens | 46 |
| **S-103** | 1+2 | 2.2.2+ | 1+2 | 2.3.0.d | Siemens | 26 |
| **S-130/730** | 1+2 | 2.3.0.d- | 1+2 | 2.3.0.d | Bombardier | 45* |
| **S-120/121** | 1+2 | 2.2.2+ | 1+2 | 3.6.0 | Ansaldo | 56 |
| **S-104** | 1+2 | 2.2.2+ | 1+2 | 3.4.0 | Alstom | 20 |
| **s-252** | 1+2 | 2.3.0.d | - | - | Siemens | 9 |
| **s-465** | 1+2 | 2.3.0.d | - | - | Siemens/Alstom | 112 |

*Table 4 ERTMS on-board baseline*

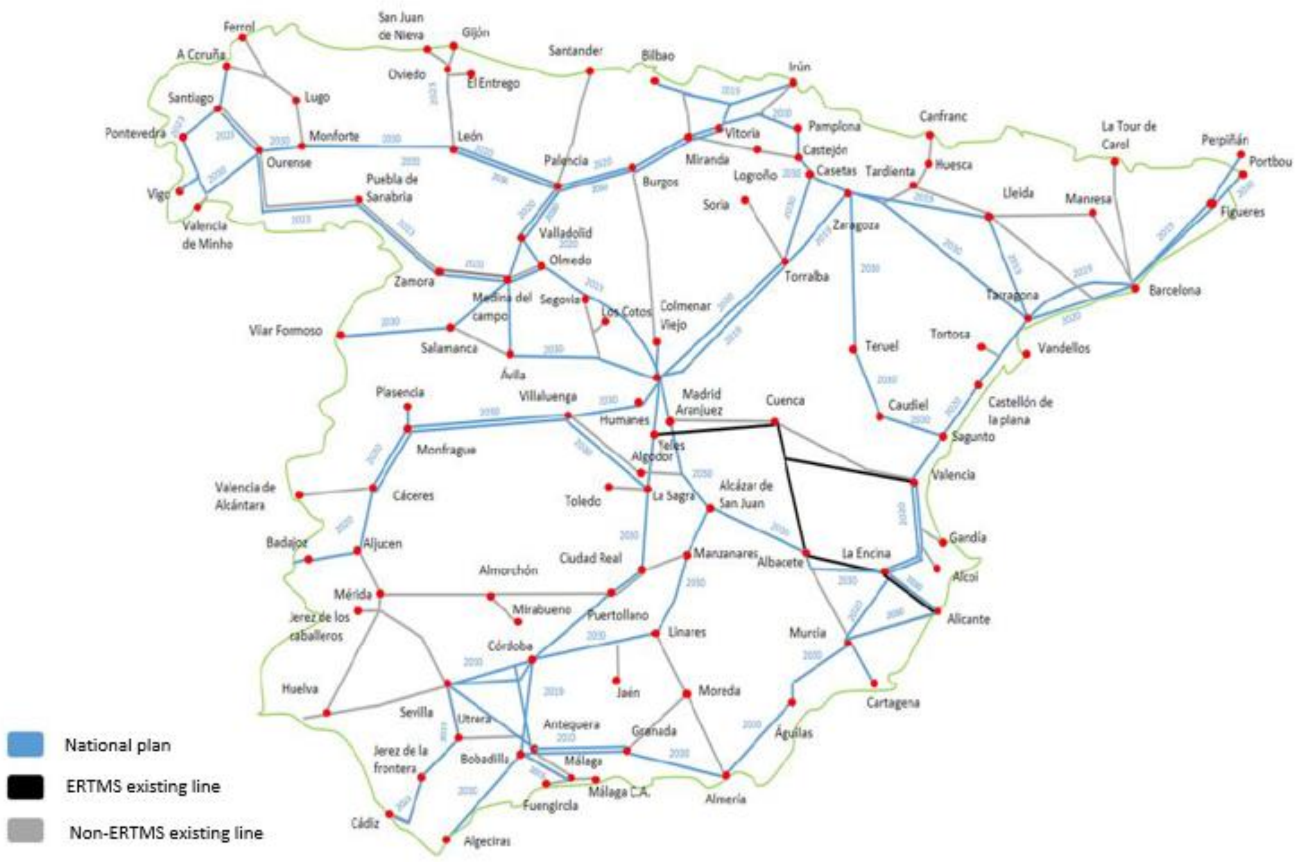



*Figure 6: Map of ERTMS deployment[6]*

Finally, the conclusions of this deployment plan are the following:

- Class B system will not be migrated to ERTMS at the earliest 2027
- Every new line will be equipped with ERTMS.
- ERTMS is to be installed in every commuting node.
- ERTMS is to be installed in most of the section within the TEN-T corridors

### 3.2.2 French strategy

According to the DRR[7] 2021 and the national implementation plan 2017, ERTMS Level 1 V2.3.0.d (full supervision) in addition to the class B system (KVB) is to be installed until 2024.

The ERTMS implementation is under study on the high-speed line Paris-Lyon, with the level 2 baseline 3 V 3.6.0, including the GPRS technology, in addition to the class B system TVM[8]. The commission date is forecasted in 2025. There will be a restriction of the number of non-quipped ETCS rolling stock on the peak-hours.

The ERTMS L2 baseline 3 V3.6.0 implementation on the conventional line Marseille-Vintimiglia will be phased until 2032 (excluded Marseille St Charles station), with a progressive dismantling of the class B system (BAL, BAL+KVB, etc.).

The whole national strategy about the level of ERTMS, the new interlocking that will replace the old signal boxes, etc. will be detailed in the next report related to the step 3 of the study.

[6] Ministerio de Fomento (2017). Plan de Implementación Nacional del sistema ERTMS

[7] DRR : document de référence du réseau – national rail network statement

[8] TVM: Transmission voie machine – signalling and protection system on the French high-speed lines.

### 3.2.3 National signalling and protection systems in France and Spanish side

Being the ERTMS the system that is aimed to be implemented in the lines under study, it is interesting to point out the main characteristics of each national signalling systems in both sides of the border, in order to analyse likely synergies between the new and the current systems.

#### *3.2.3.1 Spanish signaling and protection system: ASFA*

ASFA is one of the currently signalling and protection systems used in Spanish lines[9], being ERTMS L1 and L2, and LZB (Madrid-Sevilla) some others. The term ASFA corresponds to the Spanish acronym of signals and automatic brakes advice. The new version of ASFA, known as ASFA digital, is the one that is installed in new lines as a complement to ERTMS in lines where ERTMS is to be installed, being subject of renewal in old lines.

The functioning of this system has several differences with regard to ERTMS L2. The two actions that it performs are to send the information that comes from trackside to the cabin, and acts over the braking system in case of emergency or the inaction of the driver or in case the speed limits are overpassed. Besides, it is a punctual system and needs from lateral signalling to be able to operate in terms of train driving.

The main difference with ERTMS is that ASFA is not a dynamic continous supervision system, and it is not a whole SIL 4 system. The responsibility of the supervision relies also on the driver. In other words, if a balise is lost or not detected by the on-board equipment, ASFA does not know that and so does not react, being extremely important the attention of the driver to the line side signalling.

Considering the trackside equipment, ASFA uses two type of balises, some are placed 300 m before lateral signalling posts, which are called advanced balises, and some are placed around 5 m before the lateral signalling post, which are called main signal balises. These balises send data from track to on-board using seven different frequencies that are received by antennae placed on-board. With regard to on-board equipment, ASFA counts on these before mentioned antennae, and on the cabin system.

#### *3.2.3.2 French signalling and protection system: KVB*

The KVB in France is one of the speed and crossing control system that consists of an automatic and continuous control of the speed thanks to the beacons on track and the calculator on board. All signals on the French part of the TEN-T core network are equipped with the KVB. The reliability of the system is proved because no accident can be blamed on a KVB failure. And the number of train brake controls is decreasing[10]. This system is one of the 4 systems installed on the French railway network: KVB, DAAT (mainly on non-electrified single track), TVM (only on high speed lines) and ETCS.

The speed control is continuous, considering the rolling stock movement, but the data transmission is punctual. There are two systems:

- An on-track device (balise) for the track information: fixed balise or switchable balise, depending on the type of information that it delivers. The balises are installed by group of 2 to 5, in order to know the direction of the train. The balises are passives, and the only energy source is the 27MHz send by the on-board antenna. The information from the track is send with a 4.5MHz signal to the board.
- An on-board device (calculator, antenna) controlling the train running from the on-track information.

In the case of a non-respect of the speed limit or the stopping point by the driver, the system triggers automatically the emergency brake system of the rolling stock. To avoid the disturbance of the driver in operation, the system is totally imperceptible.

[9] Adif (2019). Declaración de la Red

[10] National implementation plan for france (NIP-CSS-TSI-France)

## 3.3 Description of the French SIGNALLING infrastructure

The provided data shown in the following tables are from the ARMEN database of SNCF Réseau. The aim is to provide the most complete information for the step 3, which analyses the feasibility analysis of the ERTMS implementation. The scope of the French part is the line 655000 Bordeaux to Irun (cross-border). It is important to include starting from now the line 570000 from Paris-Austerlitz to Bordeaux, until the connection to the HSL SEA around km 570, because the HSL will be in the future equipped with ERTMS.


*Figure 7 French scope*

### 3.3.1 Block system

The sections La Grave d'Ambarès (connection to the HSL SEA) – Bordeaux and Bordeaux – Irun is equipped with the BAL technology for the block system. The table down below presents the dates of commissioning, modernisation and forecasted regeneration per sub-section.

| SECTION | COMMISSIONNING DATE | MODERNISATION DATE | BLOCK | FORECASTED REGENERATION DATE |
|---|---|---|---|---|
| LA GRAVE D'AMBARES / BORDEAUX-SAINT-JEAN | 1951 | 1990 | BAL | 2040 |
| BORDEAUX-SAINT-JEAN / LAMOTHE | 1936 | 1970 | BAL | 2023 |
| LAMOTHE / LUGOS | 1984 | - | BAL | 2047 |
| LUGOS / YCHOUX | 1975 | 1984 | BAL | 2044 |
| YCHOUX / LABOUHEYRE | 1982 | - | BAL | 2046 |
| LABOUHEYRE / MORCENX | 1981 | - | BAL | 2044 |
| MORCENX / DAX | 1979 | - | BAL | 2042 |
| DAX / BAYONNE | 1997 | - | BAL | 2034 |
| BAYONNE / BIARRITZ | 1987 | 1998 | BAL | 2057 |
| BIARRITZ / HENDAYE | 1989 | 1999 | BAL | 2053 |
| HENDAYE / IRUN | 1969 | 1986 | BAL | 2046 |

*Table 5 line 655000 and 570000 - State of the French block system*

### 3.3.2 Signal boxes

The philosophy within the signalling system in France is different from the signalling system in Spain and Germany. In those countries, the blocking zones between stations are included and supervised within the interlocking system. However, in France, the blocking zone is independently managed by an automatic system with 3 lights signals. It is a permissive blocking system that works with a different concept. The ARGOS technology will be a more similar concept to the German/Spanish one.

The analysis of the currently installed signal boxes aims to collect all the information about their technology, total number of elements controlled by each interlocking, commissioning and renewal date, and the interoperability with ETCS subsystems. These data should be enough to perform a CBA of the ERTMS deployment.

The following figure summarises the area of action of each interlocking that operates within the lines of the scope of the study (L57000 and L655000). The list concerns only the signal boxes of the main line (services track excluded).

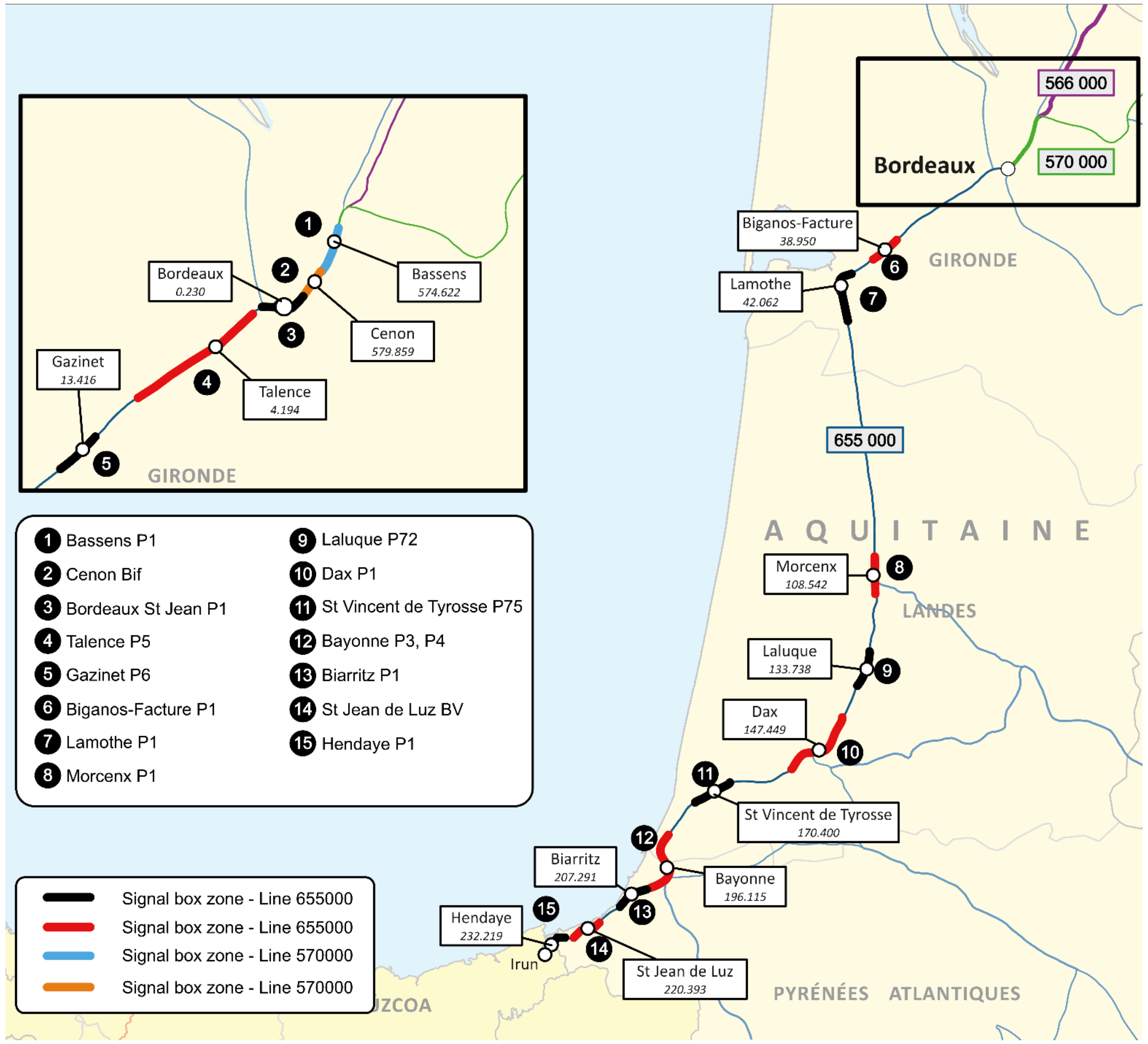



*Figure 8 Signal boxes zone*

| Name of the signal boxes | PK | Type 1 | Detailed type | Number of objects | AU | Commissioning | Renewal horizon for the reference | ERTMS Compatible | Remote control compatible |
|---|---|---|---|---|---|---|---|---|---|
| Line 570 000 | | | | | | | | | |
| Bassens Poste 1 | 574622 | PRSI | Electrical, computer command | 22 | - | 1975 | 2040 | Yes | Yes |
| Cenon poste bif | 579859 | PRSI | Electrical, computer command | 23 | - | 2008 | 2073 | Yes | Yes |
| Bordeaux St Jean poste 1 | 230 | PRSI | Electrical, computer command | 160 | 9 | 1980 | 2045 | Yes | Yes |
| Line 655 000 | | | | | | | | | |
| Talence-Médoquine Poste 5 | 4194 | PRCI | Computer signal box | 22 | 1 | 2002 | 2067 | Yes | Yes |
| Gazinet-Cestas Poste 6 | 13416 | PRCI | Computer signal box | 20 | 4 | 2002 | 2067 | - | - |
| Facture-Biganos Poste 1 | 38950 | MU45 | mechanical | 18 | - | 1956 | 2038 | - | - |
| Facture-Biganos Poste 1 Lamothe | 42062 | Sur lignes DV | Electrical and NS1 technology | 25 | - | 1998 | 2063 | - | - |
| Morcenx Poste 1 | 108542 | PRG | Electrical and NS1 technology | 33 | 3 | 1985 | 2050 | - | - |
| Laluque P72 | 133738 | PRSI | Electrical, computer command | - | 3 | 2015 | - | Yes | Yes |
| Dax Poste 1 | 147449 | PRG | Electrical and NS1 technology | 47 | 1 | 1997 | 2062 | | |
| Poste 75 | 170400 | PAI 2006 | Computer signal box | 8 | - | 2010 | - | Yes | Yes |
| Bayonne Poste 3 | 197380 | EMU | electromechanic | 25 | - | 1954 | 2038 | - | - |
| Bayonne Poste 4 | 197555 | PRG | Electrical and NS1 technology | 35 | 1 | 1987 | 2052 | - | - |
| Biarritz Poste 1 | 207291 | PRG | Electrical and NS1 technology | 28 | 3 | 1981 | 2046 | - | - |
| St-Jean-de-Luz-Ciboure Poste 1 | 220393 | Sur lignes DV | mechanical | 10 | - | 1989 | 2054 | - | - |
| Hendaye Poste 1 | 232219 | PRG | Electrical and NS1 technology | 0 | - | 1997 | 2062 | - | - |

*Table 6 line 655000 and 570000 - State of the French signal boxes*

## 3.4 Description of the Spanish signalling infrastructure

This section aims to summarise and describe the current and the projected status of the Spanish infrastructure considering the scope of the study.

Since the goal of the study is to analyse the feasibility of the ERTMS deployment, this analysis is focused on the different elements that are part of the signalling system. To do so, several elements are vital to be able to understand how the signalling of the line works:

- The block system, which is going to be managed by the RBC, due to the fact that the protection system is ERTMS L2.
- The interlocking system deployed along the line: technology, date of commissioning, related CTC, zone of control, and number of elements.
- Train detection systems.
- Operation mechanisms.
- Lateral signalling.
- ASFA balises and Eurobalises.

Once the structure of the section is set, it is also important to understand the different sections into which the study of the lines must be split. There are three main parts:

- Two sections of the conventional line, where third rail is to be installed from Júndiz to Vitoria and from Astigarraga to Irún. These two lines are already built, therefore, the block diagrams are available and the elements along the trackside must be analysed in terms of commissioning date and depreciation costs, and their compatibility with the new signalling system that is going to be installed. A third rail is to be built in order to allow UIC gauge track rolling stock to circulate through it.
- The mixed high-speed line from Vitoria to Astigarraga, Vitoria to Bilbao, and Bilbao to Astigarraga. These three branches form the so-called « Y Vasca ». This line counts on ERTMS L2 as main train protection system.

To ease the comprehension of the facility, these three sections are shown in the following figure:

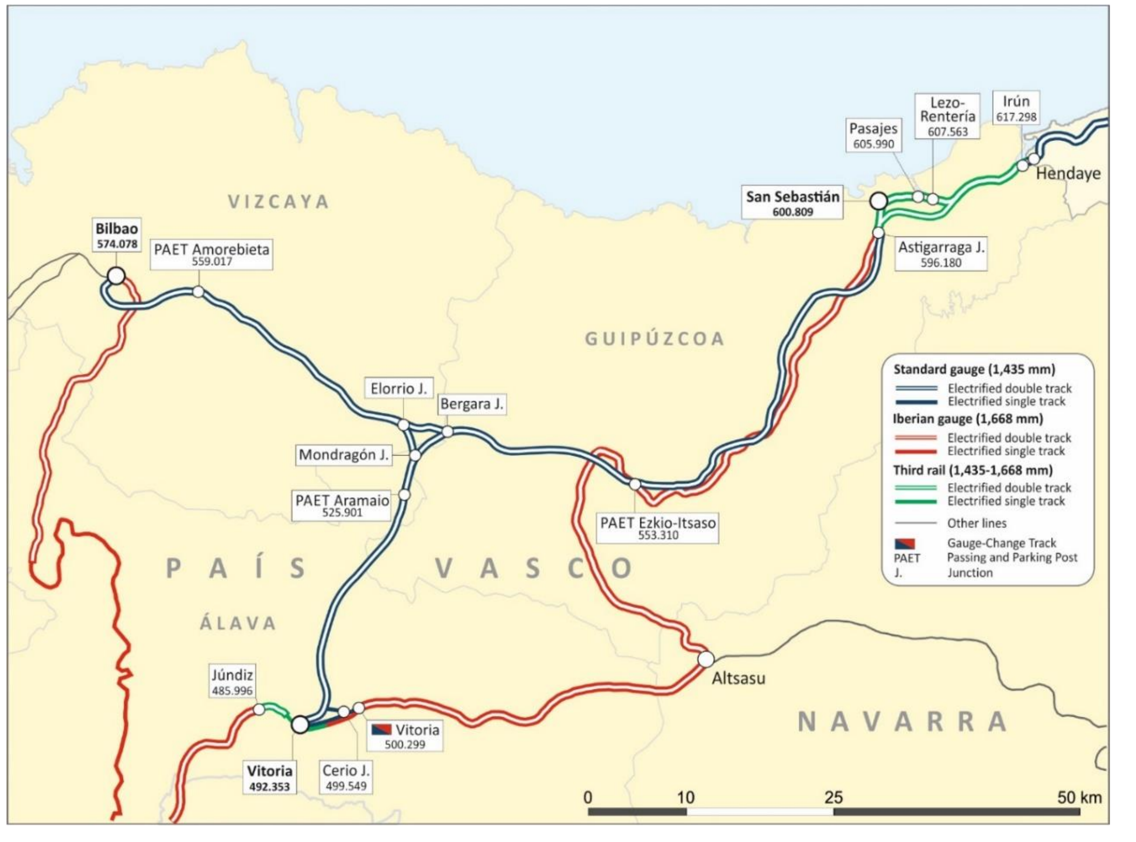



*Figure 9 Map of the Spanish infrastructure under study*

### 3.4.1 Analysis of interlocking systems

An interlocking is the mechanical, electric or electronic system that executes a logic from an Operation Plan using the actual status of the track elements (lateral signals, track occupancy devices, detectors, action mechanisms, etc.) and the orders from the Traffic Control Centre or Operator as inputs. These systems, therefore, need to interface to those elements that provided information from the track. Interlockings allow data to flow and to manage all the trackside elements and the traffic control.

The analysis of the currently installed interlocking systems aims to collect all the information about their technology, manufacturer, total number of elements controlled by each interlocking, commissioning and renewal date, and the interoperability with ETCS subsystems. These data should be enough to perform a CBA of the ERTMS deployment.

The following figure summarises the area of action of each interlocking that operates within the line under study, besides the gauge track and the PAETs (passing and parking posts) that are installed along the facility.

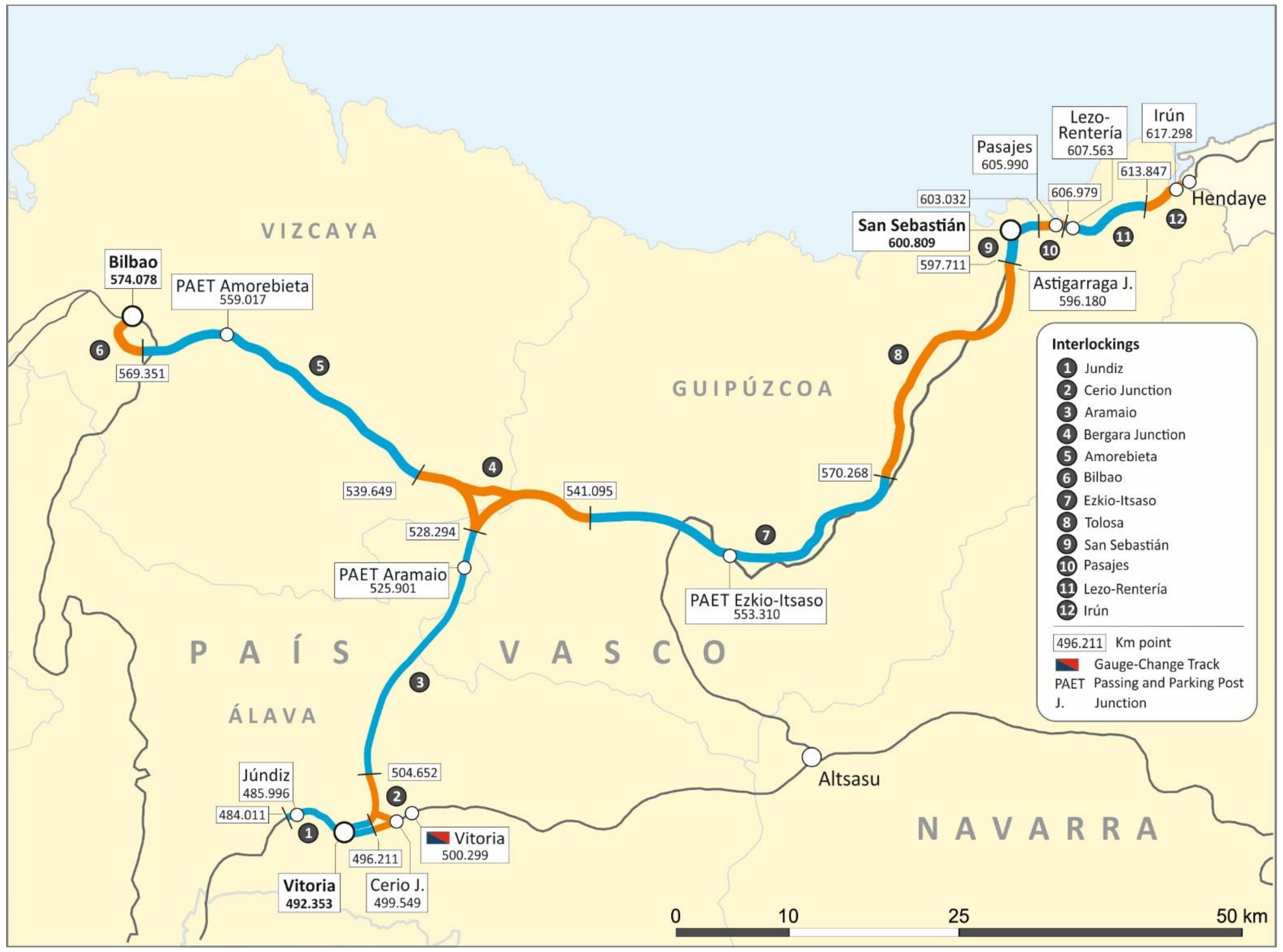



*Figure 10 Map of the area of action of interlocking facilities under study*

The following table shows the interlocking zone of action, the different depences into which the interlockings are split, technology, and the CTC that controls each of them within the « Y Vasca » section and the conventional line connected to the latter:

| Electronic Interlocking | Interlocking dependence | PK | Initial PK Section | Final PK Section | Type | | Commissioning date | Nb of objects | ERTMS compatible | Remote control compatible | CTC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jundiz | Jundiz | 485.996 | 484.011 | 487.494 | Electronic Siemens WESTRACE | CS1 | 2003 | 163 | | Yes | Miranda de Ebro |
| | Vitoria Gauge Change Train | 488.796 | 487.494 | 491.247 | | CS1 | | 72 | | Yes | |
| | Vitoria-Gasteiz | 492.283 | 491.247 | 496.211 | | CS1 | | 130 | | Yes | |
| Cerio Junction | Cerio Junction | 499.073 | 496.211 | 504.652 | Electronic | CS1N | 2025 | 158 | Yes | Yes | Miranda de Ebro |
| Aramaio | PBA LUKO | 510.846 | 504.652 | 514.373 | Electronic | CS1N | 2025 | 82 | Yes | Yes | CTC AV (Madrid Back up) |
| | PCA Albertia | 519.594 | 514.373 | 522.293 | | CS1N | | 20 | Yes | Yes | |
| | PAET Aramaio | 525.901 | 522.293 | 528.294 | | ET-Tipo 5 | | 72 | Yes | Yes | |
| Amorebieta | PBA Abadiño | 542.002 | 539.649 | 545.484 | Electronic | CS1N | 2025 | 155 | Yes | Yes | CTC AV (Madrid Back up) |
| | PCA Arteako | 550.412 | 545.484 | 555.582 | | CS1 | | 24 | Yes | Yes | |
| | PAET Amorebieta | 559.017 | 555.582 | 562.283 | | ET tipo 1E | | 47 | Yes | Yes | |
| | PCA Zarátamo | 566.595 | 562.283 | 569.351 | | CS1 | | 88 | Yes | Yes | |
| Bilbao-Abando | Bilbao-Abando | 574.086 | 569.351 | 574.524 | Electronic | CS1N | 2025 | 68 | Yes | Yes | Bilbao (Miranda Back up) |
| Bergara Junction | Mondragon Junction | 529.026 | 528.294 | 531.911 | Electronic | CS1N | 2025 | 70 | Yes | Yes | CTC AV (Madrid Back up) |
| | Elorrio Junction | 534.822 | 531.911 | 539.649 | | CS1N | | 96 | Yes | Yes | |
| | Bergara Junction | 537.459 | 531.911 | 541.095 | | ET-Tipo 1 | | 62 | Yes | Yes | |
| Ezkio-Itsaso | PCA Zumárraga | 546.050 | 541.095 | 549.297 | Electronic | CS1 | 2025 | 134 | Yes | Yes | CTC AV (Madrid Back up) |
| | PAET Ezkio-Itsaso | 553.310 | 549.297 | 558.509 | | ET-Tipo 1 | | 360 | Yes | Yes | |
| | PCA Ordizia-Itsasondo | 564.444 | 558.509 | 570.268 | | CS1 | | 224 | Yes | Yes | |
| Tolosa | PBA Tolosa | 573.850 | 570.268 | 576.966 | Electronic Siemens WESTRACE | ET-Tipo 5 | 2005 | 344 | | Yes | CTC AV (Madrid Back up) |
| | PCA Zizurkil | 581.402 | 576.966 | 585.728 | | CS1 | | 779 | | Yes | |
| | PCA Andoain | 588.946 | 585.728 | 591.569 | | CS1 | | 31 | | Yes | |
| | Astigarraga Junction | 596.180 | 591.569 | 619.353 | | CS1 | | 70 | | Yes | |
| San Sebastián | San Sebastián-Donostia Station | | 619.353 | 624.867 | Electronic Siemens WESTRACE | CS | 1969 | 200 | | Yes | Miranda de Ebro |
| Pasajes | Estación Pasajes | 627.890 | 624.867 | 628.957 | Electronic CAF S3E | CS | 2014 | 126 | | Yes | Miranda de Ebro |
| Lezo-Rentería | Lezo-Rentería Station | | 628.957 | 636.074 | Electronic CAF S3E | | 2014 | 185 | | Yes | Miranda de Ebro |
| Irún | Irún Station | 639.650 | 636.074 | | Electronic * Thales | | 2021 | 459 | | Yes | Miranda de Ebro |

*Table 7 Interlockings in Spanish side*

◘Third rail section
◘New platform

Due to the fact that this line is exclusively devoted to high-speed, the ERTMS L2 deployment means that the RBC must be taken into account.

There are some requirements regarding the RBC facilities once they are installed in the line:

- Each RBC controls a maximum number of 30 trains.
- Each RBC are connected to a maximum number of 4 interlocking and 4 collateral RBCs
- Traffic density of trains operating within the RBC control area considering a headway of 2,5 min:
    - High-speed line: 70% of the total amount of trains at a speed of 250 km/h
    - High-speed line: 30% of the total amount of trains at a speed of 200 km/h
    - Access to cities: 100 5 of the total amounts of trains at a speed of 160 km/h

Considering the line under study, the location and the control zone that are projected for each RBC are described in the following table:

| RBC | Electronic Interlocking | Interlocking dependence |
|---|---|---|
| Aramaio | Jundiz | Jundiz |
| | | Vitoria Gauge Change Train |
| | | Vitoria-Gasteiz |
| | Cerio Junction | Cerio Junction |
| | Aramaio | PBA LUKO |
| | | PCA Albertia |
| | | PAET Aramaio |
| Amorebieta | Amorebieta | PBA Abadiño |
| | | PCA Arteako |
| | | PAET Amorebieta |
| | | PCA Zarátamo |
| | Bilbao-Abando | Bilbao-Abando |
| | Bergara Junction | Elorrio Junction |
| | | Mondragon Junction |
| | | Bergara Junction |
| Tolosa | Ezkio-Itsaso | PCA Zumárraga |
| | | PAET Ezkio-Itsaso |
| | | PCA Ordizia-Itsasondo |
| | Tolosa | PBA Tolosa |
| | | PCA Zizurkil |
| | | PCA Andoain |
| | | Astigarraga Junction |
| Irún | San Sebastián | San Sebastián-Donostia Station |
| | Pasajes | Estación Pasajes |
| | Lezo-Rentería | Lezo-Rentería Station |
| | Irún | Irún Station |

*Table 8 RBC at Spanish side*

◘Third rail section
◘New platform

*Table 9 Hot boxers in Spanish side*

# 4 STEP 3: ANALYSIS OF ERTMS DEPLOYMENT SCENARIOS AND PROPOSAL OF ASSOCIATED UNIT COSTS

## 4.1 SCENARIOS FOR ERTMS IMPLEMENTATION

### 4.1.1 Spanish side

In the Spanish side, there are three main zones that are considered within the scope of the study:

- The section between Júndiz freights terminal and the Vitoria-Gasteiz station, which is part of the "Y Vasca".
- The section that forms the very same "Y Vasca" from Vitoria with its connections to Bilbao and Astigarraga-San Sebastián.
- The section between Astigarraga-San Sebastián and Irún.

It is important to notice that these sections are part of an ongoing project within the Atlantic Corridor within the framework of TEN-T. Due to this fact, the development plan is based on the public tenders and the official data provided by Adif, considering the status of the track works.

Regarding the Spanish deployment of the ERTMS, the "Y Vasca", which is the main section that is analyzed, only is equipped with ERTMS level 2, apart from ASFA as degraded mode class B signaling system, which is now the Spanish strategy for equipping High Speed Lines.

It should be noted that both the ERTMS level and the versions are the current ones and have been validated and confirmed by ADIF.

#### *4.1.1.1 Section Jundiz - Vitoria Gasteiz*

The first part of study is the section between Jundiz freight terminal and the Vitoria-Gasteiz station. This connection will be made using the conventional line with 3r rail gauge.

This section works as the link between the "Y Vasca", the conventional line that is used for freight trains and all passenger services that are not part of the HS service, and the future HSL that comes from Madrid through Burgos. This last regard could mean that in the future the CCS may be turn into a Level 2, which may be deduced from the RBC installation, which also integrates the section between Júndiz and Vitoria. In any case, the ERTMS level considered for this study is L1, as the current National Implementation Plan points out, using the baseline 2.3.0.d. Besides, ASFA Digital class B system will be used as backup protection system that will work as a degraded system if ERMS does not work properly.

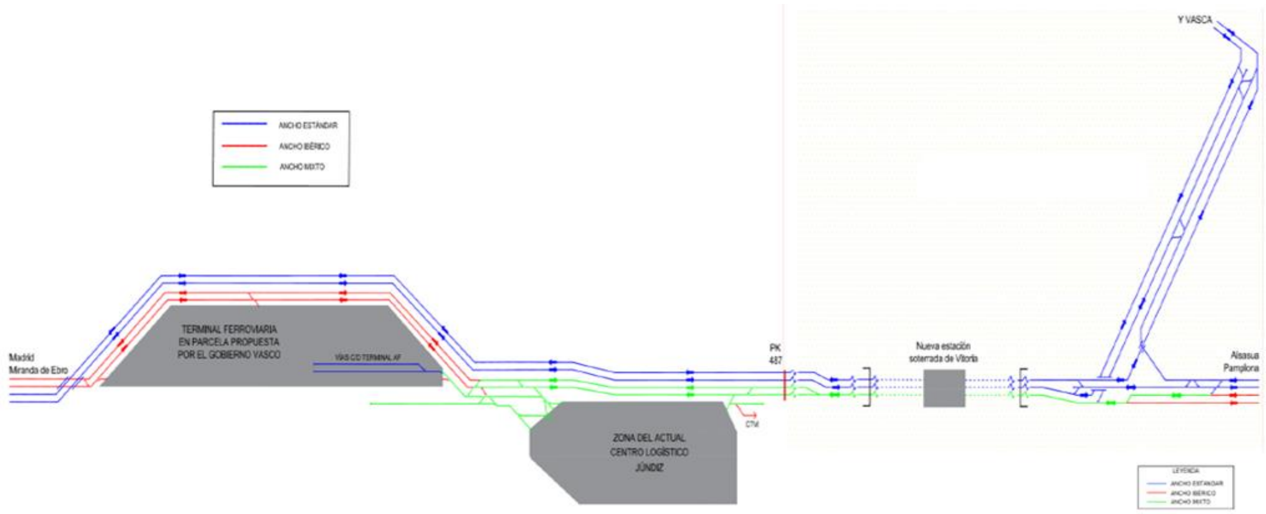


*Figure 11 Júndiz terminal and entrance to Vitoria-Gasteiz station*

#### *4.1.1.2 Y Vasca*

The next section that goes from Vitoria to Astigarraga-San Sebastián and that connects these two cities with Bilbao is called "Y Vasca". It is a HSL that is projected to be used for mixed traffic, passengers and freights, as it was described in the latter section. The design speed makes mandatory to use ERTMS L2 as CCS, using ASFA Digital as backup system again, and the transition balises and the interface between RBCs makes possible the transition from L1. The ERTMS trackside baseline is also 2.3.0.d

The "Y Vasca" is the new high-speed line that connects San Sebastian with Vitoria and Bilbao. In this section ERTMS Level 2 will be implemented with baseline 2.3.0d with ASFA Digital as a backup system.


*Figure 12: Y Vasca layout and the block system installed.*

#### *4.1.1.3 Section San Sebastian Irun*

Finally, the section between San Sebastian and Irun will be carried out with 3rd rail in the same way as the section between Júndiz and Vitoria, except that, in this case, the of level ERTMS to be implemented is L2 baseline 2.3.0.d with ASFA Digital as a backup system.

Regarding the renewal of the trackside elements, block systems and CCS, it is important to underline that the whole area under study is a project that considers the installation of these elements from the scratch. This is because of the line is a new construction facility and, consequently, the signalling system, interlockings, block systems, etc. are considered to be installed as new equipment. Therefore, the renewal costs are not considered, except for the Irún interlocking, which still works with electrical technology and whose update to an electronic interlocking has already been tendered.

To sum up the signalling infrastructure of the Spanish side, it is important to remind that a complete analysis of all the elements that form it is available in Step 1 and 2 report.

### 4.1.2 French side

These days, only French HSL are equipped with ERTMS (East HSL, SEA, BPL in L2, and Nîmes-Montpellier HSL in L1). ERTMS L1 was deployed through the freight corridor Longuyon-Bâle, while L2 is installed in the Paris-Lyon HSL and Marseille-Vintimille line. However, the high costs of the signal boxes and block systems adaptations, and the RBC connection postpone all the ERTMS deployment decisions. Consequently, no decision or choice have been taken regarding the south of Bordeaux. However, the Bordeaux node is one of the priority nodes declared by the Ministry, without any forecasted date.

The French ERTMS deployment strategy is the installation of ERTMS level 2, withdrawing the lateral signalling and class B system, except if some local conditions justify level 1, which has to be economically and technically justified.

Regarding the scope of the present study, this strategy leads to proposing a first layer scenario consisting of ERTMS L2 deployment on the entire French lines within the studied area.

#### *4.1.2.1 Scenario 1:*

A L2 deployment on the Bordeaux Hendaye section without lateral signaling. Exceptions are made for.

- Bordeaux node between HSL SEA end and the connection with Medoc line, where KVB and lateral signals are to be kept for a while, so that regional trains to North of Bordeaux and Medoc will not have to be retrofitted with EVC.
- Bayonne node between the station and Mousseroles junction zone (connection of Puyoo and St Jean Pied de Port lines), where KVB and lateral signals are to be kept, so that regional trains for the two specific destinations have not to be retrofitted until their replacement.

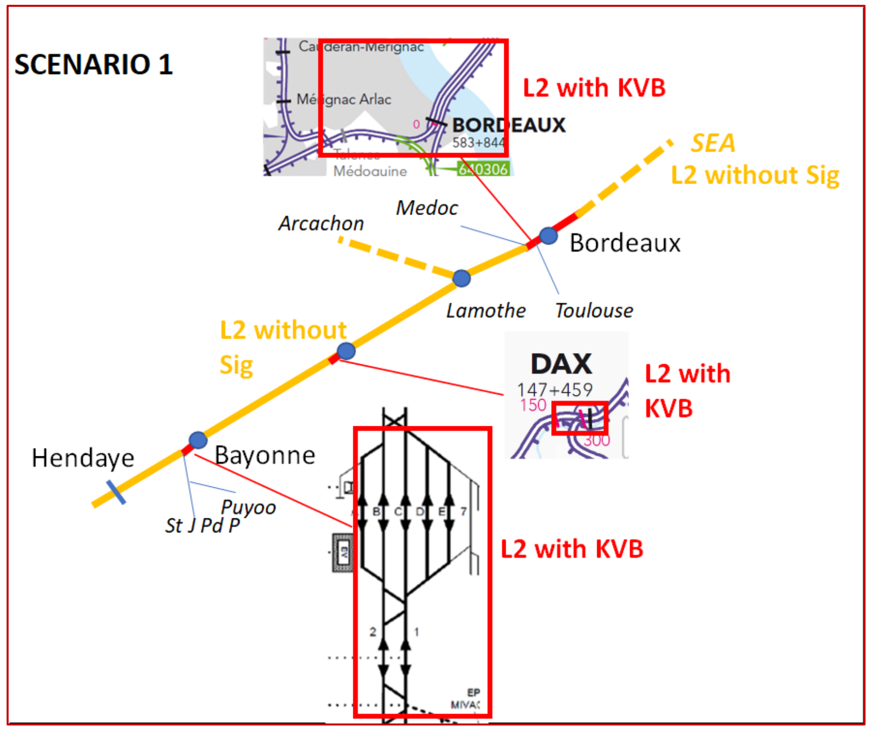



*Figure 13: ERTMS deployment on French side (scenario1)*

This scenario with a global level 2 implementation on the Bordeaux Hendaye section will require replacing all existing signalling boxes, except one electronic interlocking in St Vincent de Tyrosse, and the retrofit of all the regional rolling stock. Therefore, it is decided to propose to the EEIG the comparison with an alternative scenario based on L1 implementation instead of L2.

#### *4.1.2.2 Scenario 2 (variant)*

A L1 deployment on the Bordeaux- Lamothe (separation with the line to Arcachon) section, and a L2 deployment on the Bordeaux node between the end of SEA HSL in the North, and Lamothe The main advantage of this strategy is that the former signal boxes are kept, considering their long lifespan, as well as so is the block system. The L2 would be progressively implemented depending on the renewal dates of all signaling components, beginning around 2045-2050.

The Bordeaux Node is equipped with double system ERTMS L2 + KVB and lateral signaling.

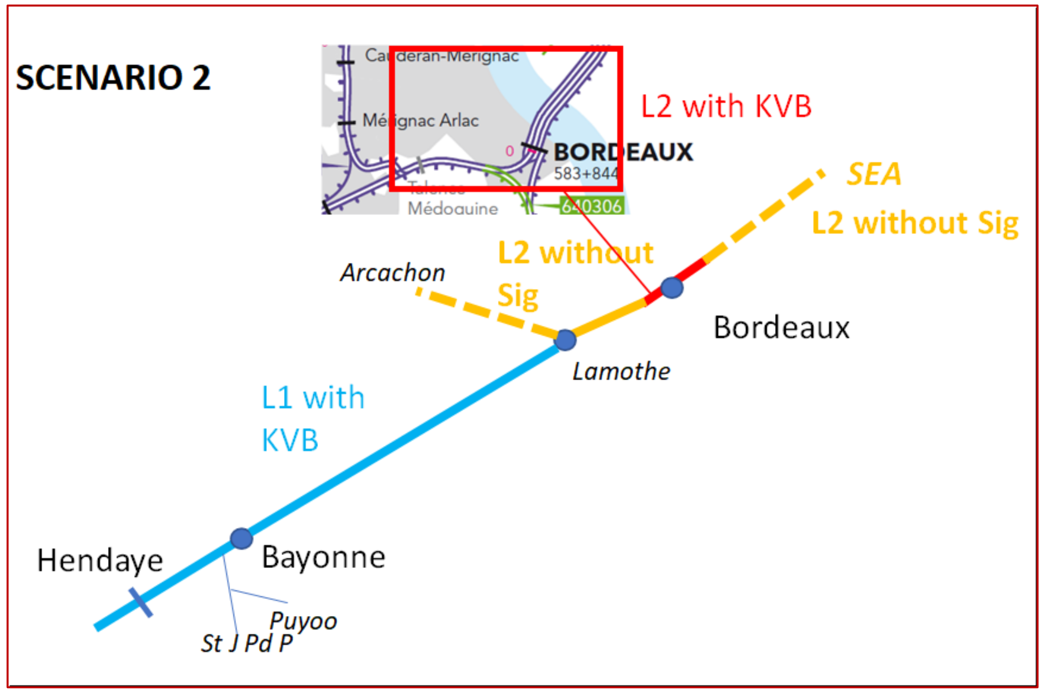



*Figure 14: ERTMS deployment on French side (scenario2)*

### 4.1.3 Border section

Both Spanish and French experts agreed that L1 implementation represents a fast, simple and safer deployment. L2 management is already demonstrated, but it will be more difficult to implement on the French side, where the Hendaye signal box is still an electrical and NS1 technology system (PRG). Some questions at the border are:

- The management of the temporary speed limitation in transitions from L2 to L1.
- The protocol of the trains transferred from one country to another.
- The communications between control centres.
- The difference of ETCS baseline versions between the two countries.

However, if L2 finally is the system chosen in France and Spain (scenario 1), ERTMS L2 is propose.
In case of the scenario 2, with L1 between Hendaye and Lamothe, would be chosen, ERTMS L1 will be also implemented in the border section.

### 4.1.4 Synthesis

#### 4.1.4.1 Scenario 1

The following diagram features the overall deployment plan as proposed for scenario 1 on the studied perimeter.

The ERTMS versions are for this case:

- Baseline 2.3.0.d at the Spanish side
- Baseline 3.6.0 at French side and border section

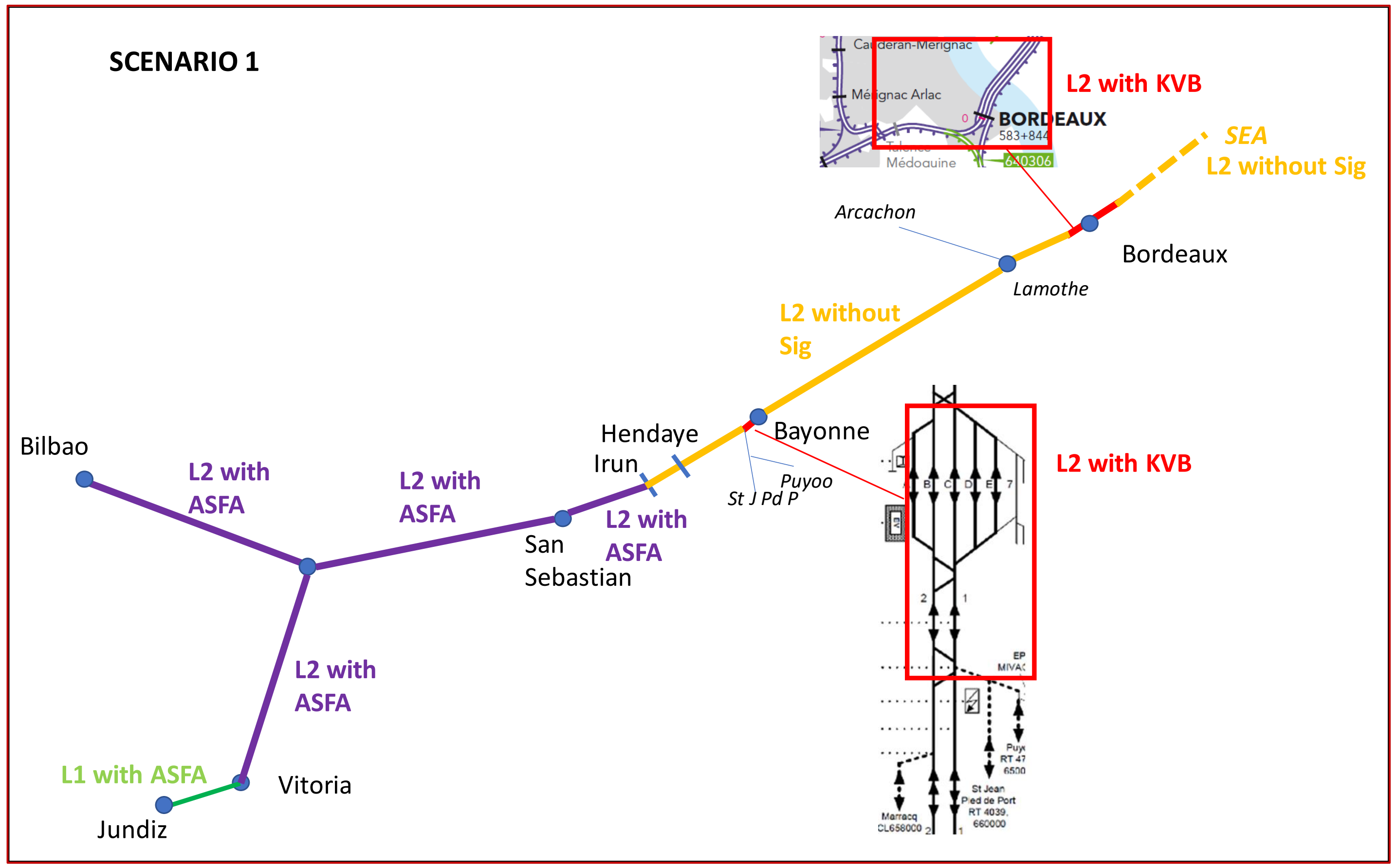



*Figure 15: Global ERTMS deployment (scenario1)*

#### 4.1.4.2 Scenario 2

The following diagram features the overall deployment plan as proposed for scenario 2 on the studied perimeter.

The ERTMS versions are for this case:

- Baseline 2.3.0.d at the Spanish side
- Baseline 3.6.0 at French side on L2 section
- Baseline 2.3.0 d at French side on L1 section

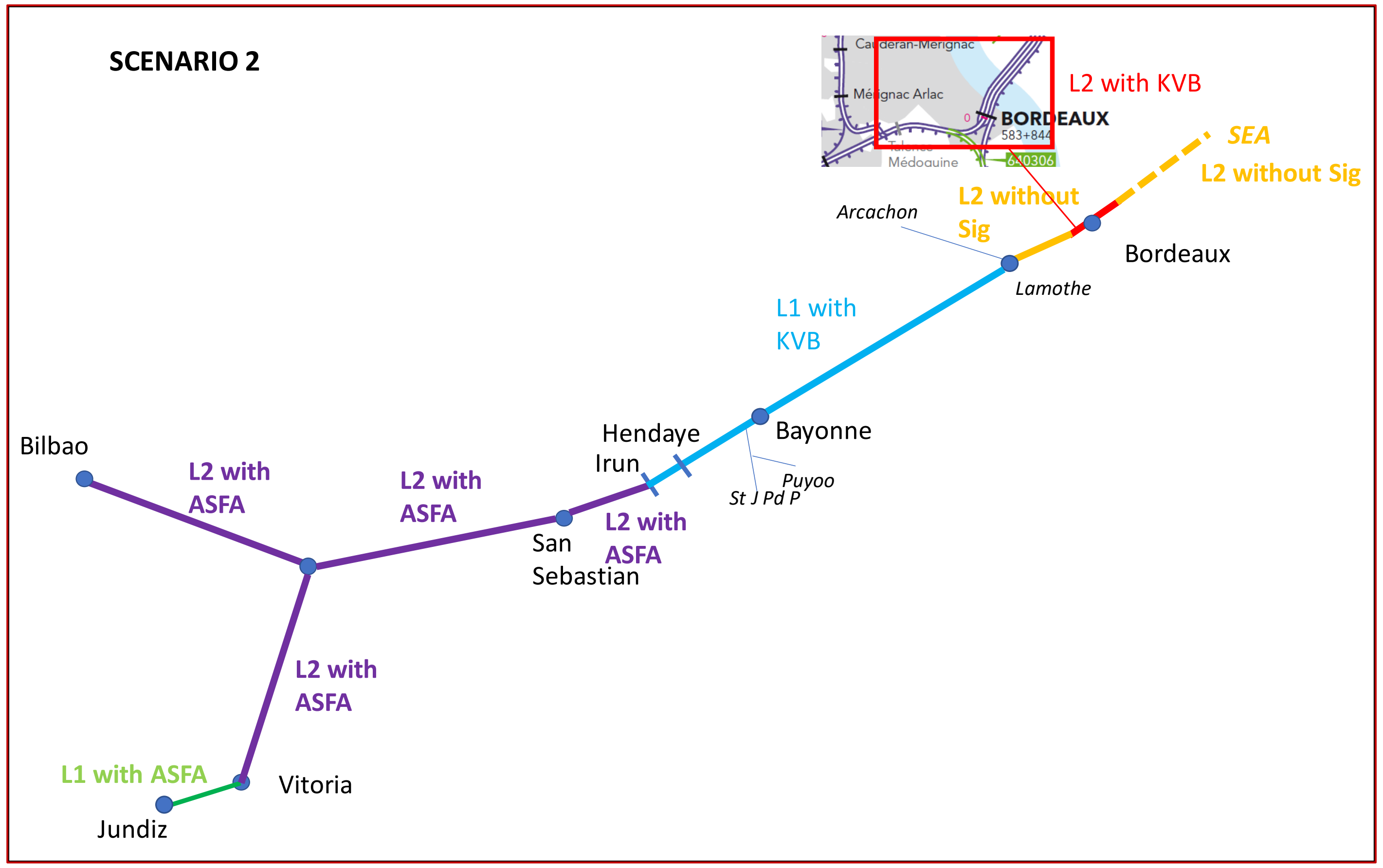



*Figure 16: Global ERTMS deployment (scenario2)*

## 4.2 Technical analysis of ERTMS deployment

### 4.2.1 French technical deployment

#### *4.2.1.1 Situation of technical homologations*

Currently, only the following situations have been approved in France:

- ETCS L1 with connection to the PLx (LEU connected to "TOR NS1 and S2" logic inputs and "lamp" inputs):
  - No direct connection to the interlockings whatever their technology is (same for BAL system).
  - This provision is explained by the fact that the "block" constitutes an independent layer from the adjacent interlockings and is locally managed with the track circuits and links from signalling centre to signalling centre. It is, therefore, not possible to centralize block information at the level of a signal box, unlike in Germany and Spain. The centralization of block information requires replacing all conventional automatic block equipment by a “digital block” installation. This is now the provision implemented on signalling renewals to allow subsequent migration to N2.
  - Regarding the strategy of SNCF engineering, given the really high costs (~ 190k€ per signal on average at the overall project level on the REX Longuyon-Basel), then the deployment of ETCS must be performed in level 2 without lateral signalling.
    ETCS level 1 is not in the French policy anymore, however it can be studied only for special and limited cases. Nonetheless, a comparison between all the points of view (technical, CAPEX, OPEX, Maintainability, implementation, etc.) must be done with the L2, before choosing this scenario.
- ETCS L2 is planned only for HS lines with connection to the RBC to the SEI and connection to the LEU for the switchable beacons to the same SEI. No. "nodal" interlocking has been approved to date for conventional lines. On the other hand, ARGOS technology is under development to be able to "connect" to the future RBCs. The first ARGOS signal boxes will be operational in 2023.

#### *4.2.1.2 Actual ERTMS implementation in France*

The ERTMS implementation in France is summarized in the following table with indication of Baselines:

| Line | ETCS level | Baseline |
|---|---|---|
| Paris-Lyon HSL under study | L2 + TVM in backup until 2030, then L2 | V3.6.0 |
| BPL, SEA, 2nd phase of East European HSL (EE HSL from Baudrecourt to Strasbourg) | L2 + TVM in backup until 2030, then L2 | V3.6.0 |
| Longuyon-Basel | L1 (+KVB) | V2.3.0.d |
| HSL CNM (Nîmes Montpellier) | L1 + KVB (migration to L2 with speed increase to 300 km/h in medium term) | V2.3.0.d |

*Table 10 ERTMS implementation in France*

The baseline 2.3.0.d is the reference, since it is designed to be compatible with ETCS baseline 3 installed on board taking into account in the design the BCA Report issued by EUAR.

The level 2 will be implemented in the version V3.6.0.

#### *4.2.1.3 Argos interlocking system.*

The ETCS deployment strategy on the RFN consists of developing an “Argos” RBC, which can only be connected to the interlockings PAI Argos and PAI 2006 stations. It is not planned to be able to connect to older interlocking technologies. This choice involves replacing all or part of the signal boxes between Bordeaux and Hendaye except some PAI 2006, which can be interfaced.

This decision to develop new principles makes possible to evolve towards fully computerised products allowing product standardization, shorter testing and commissioning processes, and ultimately significant economies of scale. Consequently, all French signal boxes will be renewed from 2024, deploying this ARGOS interlocking technology, which is more flexible, adapted to ETCS, since the RBCs will be developed on the same IT platform. Three manufacturers have been selected for the development phase, homologation + heads of series.

Therefore, the simulations of this study are carried out based on centralized ARGOS technology.

##### 4.2.1.3.1 Block system

The digital block, developed in 2019 and based on PAI ARGOS type interlocking products, will be implemented with homogeneous products between interlocking and Block with similar L1 (Layer 1) and L2 (Layer 2) modules. This allows significant cost reductions with easier migration to ETCS.

In order to facilitate the implementation of ARGOS interlocking and blocks, the principle of installing axle counters will be generalized (possibility of double running, elimination of Y provisional situations, and outsourcing, with extra costs for broken rail detection).

#### *4.2.1.4 Telecommunication*

The GSM-R system in its conventional configuration does not hold the necessary capacity for information exchange between track and on board in ERTMS L2 technology. Therefore, it is necessary to establish double coverage in ERTMS L2 corresponding to the following diagram with two BTS per radio centre:

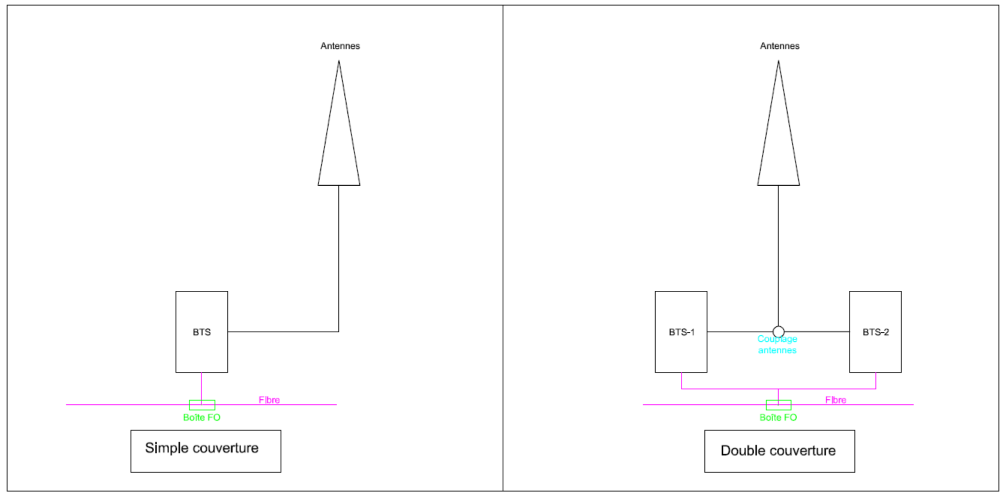



*Figure 17: GSM-R reinforcement diagram*

In some specific cases, such as dense areas, where the number of instant communications exceed GSM-R capacity a migration to GPRS, will be necessary. For example, Bordeaux node will be critical and require such a migration.

### 4.2.1.5 Reference situation for Bordeaux Hendaye section

#### 4.2.1.5.1 Lifespan of signal boxes, block, and computer layers

According to the last renewal trajectories defined by SNCF engineering for 2020, the approved lifespans considered for the study are summarized below:

| Interlocking technology | Middle life intervention | Total renewal for reference situation |
|---|---|---|
| Mechanical or electromechanical P et NP | - | If “Pérenne” no renewal of interloc<br>Trackside equipments renewal each |
| Electrical S1 | - | 60 years |
| Electrical NS1 | - | 65 years |
| Electrical with computer command | 30 years | 60 years |
| Computer interlocking | 25 years | 50 years |

*Table 11 Lifespan of signal boxes, block and computer layers*

| Conventional block (BAL) | Middle life intervention | Total renewal |
|---|---|---|
| BAL (block automatique lumineux) | No | 55 – 60 years (renewal in digital block) |

| Computer layers technology | Middle life intervention | Total renewal |
|---|---|---|
| MISTRAL | 15 years | 30 years |

For the scope of the study, the dates of renewal for block and signal boxes are summarised in the following tables:

| SECTION | COMMISSIONNING DATE | MODERNISATION DATE | BLOCK | FORECASTED REGENERATION DATE |
|---|---|---|---|---|
| LA GRAVE D'AMBARES / BORDEAUX-SAINT-JEAN | 1951 | 1990 | BAL | 2040 |
| BORDEAUX-SAINT-JEAN / LAMOTHE | 1936 | 1970 | BAL | 2026 |
| LAMOTHE / LUGOS | 1984 | - | BAL | 2047 |
| LUGOS / YCHOUX | 1975 | 1984 | BAL | 2044 |
| YCHOUX / LABOUHEYRE | 1982 | - | BAL | 2046 |
| LABOUHEYRE / MORCENX | 1981 | - | BAL | 2044 |
| MORCENX / DAX | 1979 | - | BAL | 2042 |
| DAX / BAYONNE | 1997 | - | BAL | 2034 |
| BAYONNE / BIARRITZ | 1987 | 1998 | BAL | 2057 |
| BIARRITZ / HENDAYE | 1989 | 1999 | BAL | 2053 |
| HENDAYE / IRUN | 1969 | 1986 | BAL | 2046 |

*Table 12 situation of block sections and renewal dates for the reference situation*

| Name of the signal boxes | PK | Type | Number of objects | AU | Commissioning | Reference Renewal horizon | ARGOS Compatible |
|---|---|---|---|---|---|---|---|
| Bassens Poste 1 | 574 622 | PRSI NS1 | 22 | - | 1975 | 2040 | |
| Cenon poste bif | 579 859 | PRSI NS1 | 23 | - | 2008 | 2073 | |
| Bordeaux St Jean poste 1 | 230 | PRSI NS1 | 160 | 9 | 1980 | 2045 | |
| Talence-Médoquine Poste 5 | 4 194 | PRCI NS1 | 22 | 1 | 2002 | 2062 | |
| Gazinet-Cestas Poste 6 | 13 416 | PRCI NS1 | 20 | 4 | 2002 | 2062 | - |
| Facture-Biganos Poste 1 | 38 950 | MU45 | 18 | - | 1956 | 2038 | - |
| Lamothe | 42 062 | PML NS1 | 25 | - | 1998 | 2062 | - |
| Morcenx Poste 1 | 108 542 | PRG NS1 | 33 | 3 | 1985 | 2050 | - |
| Laluque P72 | 133 738 | PRSI NS1 | - | 3 | 2015 | 2075 | |
| Dax Poste 1 | 147 449 | PRG NS1 | 47 | 1 | 1997 | 2062 | |
| St Vincent de Tyrosse Poste 75 | 170 400 | PAI 2006 | 8 | - | 2010 | 2062 | Yes |
| Bayonne Poste 3 | 197 380 | EMU | 25 | - | 1954 | 2038 | - |
| Bayonne Poste 4 | 197 555 | PRG NS1 | 35 | 1 | 1987 | 2050 | - |
| Biarritz Poste 1 | 207 291 | PRG NS1 | 28 | 3 | 1981 | 2046 | - |
| St-Jean-de-Luz-Ciboure Poste 1 | 220 393 | PML NS1 | 10 | - | 1989 | 2054 | - |
| Hendaye Poste 1 | 232 219 | MU 45 + PRG NS1 | 27 | - | 1997 | 2062 | - |
| Hendaye Poste 4 | 233 149 | EMU | 42 | - | 1966 | 2034 | - |

*Table 13 situation of signal boxes and renewal dates for the reference situation*

The renewal dates of the block come from the maintenance department of SNCF Réseau and the renewal dates of the signal boxes are from the development department of SNCF Réseau.

#### 4.2.1.5.2 Synthesis

Based on the precedent analysis, the reference situation is described in the following diagram.

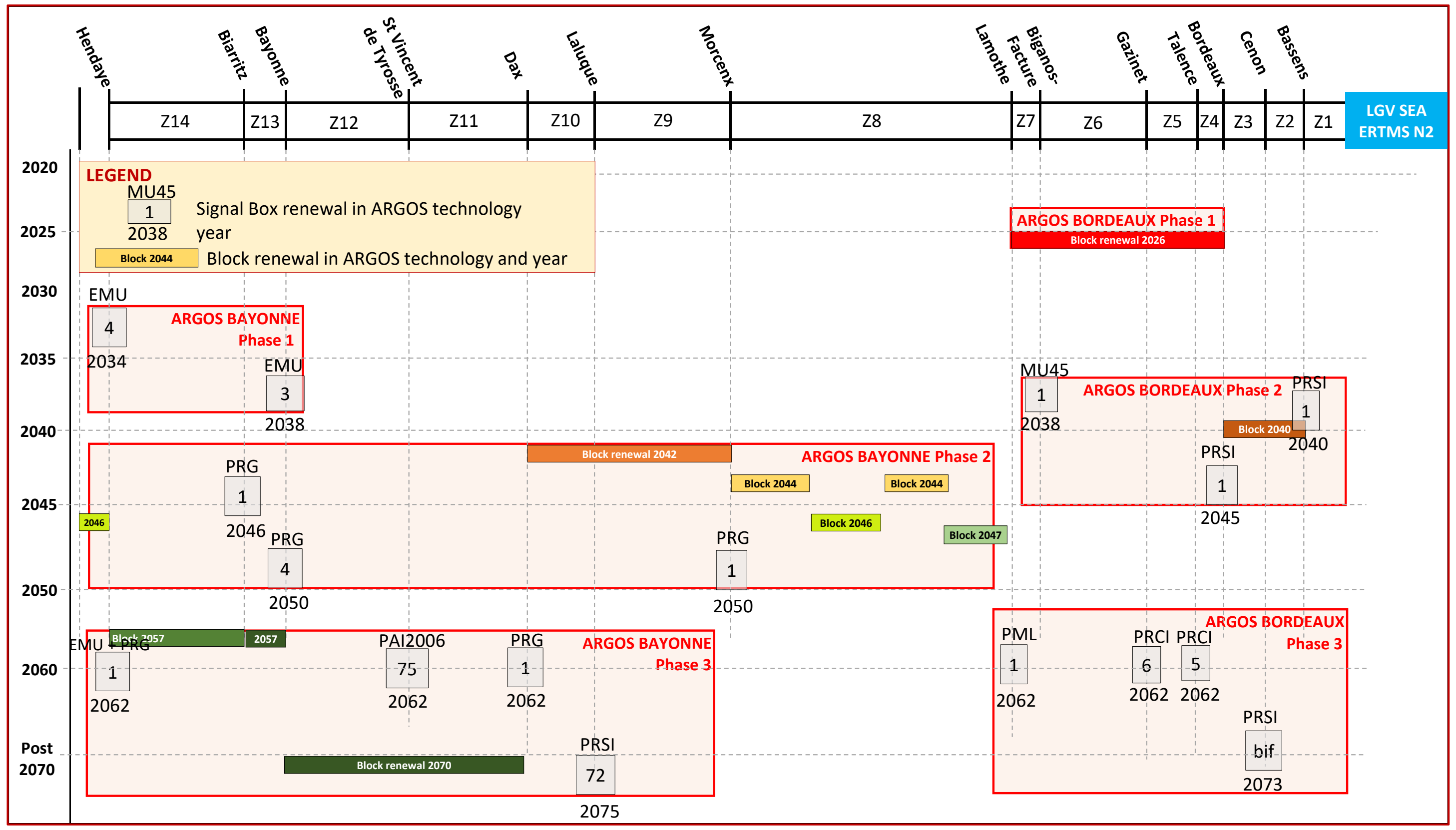



*Figure 18: Natural renewal of the block and signal boxes (reference situation)*

All block sections are renewed by digital technology. If renewed in Argos before the signal box, they constitute the first step of ARGOS implementation and a first L1 module is installed in the ARGOS L1 farm. All signal boxes are renewed in Argos technology at their natural date of regeneration. The Argos L1 farm is located in Bordeaux.

#### 4.2.1.6 Project scenario 1: ERTMS L2 implementation on the whole French section

##### 4.2.1.6.1 Description

**This scenario consists of ERTMS L2 implementation without lateral signals on the whole section.**

Some exceptions are admitted on some small section (2 or 3 km) where L2+ KVB + lateral signals will be installed to allow the rolling stock to run without ETCS on board. These sections are:

- Bordeaux St Jean Talence for the TER to Médoquine.
- Common section with the Dax Puyoo line.
- Section Bayonne Mouguerre for the connection with Toulouse.

SNCF Reseau wants to outline that there is no specification on the L2+KVB+lateral signals so far, and the corresponding cost for the definition and specification of this double system (ERTMS + class B) will be added.

In this scenario, L2 will be also forecasted on the Lamothe-Arcachon section, but this is out of the study scope.

**The date chosen for ERTMS implementation is 2029 for RBC 1 zone (Bordeaux) and 2030 for RBC 2 zone (Bayonne).** For some recent installed signal boxes, it appears that **the L3 layer constituted by on track equipment can be maintained if its residual life span exceeds 30 years.** These specific provisions are detailed in the following table:

| Name of the signal boxes | Type | Number of objects | AU | Commissioning | Renewal horizon | Residual lifespan for L3 layer in 2030 (years) | ARGOS Compatible |
|---|---|---|---|---|---|---|---|
| Bassens Poste 1 | PRSI NS1 | 22 | - | 1975 | 2030 | 10 | |
| Cenon poste bif | PRSI NS1 | 23 | - | 2008 | 2030 | 43 | |
| Bordeaux St Jean poste 1 | PRSI NS1 | 160 | 9 | 1980 | 2030 | 15 | |
| Talence-Médoquine Poste 5 | PRCI NS1 | 22 | 1 | 2002 | 2030 | 32 | |
| Gazinet-Cestas Poste 6 | PRCI NS1 | 20 | 4 | 2002 | 2030 | 32 | - |
| Facture-Biganos Poste 1 | MU45 | 18 | - | 1956 | 2030 | 38 | - |
| Facture-Biganos Poste 1 Lamothe | PML NS1 | 25 | - | 1998 | 2030 | 33 | - |
| Morcenx Poste 1 | PRG NS1 | 33 | 3 | 1985 | 2030 | 20 | - |
| Laluque P72 | PRSI NS1 | - | 3 | 2015 | 2030 | 45 | |
| Dax Poste 1 | PRG NS1 | 47 | 1 | 1997 | 2030 | 32 | |
| St Vincent de Tyrosse Poste 75 | PAI 2006 | 8 | - | 2010 | 2060 | 30 | Yes |
| Bayonne Poste 3 | EMU | 25 | - | 1954 | 2030 | 8 | - |
| Bayonne Poste 4 | PRG NS1 | 35 | 1 | 1987 | 2030 | 22 | - |
| Biarritz Poste 1 | PRG NS1 | 28 | 3 | 1981 | 2030 | 16 | - |
| St-Jean-de-Luz-Ciboure Poste 1 | PML NS1 | 10 | - | 1989 | 2030 | 24 | - |
| Hendaye Poste 1 | MU 45 + PRG NS1 | 27 | - | 1997 | 2030 | 32 | - |
| Hendaye Poste 4 | EMU | 42 | - | 1966 | 2030 | 4 | - |

*Table 14 situation of signal boxes and specific provisions for the scenario 1 situation (in yellow the signal boxes with L3 layer maintained, residual lifespan > 30 years)*

##### 4.2.1.6.2 Synthesis

Based on the precedent analysis, the situation for scenario 1 is described in the following diagram.

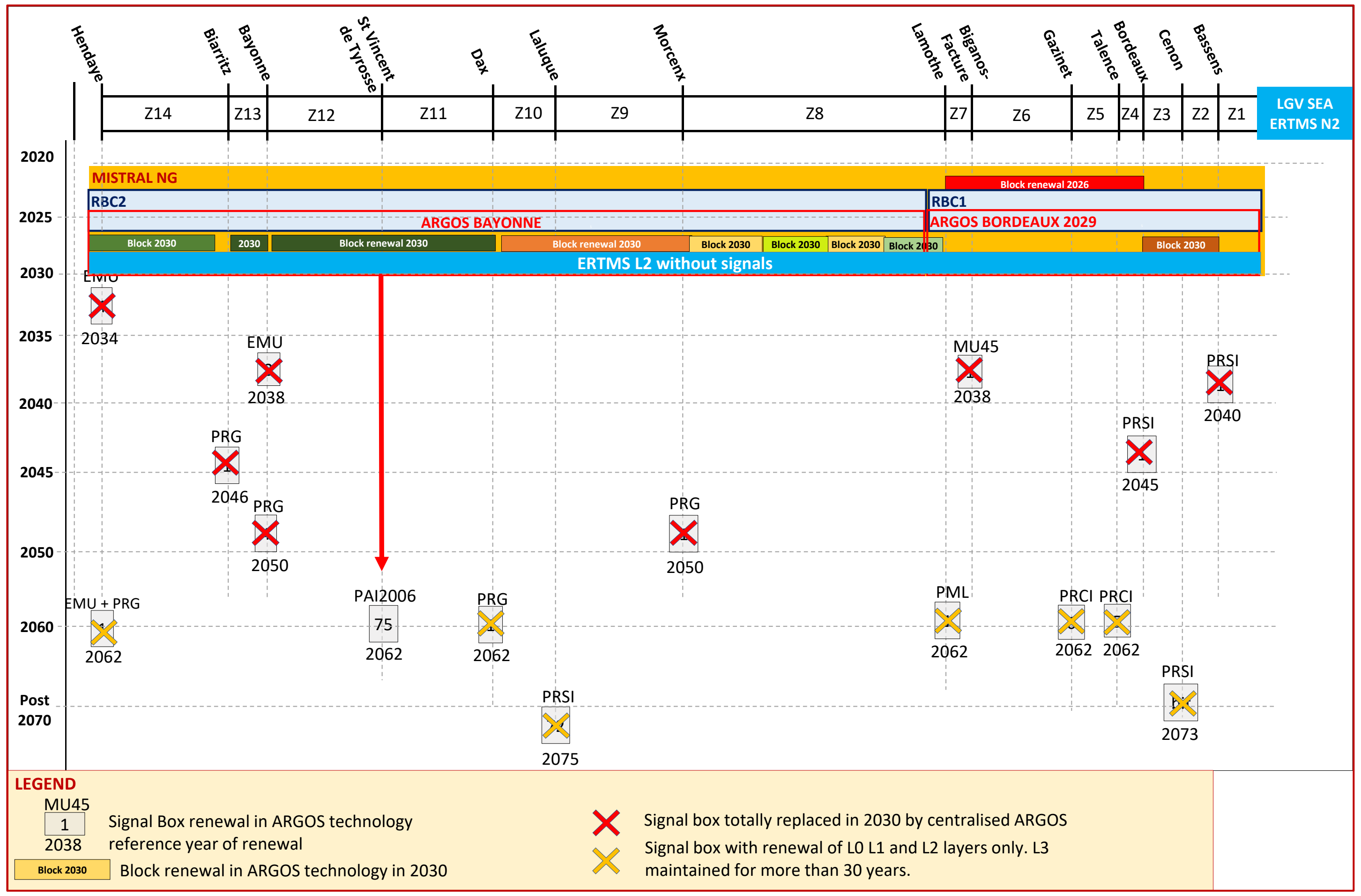



*Figure 19: ERTMS implementation in scenario 1*

**All block sections are renewed in Digital technology in 2030 because it is mandatory for ERTMS L2. All signal boxes are renewed in Argos technology for 2030 except the ST Vincent signal box (P75 PAI 2006 compatible with ARGOS).** The Argos L1 farm is located in Bordeaux. HMI Mistral NG is deployed within the scope.

#### 4.2.1.7 Project scenario 2: implementation of ERTMS L2 on North section and ERTMS L1 on South section

##### 4.2.1.7.1 Description

**This scenario represents one variant of the precedent, whose characteristics are:**

- ERTMS L2 is installed on the section between SEA connexion and Lamothe without lateral signalling in all sections, except for the Bordeaux node, where double system is maintained (ERTMS L2 + class B KVB system and signals between Bordeaux St Jean Talence for the TER to Médoquine).
- ERTMS L1 without class B system will be installed on the Lamothe-Hendaye section except Bayonne zone.
- ERTMS L1+Class B KVB and signals system will be installed on the Bayonne zone (Bayonne station and Bayonne Mousseroles section).

The choice of ERTMS L2 for SEA Lamothe section is justified by the following elements:

- Renewal of the block in 2023 on the main part.
- Density of the traffic.
- Connexion to the HSL SEA.
- Connexion to Arcachon via Lamothe (direct train from Paris).

**SNCF Réseau reminds that standards on ERTMS Level 1 + Digital block or ERTMS Level 1 + Argos does not exist yet.** They pointed out that if Level 1 is installed, then there is no possibility of an ATO improvement.

For this scenario, the signal boxes between SEA and Lamothe are the only ones concerned by an anticipated renewal in 2030.

| Name of the signal boxes | Type | Number of objects | AU | Commissioning | Renewal horizon | Residual lifespan for L3 layer in 2030 (years) | ARGOS Compatible |
|---|---|---|---|---|---|---|---|
| Bassens Poste 1 | PRSI NS1 | 22 | - | 1975 | 2030 | 10 | |
| Cenon poste bif | PRSI NS1 | 23 | - | 2008 | 2030 | 43 | |
| Bordeaux St Jean poste 1 | PRSI NS1 | 160 | 9 | 1980 | 2030 | 15 | |
| Talence-Médoquine Poste 5 | PRCI NS1 | 22 | 1 | 2002 | 2030 | 32 | |
| Gazinet-Cestas Poste 6 | PRCI NS1 | 20 | 4 | 2002 | 2030 | 32 | - |
| Facture-Biganos Poste 1 | MU45 | 18 | - | 1956 | 2030 | 38 | - |
| Facture-Biganos Poste 1 Lamothe | PML NS1 | 25 | - | 1998 | 2030 | 33 | - |
| Morcenx Poste 1 | PRG NS1 | 33 | 3 | 1985 | 2050 | ERTMS L1 | - |
| Laluque P72 | PRSI NS1 | - | 3 | 2015 | 2075 | | |
| Dax Poste 1 | PRG NS1 | 47 | 1 | 1997 | 2062 | | |
| St Vincent de Tyrosse Poste 75 | PAI 2006 | 8 | - | 2010 | 2060 | | Yes |
| Bayonne Poste 3 | EMU | 25 | - | 1954 | 2038 | | - |
| Bayonne Poste 4 | PRG NS1 | 35 | 1 | 1987 | 2052 | | - |
| Biarritz Poste 1 | PRG NS1 | 28 | 3 | 1981 | 2046 | | - |
| St-Jean-de-Luz-Ciboure Poste 1 | PML NS1 | 10 | - | 1989 | 2054 | | - |
| Hendaye Poste 1 | MU 45 + PRG NS1 | 27 | - | 1997 | 2062 | | - |
| Hendaye Poste 4 | EMU | 42 | - | 1966 | 2034 | | - |

*Table 15 situation of signal boxes and specific provisions for the scenario 2 situation (in yellow the signal boxes with L3 layer maintained, residual lifespan > 30 years)*

##### 4.2.1.7.2 Synthesis

Based on the precedent analysis, the situation for scenario 2 is described in the following diagram.

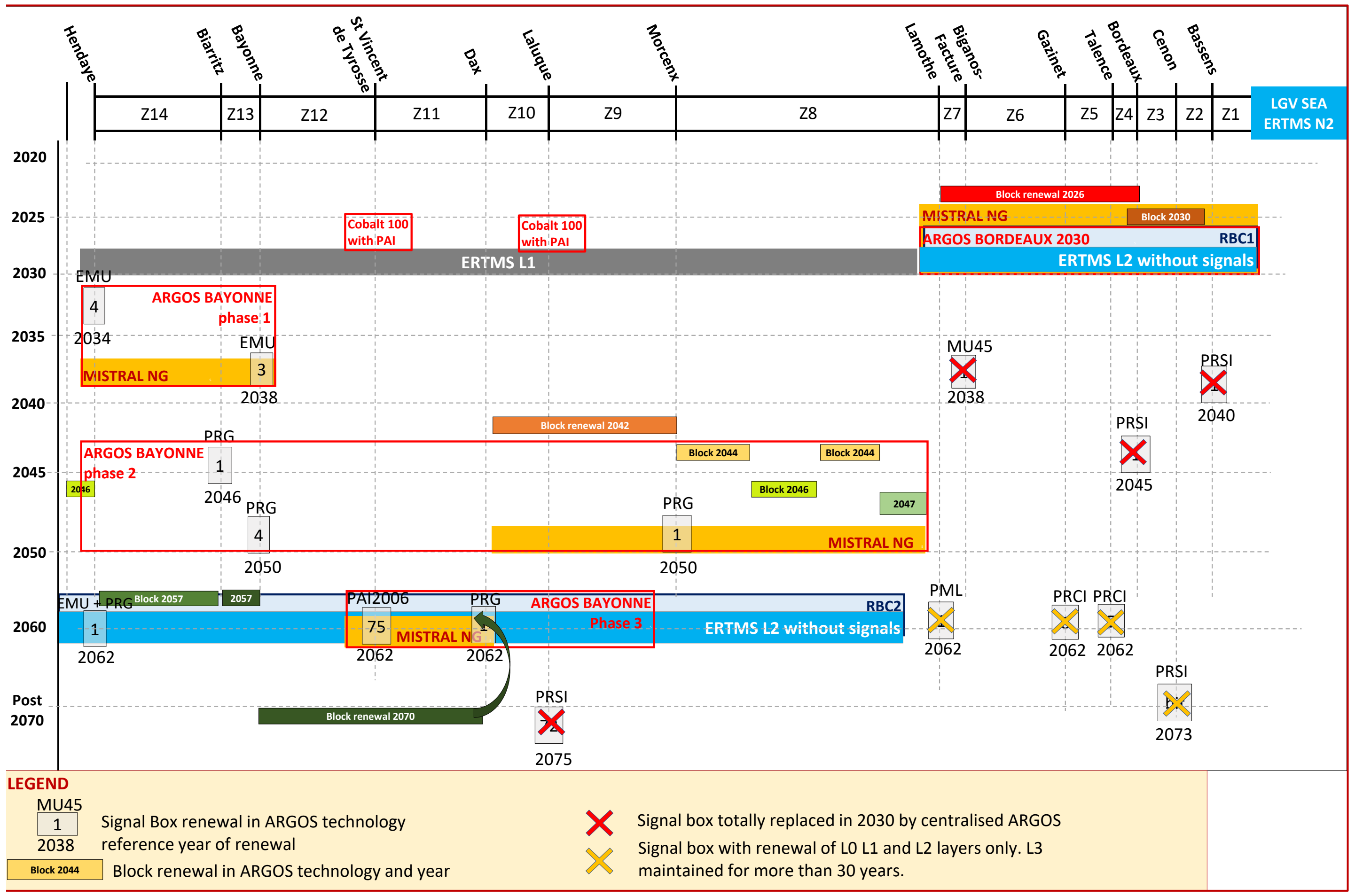



*Figure 20: ERTMS implementation in scenario 2*

All block sections are renewed in Digital technology. ERTMS L2 will be installed in 2030 between SEA connexion and Lamothe, besides all signal boxes will be renewed in Argos technology before 2030 on this section. Between Lamothe and Hendaye, ERTMS L1 is installed and signal boxes are renewed at their natural date of regeneration. When all signal boxes will have been renewed on this zone except Laluque ERTMS L2 will be likely installed in 2062 (32 years after ERTMS L1) in substitution of ERTMS L1. HMI Mistral NG will be deployed progressively on the whole perimeter. Laluque signal box is therefore anticipated from 2075 to 2062.

### 4.2.2 Spanish Technical deployment

The Spanish ERTMS future deployment is fully described in the official document submitted by the Government of Spain in 2017. This document contemplated the ERTMS deployment through the Spanish rail lines, the considered ERTMS baselines, the rolling stock retrofit, the ERTMS level that is planned for each line, etc.

#### 4.2.2.1.1 Signaling system architecture

Regarding the signalling system architecture, the provides a simplified block diagram of the system that helps to understand the architecture of the signalling system, whose security core is the electronic interlocking (ENCE).

The establishment of a route and the communication of the corresponding authorization of movement are basically carried out in six steps:

1. The traffic operator requests the assignment of the desired route to the train it controls. This operation is generally carried out automatically by the circulation control system.
2. The request is communicated to the interlocking that verifies the status of the section of track that corresponds to the requested route (busy / free).
3. If the track circuits corresponding to the section indicate that the requested route is free, the interlock activates the motors required to establish the route. The road segments that make up the trajectory are blocked from being assigned to other routes.
4. When the motors for positioning the needles have finished their movement, the end of stroke sensors indicate that the position of the needles has been established according to the path.
5. Once the path is established and blocked, the interlock actuates the affected signals so that they show the aspect corresponding to the assigned path.
6. The interlocking communicates to the operation centre that the requested route is established, and the track section is blocked and assigned to the controlled train.

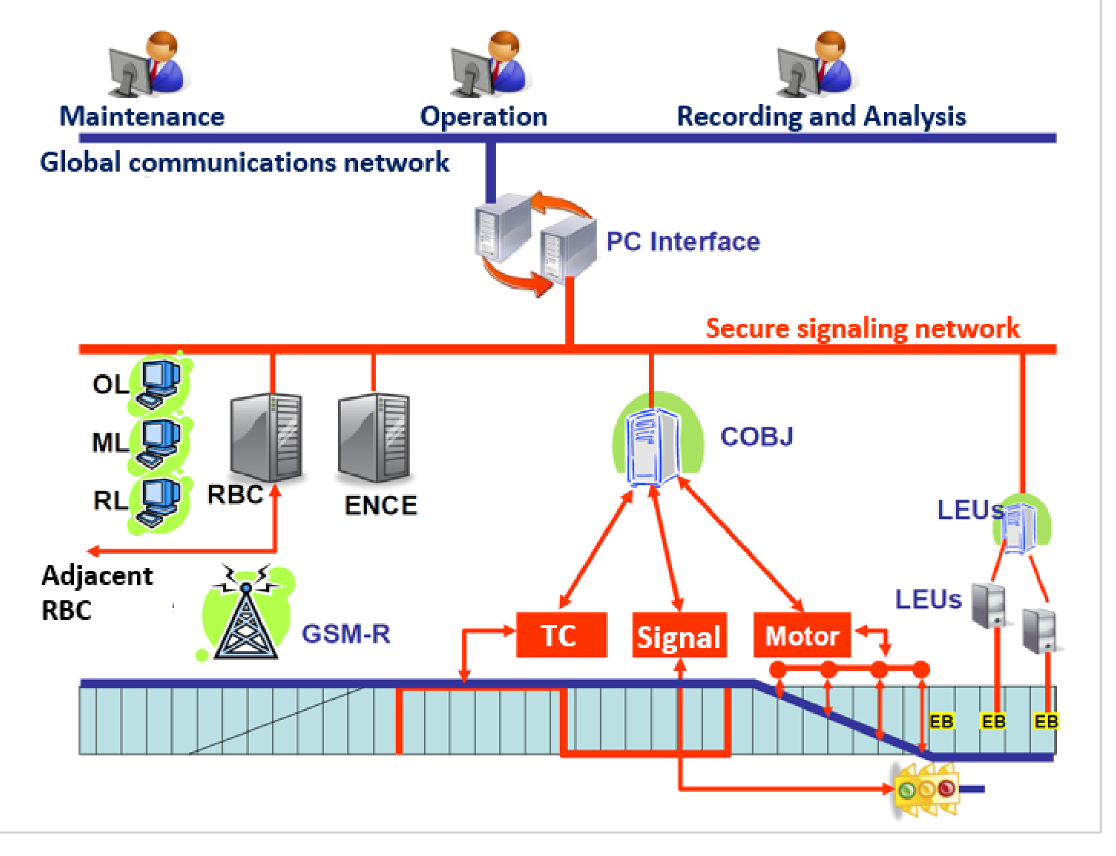



*Figure 21. Architecture and hierarchy of Spanish ERTMS deployment*

This figure introduces the trackside elements, which are developed under below, and the RBC, which is explained in the next section.

- Lateral signaling

Lateral signalling is necessary for the proper train protection and spacing. ASFA Spanish national systems connected to these light signals formed by LED diodes through the "Y Vasca".

- ASFA and ETCS balises

The ASFA balises lied on the track that is part of the main line 100. Part of this line will be part of the Corridor, where the third rail will allow UIC gauge rolling stock to operate through it. As the trackside ETCS must be installed in these sections, it is important to know where these balises are located, in order to make the most of the current facilities and build balise groups (ASFA and Euro balises) with a reduce budget. The ASFA and ETCS balises must be placed respecting the functional and technical engineering rules developed by Adif.

- Track occupancy devices

Since ERTMS L2 and the fall-back protection systems need these devices to be able to keep track of the exact position of the trains, it is necessary to collect the information regarding this kind of devices and their connection with the interlocking. For those sections that possess third rail, the technology that is used will be axle counters, due to the shortcut caused by this third rail. For the rest of the facility, track circuits based on audio frequency are used.

- Operation mechanisms

The interlocking system also needs to interface to those mechanisms that allow to perform the turnouts triggering. It is necessary that the technology that controls these devices are able to connect themselves with the CTC.

- GSM-R and RBC

This technology allows to communicate rolling stock and trackside via radio technology using a range of frequencies that are reserved only for railway technology. Besides, GSM-R is formed by several layers in order to increase the security of communications.

RBC subsystems keep track of the location of the trains within a block, interfaces to neighbouring RBCs and to the interlockings that control its area to get route information and generates movement authorities, which are sent back to them via GSM-R.

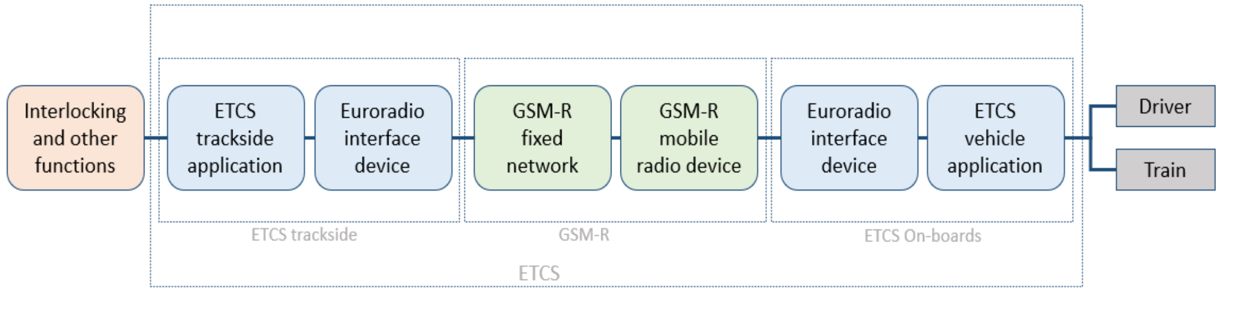



*Figure 22 GSM-R and RBC architecture within the ERTMS*

There are some requirements regarding the RBC facilities once they are installed in the line:

- Each RBC controls a maximum number of 30 trains.
- Each RBC is connected to a maximum number of 4 interlocking and 4 collateral RBCs

Considering the line under study, the location and the control zone that are projected for each RBC are described in the following table:

| RBC | Electronic Interlocking | Interlocking dependence |
|---|---|---|
| Aramaio | Jundiz | Jundiz |
| | | Vitoria Gauge Change Train |
| | | Vitoria-Gasteiz |
| | Cerio Junction | Cerio Junction |
| | Aramaio | PBA LUKO |
| | | PCA Albertia |
| | | PAET Aramaio |
| Amorebieta | Amorebieta | PBA Abadiño |
| | | PCA Arteako |
| | | PAET Amorebieta |
| | | PCA Zarátamo |
| | Bilbao-Abando | Bilbao-Abando |
| | Bergara Junction | Elorrio Junction |
| | | Mondragon Junction |
| | | Bergara Junction |
| Tolosa | Ezkio-Itsaso | PCA Zumárraga |
| | | PAET Ezkio-Itsaso |
| | | PCA Ordizia-Itsasondo |
| | Tolosa | PBA Tolosa |
| | | PCA Zizurkil |
| | | PCA Andoain |
| | | Astigarraga Junction |
| Irún | San Sebastián | San Sebastián-Donostia Station |
| | Pasajes | Estación Pasajes |
| | Lezo-Rentería | Lezo-Rentería Station |
| | Irún | Irún Station |

▫Third rail section
▫New platform.

*Table 16 Spanish side RBC deployment*

### 4.2.3 Cross border section

#### 4.2.3.1 Scenario 1

In this case, the Bordeaux-Hendaye section is fully equipped with ERTMS L2 without lateral signalling and the cross-border section will be equipped with ERTMS L2 as well

Regarding the particularities of this section, the study recommends adding class B ASFA Spanish equipment to make easier the transfer of freight locomotives on double gauge tracks.

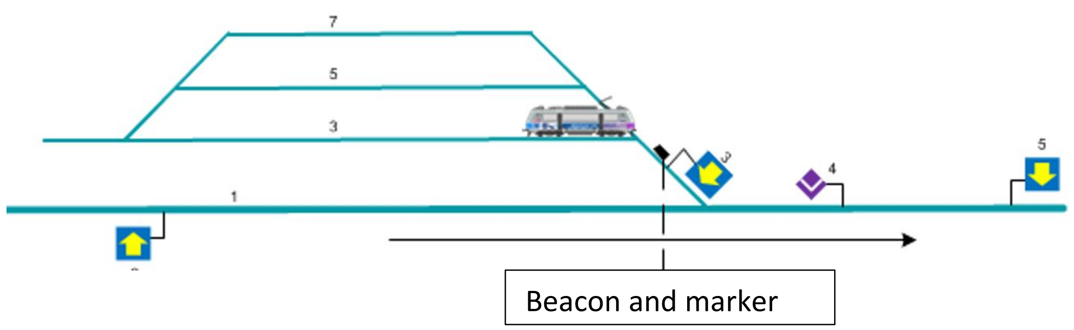
The renewal of the “PRG” interlocking of Hendaye (initial estimated date around 2062) by ARGOS technology will be effective in 2030, so the transition with Spanish technology will be easier for the following aspects:

- The management of the temporary speed restrictions.
- The operational protocols of the trains transferred from one country to another.
- The communications between the control centres

ERTMS L2 will be present on both sides which avoids any transition between different levels of ERTMS. The only transition issues to deal with are transitions:

- between different versions: 2.3.0 d in Spain and 3.6.0 in France in Irun
- transition in Hendaye with Class B equipment. The trains will always need to stop to change the Class B systems at the last signal on both sides.

The stabling areas of Hendaye and Irun can be operated without ERTMS but in these case operational cross acceptance rules should be approved between Spain and France. The only ERTMS equipment to be provided will be at the level of the input and output signals of these stabling areas with special interface with RBC.




#### 4.2.3.2 Scenario 2

In this case, the Lamothe-Hendaye is ERTMS L1 equipped. Then it will be easier to equip the cross border section with L1 too, so as to have a simpler and also safe equipment.

We recommend adding class B ASFA Spanish equipment and Class B KVB equipment to make easier the transfer of freight locomotives on double gauge tracks.

ERTMS L2 (or other system implemented at date) will be implemented in 2062 on Hendaye Irun section, when implemented in France.

The only transition issues to deal with are transitions:

- between two levels in Spain (south of Irun): L2 version 2.3.0 d in Spain and L1 version 2.3.0 d in France; SNCF réseau and ADIF pointed out the difficulties on the L1 to L2 transition, especially at the cross-border, which is a challenging node (number of manoeuvres, 3rd rail management, temporary speed restrictions, etc.).It has to be particularly studied.

- transition in Hendaye with ASFA Class B equipment. There always will be the need to stop the train at the last signal to change Class B systems.
- transition in Irun with KVB class B equipment. Also, there always will be the need to stop the train at the last signal to change Class B systems.

## 4.3 ESTIMATED COSTS METHODOLOGY

### 4.3.1 General

#### *4.3.1.1 Infrastructure unit costs*

Regarding the cost estimation, the unit price from studies in progress will be used. Those costs will be those that were already validated by SNCF Réseau, for France, and ADIF, for Spain. For each signal box renewal, a price per item (point or signal) will be applied. The unit prices used to evaluate the renewal costs in the baseline situation and in the project (ERTMS L2 situation) will be proposed to the Project Leader.

The same methodology will be applied for the unit price of the block renewals in the baseline and which are projected, using the digital BAL technology. For the ERTMS deployment, unit price will be proposed for RBC installation, GSMR reinforcement, train detectors ….

**The costs of investment will be given for each baseline and projected situation in 2030 for the 3 items:**

- Signal boxes adaptation or renewal including centralised control command and telecom costs. The future technology ARGOS will be applied as it will be operational by 2025.
- Block adaptation or renewal including telecom costs.
- ERTMS deployment.

### 4.3.2 On board retrofit unit costs

The analysis performed in step 1 allows to determine the number of on-board units that have to be updated with EVC ERTMS.

This analysis will consider:

- The units already equipped in 2025.
- The units that would be out of service during the next 10 years until 2035 (equipped or not).
- The residual units to be equipped.

**The calculation of the number of units of each type will be based on the traffic data obtained in step 1. These number will be detailed:**

- **by type of rolling stocks (number, electrified or diesel)**
- **by railway undertakings (regional, national and international traffic).**

### 4.3.3 French side

#### *4.3.3.1 Unit costs for the reference situation CAPEX*

In reference situation without ERTMS, we need to apply unit costs for signal boxes and block renewal. These costs are obtained with transposition of PAI 2006-unit costs with a reduction of 14 to 17% depending of the number of objects considered.

**Total renewal of signal box in ARGOS technology**

| k€ 2020 | Interlocking < 40 objects | 40 ≤ Intlk< 80 objects | 80 ≤ Intlk<150 objects | Interlocking ≥ 150 objects |
|---|---|---|---|---|
| ARGOS costs | 452,64 | 423,53 | 327,10 | 239,49 |

*Table 17 Cost per object for a total renewal of signal box and replacement by ARGOS technology*

For block renewal the unit costs are extracted from the economic model of SNCF Réseau. The cost is given for each individual operation. These costs are reevaluated in € 2020 (Preliminary study stage).

| | Operation | Unit | Cost value k€ 2020 |
|---|---|---|---|
| Génie Civil câbles | Local cable ducts removal | Km de ligne | 39,718k€ |
| | Civil works and cable ducts | Centre /2 | 54,281k€ |
| | Connection with existing signal boxes | Raccordement | 100,649k€ |
| | Line cable removal (signaling and low voltage) | Km de ligne | 13,240k€ |
| Center | Signalling centre removal | Centre | 10,592k€ |
| | Local ErDF connection | Centre /2 | 39,718k€ |
| Signal | Signal removal before renewal | Signal | 7,944k€ |
| | New signal | Signal | 23,830k€ |
| | KVB encoder | Signal KVB | 10,592k€ |
| | KVB Beacon | Signal KVB | 21,182k€ |
| | Information points at the track : crocodiles | Signal | 10,592k€ |
| | Signal lightning equipment , local cables and STM | Signal | 30,449k€ |
| | Technical checks and tests | Signal | 3,660k€ |
| Track circuits | removal and installation of equipment on the track<- local cables | CdV | 43,689k€ |
| | Track circuit logic (transmitter, receiver) | CdV | 31,055k€ |
| | Insulated joint removal | CdV | 19,859k€ |
| | Technical checks and tests | CdV | 3,660k€ |
| Vérifications techniques (VT) et essais globaux | | Km de voie | 0,999k€ |
| **Specific works for digital block in ARGOS technology** | Optical fibre toward L1 farm | Centre /2 | 65,099k€ |
| | Shelter Digital block (including technical checks and tests) | Centre /2 | 213,897k€ |
| | Signals Digital block (including local switches)) | Signal | 36,586k€ |
| | Track circuit Digital block | Cdv | 31,564k€ |
| | Installation of a dedicated N1 module | N1 | 550,414k€ |
| | Pooling of a module in an existing L1 ARGOS module | N1 | 359,385k€ |
| SIAM ST3 monitoring system implementation | | Centre/2 | 53,00k€ |
| Level crossing (SAL 2, SAL 2B ou SAL 4) | Renewal of a complete level crossing system | PN | 215,80k€ |
| | Renewal of level crossing mechanism | PN | 64,87k€ |

*Table 18 Cost per operation for a total renewal of block BAL and replacement by digital block ARGOS technology*

#### *4.3.3.2 Unit price to consider for the ERTMS Level 1 implementation - CAPEX*

The ERTMS level 1 implementation is considered only in the scenario 2. The benchmark for ground implementation comes from the Longuyon Bâle project, which is currently in progress.

For the study application, the best parameter seems to be the cost per signal including the LEU, the commutable beacons, including KVB and all annex costs such as training, maintenance tools, temporary speed restrictions tools etc…

A cost of 196 € /signal (base 2020) is taken, including, of course, class B signals + KVB

#### 4.3.3.4 Unit price to consider for the Level 2 deployment - CAPEX

For ERTMS L2 deployment in France, a first base of unit costs is built based on the new ARGOS technology, in cooperation with SNCF Reseau. Taking into consideration that the ARGOS development is still in progress, this basis can be considered as a first draft, subject to modifications when the signalling companies will formalise their prices next year.

In any case, these prices have been elaborated on the PAI 2006 technology (last contract of informatics interlocking production) and can be used for the comparison between scenarios with a sufficient reliability.

#### 4.3.3.5 Signal boxes in ERTMS L2 + ARGOS technology

Regarding the ERTMS L2 technology without lateral signalling, the unit prices are lower than those applied for the reference situation (Table 9).

**Total renewal of a signal box with ERTMS L2 without lateral signals**

| k€ 2020 | Interlocking < 40 objects | 40 ≤ Intlk< 80 objects | 80 ≤ Intlk<150 objects | Interlocking ≥ 150 objects |
|---|---|---|---|---|
| ARGOS costs | 339,16 | 301,75 | 239,40 | 175,42 |

*Table 19 Cost per object for a total renewal of signal box and replacement by ARGOS technology in ERTMS L2 situation*

In some specific situations, the L3 layer can be interfaced without renewal, if the residual lifespan of this layer is more than 30 years. This leads to a cost reduction compared to the previous situation of total renewal.

**Partial renewal of a signal box with ERTMS L2 without lateral signals and interface with existing L3 layer (residual lifespan more than 30 years)**

| k€ 2020 | Interlocking < 40 objects | 40 ≤ Intlk< 80 objects | 80 ≤ Intlk<150 objects | Interlocking ≥ 150 objects |
|---|---|---|---|---|
| ARGOS costs | 253,24 | 201,13 | 159,01 | 116,51 |
| Cost reduction compared with total renewal ARGOS | -25% | -33% | -34% | -34% |

*Table 20 Cost per object for a partial renewal of signal box and replacement by ARGOS technology in ERTMS L2 situation.*

#### 4.3.3.6 Block renewal in ERTMS situation

For ERTMS situation the unit costs used for the reference situation will apply for the project situation (report to Table 18)

#### 4.3.3.7 ERTMS specific costs

Unit costs are used to assess specific works related to ERTMS deployment online and in stations (markers, beacons, GSMR reinforcement, etc.).

The corresponding unit prices are given in the following Table 21 (value 2020).

| | | | |
|---|---|---|---|
| **Specific works for ERTMS L2 implementation** | RBC in connection with L1 module | RBC unit | Variable |
| | Two fix beacons for each signal | Signal | 21,529k€ |
| | GSM-R reinforcement (BTS, except GPRS deployment) | Line length in km | 10,194k€ |
| | Validation tests for ERTMS | RBC | 364,593k€ |
| | ERTMS markers implementation | Marker | 5,580k€ |
| | Lateral signals removing | Signal | 37,200k€ |

*Table 21 Unit costs for specific works in ERTMS L2 situation*

The price for RBC depends on its control capacity. Regarding the present study, we propose a model with fixed and variable part:

$$Cost\ (k€) = 800 + 33 \cdot object\ number$$

The number of objects includes the number of points and signals in signal boxes and the number or signals in block sections. The application to the two RBC gives the following costs.

| Model application | y =33*Nb objet+800 | | |
|---|---|---|---|
| RBC1 Bordeaux | 327 | 11 541 | k€ 2020 |
| RBC2 Bayonne | 494 | 17 052 | k€ 2020 |

#### 4.3.3.8 Unit costs for Mistral NG implementation

For the Mistral NG model, we suggest applying a ratio of the number of routes ordered in Mistral. The unit cost in € 2020 is 23,86 k€ per route.

| Coût à l'itinéraire | Unit cost | |
|---|---|---|
| **Mistral NG** | 22,25 | EC 01 2017 |
| | 23,86 | EC 01 2020 |

*Table 22 modèle de coût Mistral à l'itinéraire*

#### 4.3.3.9 Unit costs for on board units retrofit

Regarding the on-board retrofit, the proposal is to use an economic model based on a fixed part of development per series of machines amortized on the number of machines to be fitted and a variable part per machine to be retrofitted.

| k € 2018 | Economic model data | |
|---|---|---|
| Type | Fixed part per series | Variable part per trainset |
| Regiolis B 84500 Z 51500 | 1740 | 170 |
| AGC BGC B 81500 | 3990 | 470 |
| Regio 2N Z 55500 | 4060 | 300 |
| TER 2N NG | | 460 |
| TER 2N PG | 3140 | 520 |
| BB 75000 75400 | 2880 | 300 |
| BB 27000 | 3240 | 310 |
| BB 60000 | 2380 | 310 |
| BB 69000 | 1950 | 340 |
| BB 69400 | 1780 | 340 |
| TGV D | 0 | 310 |
| BB26000 | 1780 | 340 |
| BB22200 | 1780 | 340 |
| BB36000 | 4570 | 440 |
| Classe66 | 1950 | 340 |
| BR185 | 1780 | 340 |
| EURO 4000 | 1780 | 340 |
| TRAXX F140 | 1780 | 340 |

*Table 23 proposed retrofit costs for on board units.*

For maintenance machines, the hypothesis of mobile EVC, which can be used on every infrastructure OBU with a unit cost of 50 k€ per EVC, is taken.

#### *4.3.3.10 Estimated impact on the maintenance and operation OPEX (infrastructure)*

For OPEX general assessment and **valuation of the impact of ERTMS deployment on the maintenance and operation cost for signaling equipment on the conventional network**, it is suggested to deal with one of RC basic model based on SNCF cost data coming from the field (the so called ''Matrice des 10 000 points'').

From this model, it is possible to **extract a kilometric ratio for the current maintenance cost of signalling equipment within a defined railway line included in French network**.

The current cost will represent the reference situation.

The project situation can be estimated by application of a relevant coefficient.

As it was previously said, this is considered as a basic approach (because it cannot reflect the reality of the density of equipment and especially objects in a given kilometer point, either signal box area or block area). However, it is sufficient at this stage of the study to characterize the economic effects and related hypothesis to be described.

To capture the impact of an ERTMS deployment according to the specific technology used, we have referred to the following coefficients.

| ERTMS technology | Maintenance cost of signaling equipment |
|---|---|
| ERTMS L1 | Overcost with low impact: **+ 2%**<br>Overcost **+ 10%** if ERTMS L1 + KVB |
| ERTMS L2 with lateral signals | Overcost **+ 10%** (impact is more significant in that case) |
| ERTMS L2 without lateral signals | Cost saving **- 30%** |

*Table 24 Impact of an ERTMS deployment according to the specific technology used at French side*

### 4.3.4 Spanish side

The Spanish ERTMS deployment costs differ from the French ones due to the current development of this CCS though the Spanish lines and the technology regarding the interlocking and block systems. Therefore, those costs linked to the renewal of interlockings (signal boxes technology in France), apart from the one that has already been tendered for Irún station, are not included within this analysis.

As it has been exposed through the former sections, the Spanish infrastructure status is defined by the status of the works, due to the "Y Vasca" is a brand-new line. Consequently, the considered costs are those that are related to the CCS installed through this line, that is to say, those costs linked to the ERTMS deployment. Regarding the other two sections.

- The Júndiz freights Terminal- Vitoria uses a third rail technology and ERTMS L1 as CCS. Nevertheless, due to the length of this section, which is a small link between the future HSL Madrid-Burgos-Vitoria, and to the fact that lateral signalling and LEU are going to be considered even if L2 is used, the costs that apply to this section are the same that those that apply to the "Y Vasca".
- The Astigarraga-San Sebastián-Irún section, on the other hand, uses ERTMS L2 as CCS and the third rail technology. Therefore, the considered costs are, again, those considered for the "Y Vasca".

#### *4.3.4.1 Unit costs for ERTMS implementation*

The costs of the ERTMS deployment are based on the official cost data sheet that the Spanish Infrastructure Manager, Adif, provides. Besides, the tables that is exposed down below are also built using several public tenders of track works within the Spanish rail network, which are also under the same principles, allowing a better estimation of the ERTMS deployment.

On the other hand, before exposing the ERTMS deployment costs, it is important to detail those elements that form the ERTMS CCS, or in other words, those elements that are considered within the budget calculation. To do so, it is vital to be aware of the ERTMS technology and the different elements that are necessary to install at the trackside. Consequently, level 1 and level 2 should consider different devices, since L2 does not impose the use of lateral signalling, as level 1 does. Nevertheless, considerations of degraded CCS situations if ERTMS does not properly work must be taken into account that is the reason why lateral signalling with ASFA is mandatory by Adif´s requirements through the whole facility scope.

Additionally, the third rail technology causes some issues in terms of signalling, due to the fact that the future operation of the line is to be perform in two different gauges at the same time. However, this issue will not be considered within the cost estimation because of there is no official agreement about this topic.

| LEU interface with signals | Local operation centres |
|---|---|
| Switch balise | GSM-R antennae |
| Fixed balise | Ancillary and detection systems |
| Transition balises between L1 /L2 and baselines | Lateral signals |
| Track occupancy devices | ASFA balises |
| Fixed telecommunications | Number and cost of RBC |
| +Interface between RBCs and interlockings | Energy and devices remote control |
| Energy facilities | |

*Table 25 Spanish side considered costs elements.*

Once the different elements have been exposed, the costs of those that are deployed through the facility are the following.

| Element | Description | | Unit | Unit cost (M€) | |
|---|---|---|---|---|---|
| | | | | Single track | Double track |
| **Interlocking** | Rated by the number of elements that controls | High | Number of | **3,084** | |
| | | Medium | Number of | **2,427** | |
| | | Low | Number of | **1,770** | |
| **Track occupancy devices** | Within this point, the following is included: track circuits and axle counters, those ones installed in singular zones of the track, cables and civil works | | km | **0,118** | **0,195** |
| **ASFA** | Fixed facilities | | km | **0,019** | **0,019** |
| **ERTMS ATP/ATC (CCS)** | Trackside, in-door components, and interfaces (balises, RBC, IXL interfaces, Central Post interfaces, etc), civil works and safety protection | | km | **0,144** | **0,206** |
| **GSM-R** | Within this point, the following is included: double layer, voice and data transmission, radio towers, civil works, power cables, tunnel, and basic infrastructure for operators | | km | **0,251** | **0,251** |
| | MSC | | Number of | **9,88** | **9,88** |
| **Fixed telecommunications** | Within this point, the following is included: wires, connections and feeding, fixed equipment and terminals, power buildings, civil works, etc. | | km | **0,253** | **0,421** |
| **Energy Substations** | One each 60 km of track | | km | **0,517** | **0,517** |
| **Ancillary and detection systems** | Lateral wind detectors | | km | **0,005** | **0,005** |
| | Hot boxes detector | | km | **0,025** | **0,041** |
| | Obstruction detector | | km | **0,003** | **0,005** |
| **Energy remote control** | Remote control each 15 Km | | Km | **0,029** | **0,029** |
| | Regional Centre of Control and CM; each 60 Km | | Km | **0,027** | **0,027** |
| | Operation Control Centre | | ud | **1,607** | **1,607** |
| | Communications | | ud | **0,745** | **0,745** |
| | OCL isolator | | Km | **0,011** | **0,012** |
| | Consumer Isolator | | Km | **0,012** | **0,016** |
| | Tunnel Lighting | | Km | **0,014** | **0,014** |

*Table 26 Spanish side trackside costs*

For the purposes of this Project, only those elements that affect the exclusive installation of the ERTMS have been used to calculate the costs. The following table shows the total of the unit costs used for the different types of interlocking rated by the number of elements that controls.

| Type of interlocking | Total Unit cost per number of interlocking (M€) | Total Unit cost per km(M€) |
|---|---|---|
| **High** | **3,084** | **0,878** |
| **Medium** | **2,427** | **0,878** |
| **Low** | **1,770** | **0,878** |

*Table 27 Spanish side trackside total unit costs*

Since the beginning of 2021, Adif has published a new set of costs that, so far, do not seem to affect the cost here exposed.

#### *4.3.4.2 Operation and maintenance costs of ERTMS deployment (Spanish side)*

The estimated budget regarding the maintenance costs of the ERTMS signalling equipment is calculated based on several public tenders for Spanish high-speed lines. These costs are an approximation due to the differences between different facilities and the number of elements between different lines. Therefore, what is here exposed must not be taken as an exact calculation, but only as a tool to obtain an approximation.

Adif has also confirmed that there is an operating fee, which includes the service provided by their technicians. This cost depends on the labor time that is devoted to maintaining all safety facilities (interlocking, signaling systems, track circuits, mechanism motors, ERTMS, etc.).

Consequently, the rough cost of ERTMS maintenance and operating cost are between **5.000-6.000 €/km·year**.

| Railway line | Maintenance cost of signalling equipment |
|---|---|
| **Spanish side lines** | **5.000-6.000 k€/km** |

*Table 28 Operation and maintenance costs in k€/km at Spanish side*

#### *4.3.4.3 Unit costs for on board units retrofit (Spanish side).*

The unit cost of rolling stock retrofit and the onboard ERTMS deployment is not an official datum due to the process that the RU, Renfe, usually follows to purchase rolling stock. In other words, the Spanish RU purchases the vehicles with all the systems that are mandatory to circulate through the Spanish lines (CCS within them). This means that the ERTMS onboard deployment budget is available since the total budget is not disaggregated.

Therefore, the following costs come from public tenders that the RU published in 2017[11] in order to purchase the same rolling stock series that are going to be used in the line under study.

| € 2017 | | Economic model data |
|---|---|---|
| Type | | Cost per series (k€) |
| Cercanias | s-446 | Not available |
| | s-447 | 245 |
| Regional trains | s-470 | 226 |
| | s-449 | 226 |
| Long distance trains | s-120 | 270 |
| | s-130 | 281 |
| | s-252 | 226 |
| Freight trains | s-253 | Not available |
| | s-251 | Not available |
| | s-333.3 | Not available |
| | s-335.3 | Not available |
| | s-601 | Not available |

*Table 29 Rolling stock and retrofit costs.*

[11] Boletín Oficial del Estado Jueves 25 de junio de 2017 Núm

# 5 STEP 4: ECONOMIC ANALISIS AND OTHER EFFECTS OF ERTMS IMPLEMENTATION

## 5.1 ECONOMIC ANALYSIS

### 5.1.1 Implementation of an economic model

An Excel model based on step 1 and 2 technical data and on step 3 unit costs has been implemented to reproduce the CAPEX and OPEX costs of the situations defined in step 3, namely:

- In France: the reference situation and the project situation for project scenarios 1 and 2 to establish a differential balance and compare scenario 1 and 2.
- In Spain, the differential balance obtained directly, the deployment situation being simpler with only one project scenario.

| HE | parameter sheet |
|---|---|
| POSTES<br>BLOCK<br>AXAN<br>TRONCON_IS<br>SIGNAUX | French datas on signalling assets |
| OPALE datas<br>Interlocking costs<br>Mistral NG costs<br>BALEQ costs<br>RBC costs<br>N1 costs | French cost models used for frenh side simulation |
| Construction<br>REF<br>SC 1<br>SC 2 | French CAPEX simulations |
| Synthesis F | CAPEX Synthesis France |
| Synthesis F ACT | CAPEX Synthesis NPV France |
| Espagne | CAPEX + OPEX ERTMS Spain |
| OPEX FR<br>OPEX FR synth delta<br>OPEX Sc1<br>OPEX Sc2<br>OPEC FR ACT | OPEX model for France |
| RS Spain<br>RS France | CAPEX for rolling stock retrofit |
| Synthesis F+E<br>Synthesis € 2020<br>Synthesis NPV | All synthesis sheets (for CAPEX OPEX and rolling stock) |

*Figure 23: Excel model structure*

The Excel dedicated model, based on Spanish and French costs, is divided in several datas and calculation sheets.

HE sheet contains all modifiable parameters such as:

- Calculation period
- Discount rate valor
- Inflations rates
- Investment repartition

Calculation sheets are configurated for

- CAPEX simulations on French Spanish and both sides for infrastructure expenses
- OPEX simulations
- CAPEX simulations for on board retrofit

Synthesis sheets give the economic balance for OPEX and CAPEX on the whole perimeter.

The construction sheet collects all the data on the France side necessary for the calculation of infrastructure CAPEX

| | | | | | | Poste | | | | Zone | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nom | Type | Type/1 | Num Ligne | PKD | PKF | Nb objets pris en compte dans ERTMS | Nb objets postes pris en compte dans ARGOS | Nb signaux (pour dépose et balises) | Nb Itinéraires/Au | Nb objets zones incluses dans ARGOS | Nb N1 dédiés au block | Raccordement à un poste encadrant | Reprise de postes si block déployé à une date différente |
| **ARGOS BORDEAUX** | **Poste** | **ARGOS** | **450/515** | **569785** | **45503** | **274** | **274** | **123** | **859** | **53** | **7** | **14** | **7** |
| AMBARES poste 47 | Poste | PAI 2006 | 570000 | 569785 | 571165 | 10 | 10 | 4 | 15 | | | | |
| Z1 | Zone | BAL | 570000 | 571165 | 571355 | | | | | 0 | 1 | 2 | |
| BASSENS poste 1 | Poste | PRSI | 570000 | 571355 | 575181 | 22 | 22 | 11 | 29 | | | | 1 |
| Z2 | Zone | BAL | 570000 | 575181 | 578234 | | | | | 5 | 1 | 2 | |
| CENON poste Bif | Poste | PRSI | 570000 | 578234 | 578774 | 23 | 23 | 3 | 23 | | | | 1 |
| Z3 | Zone | BAL | 570000 | 578774 | 581611 | | | | | 13 | 1 | 2 | |
| BORDEAUX-SAINT-JEAN poste 1 | Poste | PRSI | 570000 | 581611 | 1697 | 160 | 160 | 68 | 697 | | | | 1 |
| Z4 | Zone | BAL | 655000 | 1697 | 3424 | | | | | 5 | 1 | 2 | |
| TALENCE poste 5 | Poste | PRCI | 655000 | 3424 | 4232 | 10 | 10 | 7 | 20 | | | | 1 |
| Z5 | Zone | | 655000 | 4232 | 12602 | | | | | 5 | 1 | 2 | |
| GAZINET CESTAS poste 6 | Poste | PRCI | 655000 | 12602 | 13728 | 22 | 22 | 13 | 35 | | | | 1 |
| Z6 | Zone | | 655000 | 13728 | 37460 | | | | | 24 | 1 | 2 | |
| BIGANOS-FACTURE poste 1 | Poste | MU45 | 655000 | 37460 | 38909 | 19 | 19 | 10 | 30 | | | | 1 |
| Z7 | Zone | | 655000 | 38909 | 39719 | | | | | 1 | 1 | 2 | |
| LAMOTHE poste 1 | Poste | PML | 655000 | 39719 | 45503 | 18 | 18 | 11 | 25 | | | | 1 |
| **ARGOS Bayonne** | **Poste** | **ARGOS** | **655000** | **45503** | **233231** | | **314** | **136** | **444** | **180** | **7** | **14** | **7** |
| Z8 | Zone | BAL | 655000 | 45503 | 108068 | | | | | 51 | 1 | 2 | |
| MORCENX poste 1 | Poste | PRG | 655000 | 108068 | 109762 | 52 | 52 | 20 | 95 | | | | 1 |
| Z9 | Zone | BAL | 655000 | 109762 | 132500 | | | | | 22 | 1 | 2 | |
| LALUQUE poste 72 | Poste | PRSI | 655000 | 132500 | 134450 | 25 | 25 | 11 | 25 | | | | 1 |
| Z10 | Zone | BAL | 655000 | 134450 | 146495 | | | | | 13 | 1 | 2 | |
| DAX poste 1 | Poste | PRG | 655000 | 146495 | 148139 | 56 | 56 | 18 | 85 | | | | 1 |
| Z11 | Zone | BAL | 655000 | 148139 | 170100 | | | | | 27 | 1 | 2 | |
| SAINT-VINCENT-DE-TYROSSE poste 75 | Poste | PAI 2006 | 655000 | 170100 | 170783 | 12 | 12 | 5 | 8 | | | | 1 |
| Z12 | Zone | BAL | 655000 | 170783 | 195381 | | | | | 28 | 1 | 2 | |
| BAYONNE poste 1 | Poste | BV50 | 655000 | 195381 | 197438 | 10 | 10 | 5 | 10 | | | | 1 |
| BAYONNE poste 3 | Poste | EMU | 655000 | 197380 | 195381 | 36 | 36 | 11 | 50 | | | | |
| BAYONNE poste 4 | Poste | PRG | 655000 | 197639 | 199937 | 41 | 41 | 21 | 60 | | | | |
| Z13 | Zone | BAL | 655000 | 199937 | 206185 | | | | | 7 | 1 | 2 | |
| BIARRITZ poste 1 | Poste | PRCI | 655000 | 206185 | 208010 | 25 | 25 | 16 | 30 | | | | 1 |
| Z14 | Zone | BAL | 655000 | 208010 | 230347 | | | | | 32 | 1 | 2 | |
| HENDAYE poste 1 | Poste | MU45 | 655000 | 230347 | 232397 | 20 | 20 | 11 | 25 | | | | 1 |
| HENDAYE poste 1 PRG | Poste | PRG | 655000 | 230347 | 232397 | 7 | 7 | 2 | 4 | | | | |
| HENDAYE poste 4 | Poste | EMU | 655000 | 233163 | 233231 | 42 | 42 | 21 | 60 | | | | |

*Figure 24: Construction sheet structure and data*

### 5.1.3 CAPEX and OPEX analysis for infrastructure

For the CAPEX comparison between reference situation and project situations - scenarios 1 and 2 – we have chosen to work in € 2020 constant without inflation and in discounted €.

The issue is the value of the discount rate to apply in the model. Initially, the discount rate in France was 8%.

In the United States, the discount rates are multiple. Since 2003, the Office of Management and Budget (OMB) recommends that project costs and benefits be discounted at two constant rates: 3% and 7%.

In the United Kingdom, the discount rate is based on the Ramsey formula at 3.0% beyond 30 years

Currently, the French discount rate set by the Quinet Commission (2013) recommends a risk-free discount rate of 2.5% to 2070. A risk premium, specific to each project, is added according to its macroeconomic sensitivity (β) and systemic risk premium. It is set at 2.0% up to 2070.In Spain it is fixed at 5%.

For European Commission there is no fixed recommendation. So, for the study we propose a **discount rate of 4,5%** including 2% of risk extra rate.

The period for the simulation is from 2020 to 2070 (50 years). This period is long to have a convenient comparison between scenario 1 and 2.

#### *5.1.3.1 Global analysis*

The results of the economic balance between the different situations is given hereunder in constant € and then in NPV values with a discount rate of 4,5%. For details the Excel file of the economic model gives all intermediate calculations.

**Synthesis CAPEX — € constant 2020 — 2020 - 2070**

| CAPEX | France | | | | | | Spain | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | interlocking | block sections | ERTMS N2 | ERTMS N1 | total | Delta PRO-REF | ERTMS N1/N2 | Delta PRO-REF | Delta PRO-REF |
| Référence | 420 892k€ | 345 573k€ | | | 766 466k€ | | 160 634k€ | | |
| Scénario 1 | 278 250k€ | 251 238k€ | 73 698k€ | | 603 185k€ | - 163 280k€ | 195 010k€ | 34 376k€ | - 128 904k€ |
| Scénario 2 | 436 577k€ | 326 837k€ | 61 655k€ | 69 344k€ | 894 414k€ | 127 948k€ | 195 010k€ | 34 376k€ | 162 324k€ |

| OPEX | France | PRO-REF | Spain | Spain PRO-REF | Total PRO-REF |
|---|---|---|---|---|---|
| Référence | 155 175k€ | | 25 731k€ | | |
| Scénario 1 | 125 620k€ | - 29 554k€ | 31 500k€ | 5 769k€ | - 23 785k€ |
| Scénario 2 | 152 085k€ | - 3 090k€ | 31 500k€ | 5 769k€ | 2 679k€ |

xxxx k€ Y Vasca ERTMS costs in reference

*Table 30: economic results for Scenarios 1 and 2 (€ constant)*

For Spanish side, the costs in reference situation are the signalling costs corresponding to the Y vasca that would be spent anyway. The cost in project is the total cost of all sections (ie. Y vasca, Júndiz ERTMS L1 section and San Sebastian Irun ERTMS L2 section). The difference between project and reference corresponds to the ERTMS implementation on the two sections Júndiz and San Sebastián Irun (ie 34,4 M€).

**Synthesis CAPEX — € Net Present Value — 2020 - 2070 — 4,50%**

| CAPEX | France | | | | | | Spain | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | interlocking | block sections | ERTMS N2 | ERTMS N1 | total | Delta PRO-REF | ERTMS N1/N2 | Delta PRO-REF | Delta PRO-REF |
| Référence | 199 339k€ | 161 044k€ | | | 360 383k€ | | 140 943k€ | | |
| Scénario 1 | 172 814k€ | 199 295k€ | 67 679k€ | | 439 788k€ | 79 405k€ | 171 111k€ | 30 168k€ | 109 573k€ |
| Scénario 2 | 216 085k€ | 162 670k€ | 53 377k€ | 54 219k€ | 486 351k€ | 125 969k€ | 171 111k€ | 30 168k€ | 156 136k€ |

| OPEX | France | France PRO-REF | Spain | Spain PRO-REF | Total PRO-REF |
|---|---|---|---|---|---|
| Référence | 85 134k€ | | 12 289k€ | | |
| Scénario 1 | 71 363k€ | - 13 771k€ | 15 044k€ | 2 755k€ | - 11 016k€ |
| Scénario 2 | 85 082k€ | - 52k€ | 15 044k€ | 2 755k€ | 2 703k€ |

xxxx k€ Y Vasca ERTMS costs in reference

*Table 31: economic results for Scenarios 1 and 2 (€ NPV with 4,5% discount rate)*

The scenario 2 appears to be the worst scenario in € constant and in NPV costs. The main reason is the extra cost due to ERTMS N1 equipment of 74 M€ that is not counterbalanced by the costs saving of signal boxes replacement. The scenario 1 compared to reference situation gives an advantage in CAPEX of 128,9 M€ in € 2020.

In NPV, the scenario 1 is still better than scenario 2, but with a negative effect of 109,5 M€. This is due to the fact that the planned expenditures come much earlier in the project scenario before 2030 whereas they are phased out until 2070 in reference situation.

#### *5.1.3.2 Analysis per section in France*

For Spanish side, the cost breakdown per section has been given.

For France, the breakdown of CAPEX and OPEX costs according to the following sub-sections has been obtained in the Excel economic model:

- SEA Bordeaux Lamothe (inc)
- Lamothe (exc) Dax (inc)
- Dax (exc) Hendaye

This detail would be useful for example in case of the GPSO project phase between Bordeaux and Dax. The following tables give the Breakdown for the 3 sections in € constant and NPV.

**synthesis of CAPEX and OPEX per section in France — € constant**

| CAPEX | SEA Bordeaux Lamothe | Lamothe (exc) Dax (inc) | Dax(exc) Hendaye (inc) | TOTAL |
|---|---|---|---|---|
| Référence | 250 149k€ | 234 693k€ | 281 625k€ | 766 466k€ |
| Scénario 1 | 210 812k€ | 209 929k€ | 182 445k€ | 603 185k€ |
| Scénario 2 | 210 812k€ | 296 794k€ | 386 808k€ | 894 414k€ |

| OPEX | SEA Bordeaux Lamothe | Lamothe (exc) Dax (inc) | Dax(exc) Hendaye (inc) | TOTAL |
|---|---|---|---|---|
| Référence | 61 842k€ | 43 426k€ | 49 906k€ | 155 175k€ |
| Scénario 1 | 53 302k€ | 33 415k€ | 38 904k€ | 125 620k€ |
| Scénario 2 | 53 302k€ | 48 213k€ | 50 570k€ | 152 085k€ |

*Table 32: Cost breakdown per section on French side in € constant 2020*

**synthesis of CAPEX and OPEX per section in France — € Net Present Value**

| CAPEX | SEA Bordeaux Lamothe | Lamothe (exc) Dax (inc) | Dax(exc) Hendaye (inc) | TOTAL |
|---|---|---|---|---|
| Référence | 132 851k€ | 118 839k€ | 108 693k€ | 360 383k€ |
| Scénario 1 | 147 313k€ | 155 097k€ | 137 378k€ | 439 788k€ |
| Scénario 2 | 147 313k€ | 170 266k€ | 168 772k€ | 486 351k€ |

| OPEX | SEA Bordeaux Lamothe | Lamothe (exc) Dax (inc) | Dax(exc) Hendaye (inc) | TOTAL |
|---|---|---|---|---|
| Référence | 33 929k€ | 23 825k€ | 27 380k€ | 85 134k€ |
| Scénario 1 | 29 819k€ | 18 693k€ | 22 851k€ | 71 363k€ |
| Scénario 2 | 29 819k€ | 26 972k€ | 28 291k€ | 85 082k€ |

*Table 33: Cost breakdown per section on French side in NPV 4,5%*

The cost analysis for French side can be synthesized as follows:

- In constant € , the cost of 766 M€ for reference has to be provisioned for the CCR operation. The cost for the ERTMS implementation in scenario 1 is 163 M€ less than this cost. That means that the ERTMS operation is very profitable for SNCF Réseau because the extra costs of ERTMS are largely covered by the savings made on the regeneration of signal boxes and blocks.
- In NPV calculation the situation is different because the ERTMS deployment expenses occur much earlier than in the reference situation and the economic calculation disadvantages the project situation. The extra cost for scenario 1 is, in this case, of 79 M€ (NPV), amount roughly equal to the ERTMS deployment expenditure of 68 M€.

### 5.1.4 CAPEX analysis for on board equipment

Considering the unit costs proposed in step 3 analysis, we have estimated the cost of on-board equipment for France and Spain. The equipment of international trains has been taken into account with the French side.

#### *5.1.4.1 CAPEX OBU equipment for French side*

We consider that all TGV will be fitted with ERTMS L2 in 2030. Intercités trains between Bayonne Hendaye and Toulouse are Coradia trains already equipped with ERTMS. For passenger trains the only retrofit concerns regional trains that are calculated on the projected services.

| **Projected regional service in France (2030)** | **Regional** | | | |
|---|---|---|---|---|
| | Number of daily services (one way) | | | Number of retrofited trainsets |
| O/D Rolling stock | Z51500 Regiolis | Z55500 Regio 2N | B81500 | |
| Bordeaux-st-Jean <-> Arcachon | - | 44 | - | 22 |
| Bordeaux-st-Jean <-> Hendaye | 13 | - | - | 7 |
| Bordeaux-st-Jean <-> Mont-de-Marsan | - | - | 14 | 6 |
| Dax <-> Hendaye | 15 | - | - | 6 |
| Bayonne <-> Hendaye | 9 | | | 3 |
| Bordeaux <-> Pau Tarbes | 9 | - | - | 5 |
| Bayonne <-> Pau Tarbes | 5 | - | - | 0 |
| Dax <-> Pau | 12 | - | - | 0 |
| **Number of trainsets for retrofit scenario1** | 21 | 22 | 6 | **49** |
| **Cost M€ (€ 2020)** | 5,52 | 11,09 | 7,09 | **23,70** |
| **Number of trainsets for retrofit scenario2** | 11 | 22 | 6 | **27** |
| **Cost M€ (€ 2020)** | 3,76 | 11,09 | 7,09 | **21,93** |

*Table 34: CAPEX costs for passenger trains retrofit*

For freight we added the retrofit due to new freight international services introduced for 2030.

| **Freight service France and international** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Actual service in France** | | BB 26000/ 27000 | BB 60000 | BB 75000 | BB 37000 | EURO 4000 | TRAXX F140 | |
| Number of retrofit for actual services | | 13 | 2 | 2 | 8 | 1 | 3 | |
| **Projected service in 2030** | number | | | | | | | |
| Conventional and intermodal freight (international) | 18 | | | | | 36 | | |
| Autoroute ferroviaire Vitoria-Dourges | 8 | | | | | | 16 | |
| Conventional and intermodal freight (France) | 8 | | | | 6 | | | |
| **Number of trainsets for retrofit scenario 1 and 2** | | 13 | 2 | 2 | 14 | 37 | 19 | **87** |
| **Cost M€ (€ 2020)** | | 7,56 | 3,12 | 3,62 | 11,16 | 14,94 | 8,57 | **48,98** |

*Table 35: CAPEX costs for freight trains retrofit*

#### *5.1.4.2 CAPEX OBU equipment for Spanish side*

For passenger and freight trains, the following services have been considered, both current and projected future services. ALVIA 120 is already ERTMS equipped.

In the future service, due to the fact that which is the rolling stock that will be used for each type of service, we estimate that it will be carried out with the series most used today.

It should be noted that the ALVIA 120 series is already ERTMS equipped.

| | **Daily trains** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Passengers Daily trains** | **Cercanías** | | **Medium-distance** | | | | | **Long-distance** | | | |
| **Type of service** | **Cercanías** | | **Regional Express** | | | **Medium Distance** | | **Tren Hotel** | **Intercity** | **Alvia** | |
| **Series** / **Route (one way)** | **446** | **447** | **447** | **449** | **470** | **449** | **470** | **252** | **252** | **120** | |
| Miraflores - Miranda de Ebro | | | | | **1** | | | | | | |
| Lisboa-San Sebastián- Hendaye | | | | | | | | **1** | | | |
| Intermodal Abando Ind.Prieto - Miranda de Ebro | | | | | | | | | **1** | **2** | |
| Barcelona(Sants) - San Sebastián | | | | | | | | | | **2** | |
| Madrid (Chamartín) - San Sebastián | | | | | | | | | | **2** | |
| Castejón de Ebro - Intermodal Abando Ind.Prieto | | | | | | | | | | **2** | |
| Madrid (Príncipe Pío) - San Sebastián | | | | | | **2** | | | | | |
| Pamplona - Miranda de Ebro | | | | | **1** | | | | | | |
| A Coruña -San Sebastián | | | | | | | | | **1** | | |
| Pamplona - Vitoria | | | | | **1** | | | | | | |
| Madrid (Chamartín)- Vitoria | | | | | | | | | | **1** | |
| Madrid (Príncipe Pío) - Vitoria | | | | | | **1** | | | | | |
| Irún - Vitoria | | | **1** | | | | | | | | |
| Miranda de Ebro - San Sebastián | | | | **1** | | | | | | | |
| Miranda de Ebro - Burgos | | | | | **1** | | | | | | |
| San Sebastián - A Coruña | | | | | | | | | **1** | | |
| Vitoria - Castejón de Ebro | | | | | **1** | | | | | | |
| Vitoria - Miranda de Ebro | | | | | **1** | | **1** | | | | |
| Orduña - Bilbao | **42** | | | | | | | | | | |
| San Sebastián - Irún | | **20** | | | | | | | | | |
| **Number of trainsets for retrofit** | **15** | **8** | **No** | **1** | **3** | | | **2** | **1** | **No** | |
| **Projected service in Spain 2030** | | | | | | | | | | | |
| Long-distance | | | | | | | | | | **8** | |
| Medium-distance | | | | | | **27** | | | | | |
| Regional | | | | | **54** | | | | | | |
| Cercanías | **38** | | | | | | | | | | |
| **Number of trainsets for retrofit** | **9,5** | | **No** | | **18** | **13,5** | | | | | |
| **Cost M€ (€ 2020)** | **10,52** | **2,08** | | **0,24** | **5,04** | **3,24** | | **0,48** | **0,24** | **No** | **21,83** |

*Table 36: CAPEX costs for passenger trains retrofit*

| Freight : daily trains | Freight locomotive | | | | |
|---|---|---|---|---|---|
| **Type of service** | **253** | **333** | **335** | **601E** | |
| Bilbao Mercancías - Miranda de Ebro | 4 | 1 | 3 | 1 | |
| Miranda de Ebro - Bilbao Mercancías | 5 | | 4 | 1 | |
| Irún - Júndiz | 2 | | | | |
| Júndiz - Irún | 3 | | | | |
| Altsasu - Hendaya | 2 | | | | |
| Hendaya - Júndiz | 1 | | | | |
| Altsasu - Lezo Rentería | 4 | | | | |
| Lezo Rentería - Altsasu | 3 | | | | |
| Altsasu - Júndiz | 3 | | | | |
| Júndiz - Altsasu | 1 | | | | |
| Irún - Pasaia | 1 | | | | |
| Pasaia - Irún | 1 | | | | |
| **Number of locomotives for retrofit** | 10 | | 2 | 1 | |
| **Projected service in Spain 2030** | | | | | |
| Fret conventionel & TC (UIC) | 18 | | | | see french side |
| Autoroute ferroviaire Vitoria-Dourges | 8 | | | | see french side |
| **Number of locomotives for retrofit** | 16 | | 2 | 1 | |
| **Cost M€ (€ 2020)** | **7,21** | | **2,75** | **2,30** | **12,26** |

*Table 37: CAPEX costs for freight trains retrofit*

### 5.1.5 Economic synthesis

The economic synthesis is given in the two flowing tables considering the agglomeration of CAPEX and OPEX costs for on track ERTMS implementation and CAPEX costs for on board implementation.

| | Reference | | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|---|---|
| CAPEX | Interlockings France M€ | 421 | Interlockings France | 278 | Interlockings France | 437 |
| | Block France M€ | 346 | Block France | 251 | Block France | 327 |
| | | | ERTMS N1 France | | ERTMS N1 France | 69 |
| | | | ERTMS N2 France | 74 | ERTMS N2 France | 62 |
| | ERTMS Sp Y Vasca M€ | 161 | ERTMS Spain | 195 | ERTMS Spain | 195 |
| | TOTAL | 927 | TOTAL | 798 | TOTAL | 1 089 |
| CAPEX | Delta Scenario - Reference | | Scenario 1 - REF | -129 | Scenario 2 - REF | 162 |
| OPEX | French side M€ | 155 | French side | 126 | French side | 152 |
| | Spanish side M€ | 26 | Spanish side | 32 | Spanish side | 32 |
| OPEX | BALANCE OPEX | | Positive : YES | -24 | Positive : NO | 3 |
| CAPEX + OPEX | TOTAL IM | | Positive : YES | -153 | Positive : NO | 165 |
| CAPEX ON BOARD | | | On Board France | 72,7 | On Board France | 70,9 |
| | | | On Board Spain | 34,1 | On Board Spain | 34,1 |
| | | | Total Scenario 1 | 107 | Total Scenario 2 | 105 |
| Global Balance IM + UTK | | | Positive : YES | -46 | Positive : NO | 270 |

*Table 38: Economic synthesis in constant € 2020*

| | Reference | | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|---|---|
| CAPEX | Interlockings France M€ | 199 | Interlockings France | 173 | Interlockings France | 216 |
| | Block France M€ | 161 | Block France | 199 | Block France | 163 |
| | | | ERTMS N1 France | | ERTMS N1 France | 54 |
| | | | ERTMS N2 France | 68 | ERTMS N2 France | 53 |
| | ERTMS Sp Y Vasca M€ | 140,9 | ERTMS Spain | 171 | ERTMS Spain | 171 |
| | TOTAL | 501 | TOTAL | 611 | TOTAL | 657 |
| CAPEX | Delta Scenario - Reference | | Scenario 1 - REF | 110 | Scenario 2 - REF | 156 |
| OPEX | French side M€ | 85 | French side | 71 | French side | 85 |
| | Spanish side M€ | 12 | Spanish side | 15 | Spanish side | 15 |
| OPEX | BALANCE OPEX | | Positive : YES | -11 | Positive : NO | 3 |
| CAPEX + OPEX | TOTAL IM | | Positive : NO | 99 | Positive : NO | 159 |
| CAPEX ON BOARD | | | On Board France | 46,8 | On Board France | 45,7 |
| | | | On Board Spain | 22,0 | On Board Spain | 22,0 |
| | | | Total Scenario 1 | 69 | Total Scenario 2 | 68 |
| Global Balance IM + UTK | | | Positive : NO | 167 | Positive : NO | 226 |

*Table 39: Economic synthesis NPV 4,5%*

These syntheses give confirmation of the fact that the best scenario is scenario 1 given other advantages analysed in the next chapter § 3.2.

## 5.2 ANALYSIS OF THE OTHER EFFECTS OF ERTMS DEPLOYMENT

### 5.2.1 Capacity in nodes and on line:

#### *5.2.1.1 Capacity in nodes*

##### 5.2.1.1.1 UIC references

The effect of train operation using ETCS on capacity consumption has been studied first by UIC. A study was commissioned in 2010 on the influence of ETCS on the capacity of important nodes. The examples of Munich (DB) as a dead-end station and Bern (SBB) as a transition station were modelized.

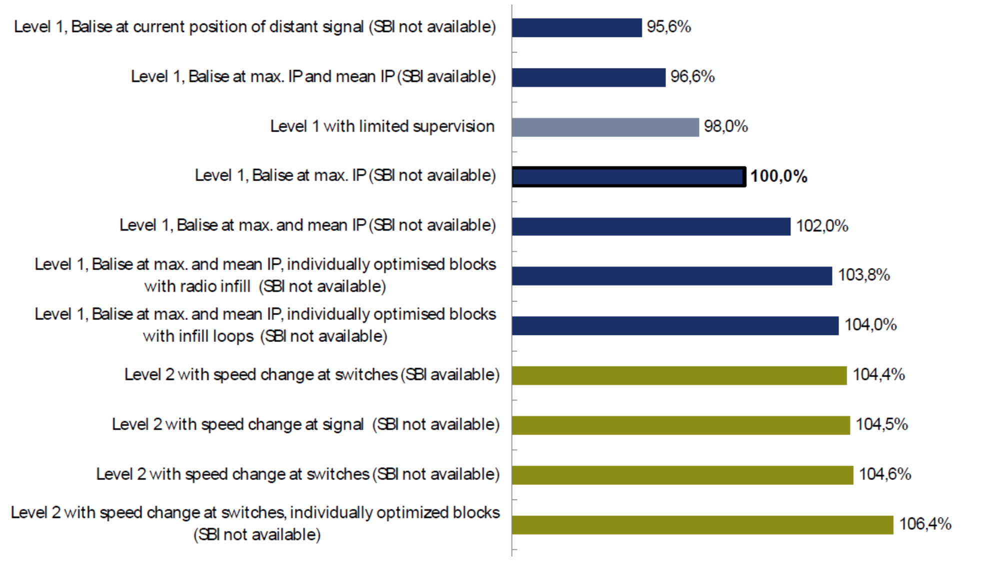



*Figure 25: Results of UIC analysis for different ETCS configurations*

The effect of ETCS level 2 on the capacity considering that the two studied stations are already optimized gives a capacity increase of 11%.

In France we have collected data on 3 studies and we give a synthesis of results hereunder

##### 5.2.1.1.2 Lyon node (Rail Concept study)

We have studied the implementation on Lyon node in different configurations with different increase of the path number in Part Dieu.

If the capacity created by ERTMS is used only for the benefit of regularity without increasing train paths, this gain in regularity is maximum

On the contrary, the more capacity we use to create new train paths, the less the gain in regularity is important.

The following table, which is a summary of the study, clearly reflects this double effect linked to ERTMS L2.

| Station Part Dieu | Situation without ERTMS | Different configurations of grid with ERTMS | | |
|---|---|---|---|---|
| | | Situation E1<br>No new paths | Situation E3<br>With new paths | Situation E4 with more new paths |
| Number of train path per hour | 45 | 45 | 51,5 | 57 |
| Train path increase | | 0% | + 14% | + 27 % |
| Delay reduction (% of mn) | | - 34% | - 27% | - 10% |

*Table 40: Capacity and regularity increase with ERTMS L2 on Lyon node*

##### 5.2.1.1.3 Rennes node (Other consulting study)

The study on Rennes node was only a capacity analysis to determine the number of possible new paths with ERTMS L2 implementation in the station

| | Number of train paths without ERTMS | Additional train paths with ERTMS L2 |
|---|---|---|
| Train paths Towards St Malo | 4 | 2 |
| Train paths towards St Brieuc | 6 | 1 |
| Train paths towards Laval | 8 | 2 |
| Train path towards Redon | 6 | 2 |
| Total | 24 | 7 represents + 29% |

*Table 41: Capacity increase with ERTMS L2 on Rennes node*

The capacity increase can be + 29% if all new train paths are activated. If not, regularity will also increase.

##### 5.2.1.1.4 Nantes node (Other consulting study)

The study on Nantes node has considered the gain in capacity linked to the reduction in the blocking of trains entering or leaving Nantes station.

The following table illustrates the reduction for the blocking times in all directions.

| | With conventional BAL system | With ERTMS L2 |
|---|---|---|
| Blocking time between trains **same direction** | 4 mn | 3 mn |
| Blocking time between trains entering and leaving (opposite direction on **West side** of the station) | 6 mn | 4mn 30 |
| Blocking time between trains entering and leaving (opposite direction on **East side** of the station) | 7 mn | 5 mn |

*Table 42: Capacity increase with ERTMS L2 on Nantes node*

In the case of Nantes, the reduction in headways was used to improve the operational robustness of the node.

#### 5.2.1.2 Capacity on line

The capacity increase on a conventional line due to ERTMS L2 without signals can be justified the decrease of spacing between trains because

- The system considers the actual speed of the train and its actual braking capacity, and not the position of the train and the braking capacity of the train with the worst braking device likely to travel the line,
- and that the driver is informed in quasi real time by EVC (10s to 20s of information exchange are necessary) of the release of a block by the train in front of him without waiting to be in sight of the next signal.

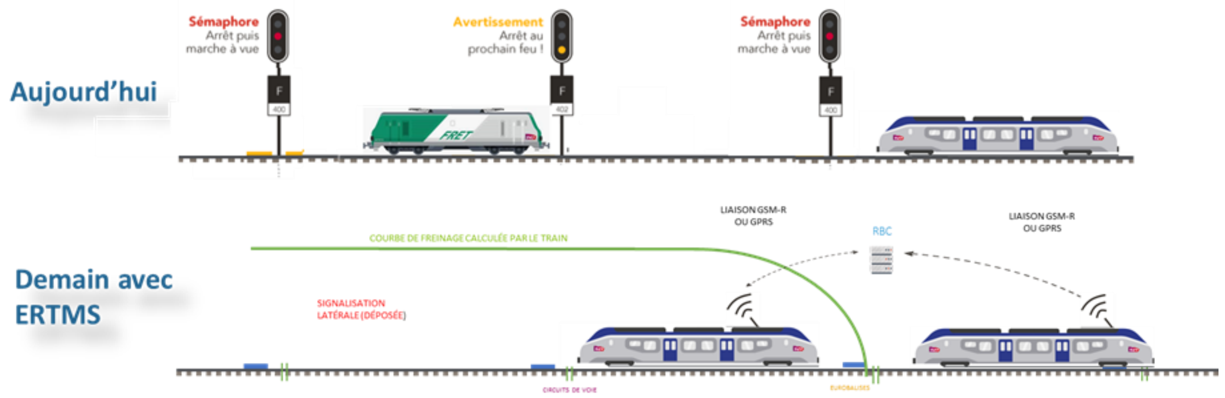



*Figure 26: Illustration of the spacing reduction with ERTMS L2.*

With ERTMS L2, the train will itself calculate, depending on its braking capacity, the right time to notify the driver the warning indication in the cabin, at the distance that will allow him to stop before the stop signal delimiting the entry point into the block occupied by the previous train.

An application to Marseille Vintimille section indicates the headway reduction obtained with ERTMS L2 for different train categories on different sections (considering the block performance and the suppression of VISA system).

| Section | Train path category | Headway with BAL system (minutes) | Headway with ERTMS L2 (minutes) |
|---|---|---|---|
| Marseille Toulon | High speed TGV | 4’ | 3’ |
| | Regional train | 5’30” | 4’30” |
| | Freight train | 5’ | 4’ |
| Toulon Les Arcs | High speed TGV | 3’30” | 2’30” |
| | Regional train | 7’ | 4’30” |
| | Freight train | 6’ | 4’ |
| Les Arcs St Raphael | High speed TGV | 3’30” | 2’ |
| | Regional train | 7’30” | 4’ |
| | Freight train | 5’ | 3’ |
| St Raphael Cannes | High speed TGV | 4’ | 2’30” |
| | Regional train | 7’30” | 4’30” |
| | Freight train | 6’ | 4’ |
| Cannes Nice | High speed TGV | 4’ | 3’ |
| | Regional train | 7’30” | 6’30” |
| | Freight train | 5’ | 4’ |
| Nice Vintimille | High speed TGV | 5’ | 3’30” |
| | Regional train | 8’ | 6’30” |
| | Freight train | 6’ | 5’ |

*Table 43: Headway reduction with ERTMS L2 on Marseille Vintimille section*

On this section the traffic density varies greatly depending on the section with a larger number of trains in Marseille and around Nice

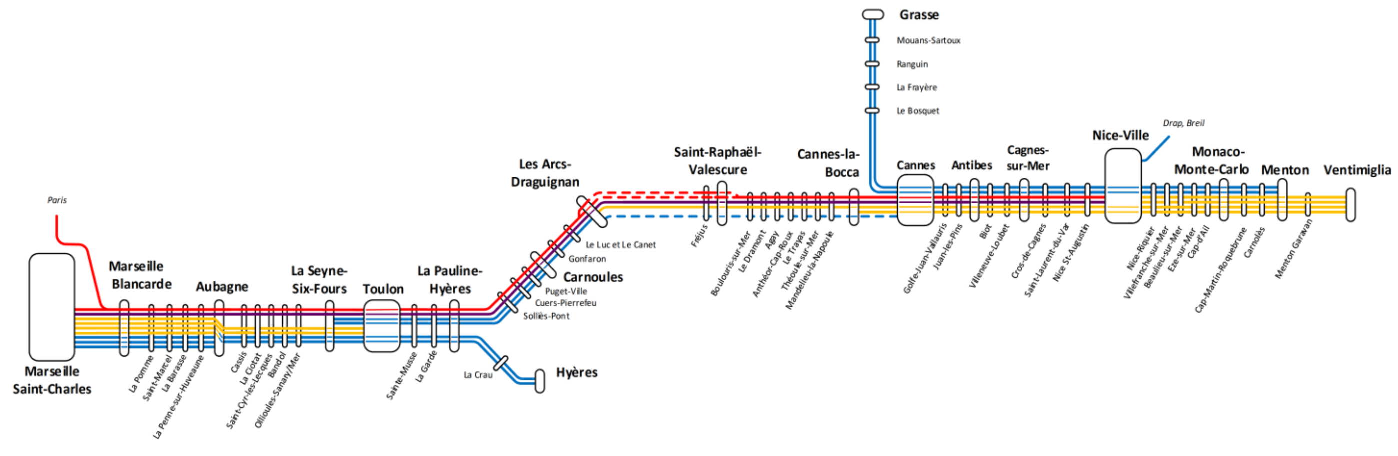


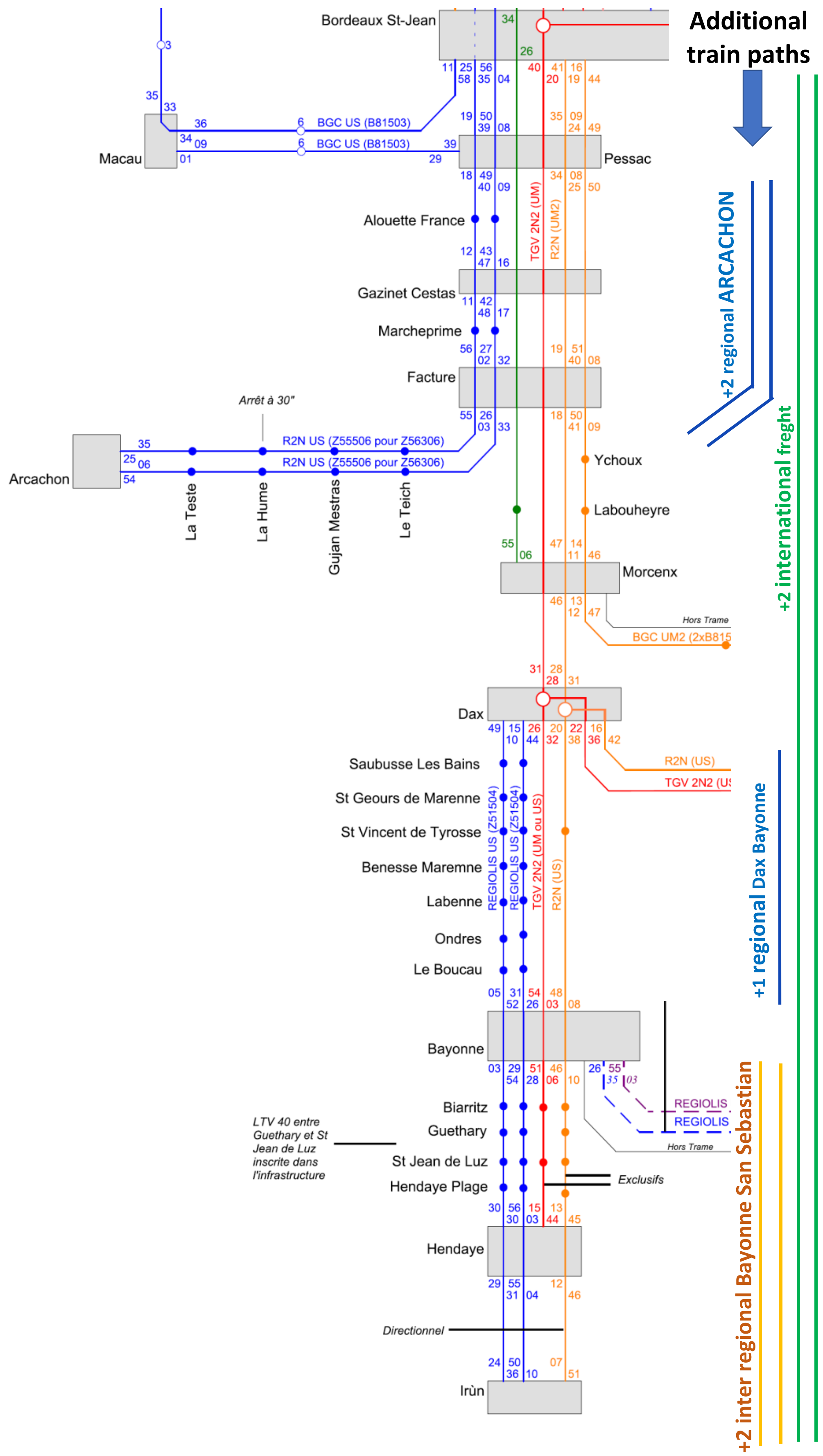

*Figure 27: Traffic grid on peak hour*

The choice can be to add train paths or to improve the operational robustness or to make a combination of the two solutions.

The capacity increase is 25 to 33 % depending on the sections including some effects due to redevelopment of track plans. It allows to add one or two train paths in Marseille or Nice nodes.

Without any train path addition, the impact of unit incidents in ERTMS is less than in BAL, mainly for delays of less than 5 min (-50% on average). The decrease is also noticeable in terms of the number of trains affected in all incidents (-32% on average for delays of less than 5 minutes).

### 5.2.2 Application to Bordeaux Hendaye section




Our experience on the different studies already performed with ERTMS L2 implementation can be transposed on Bordeaux Hendaye section.

ERTMS N2 appears to be the only valid solution to add the train path necessary for the future service:

- Two train paths for international freight
- Two additional train paths for Arcachon on peak hour
- One additional train path between Dax and Bayonne
- Two additional train paths for the new service Bayonne San Sebastian
- The TGV train path to Hendaye will be continued till Bilbao and Madrid.

### 5.2.3 Application to Vitoria Irun section

The section where the traffic is maximal is between San Sebastian and Irun. As example, the maximal grid on the Bayonne San Sebastián would be the following one, according to the extra train paths to be created.

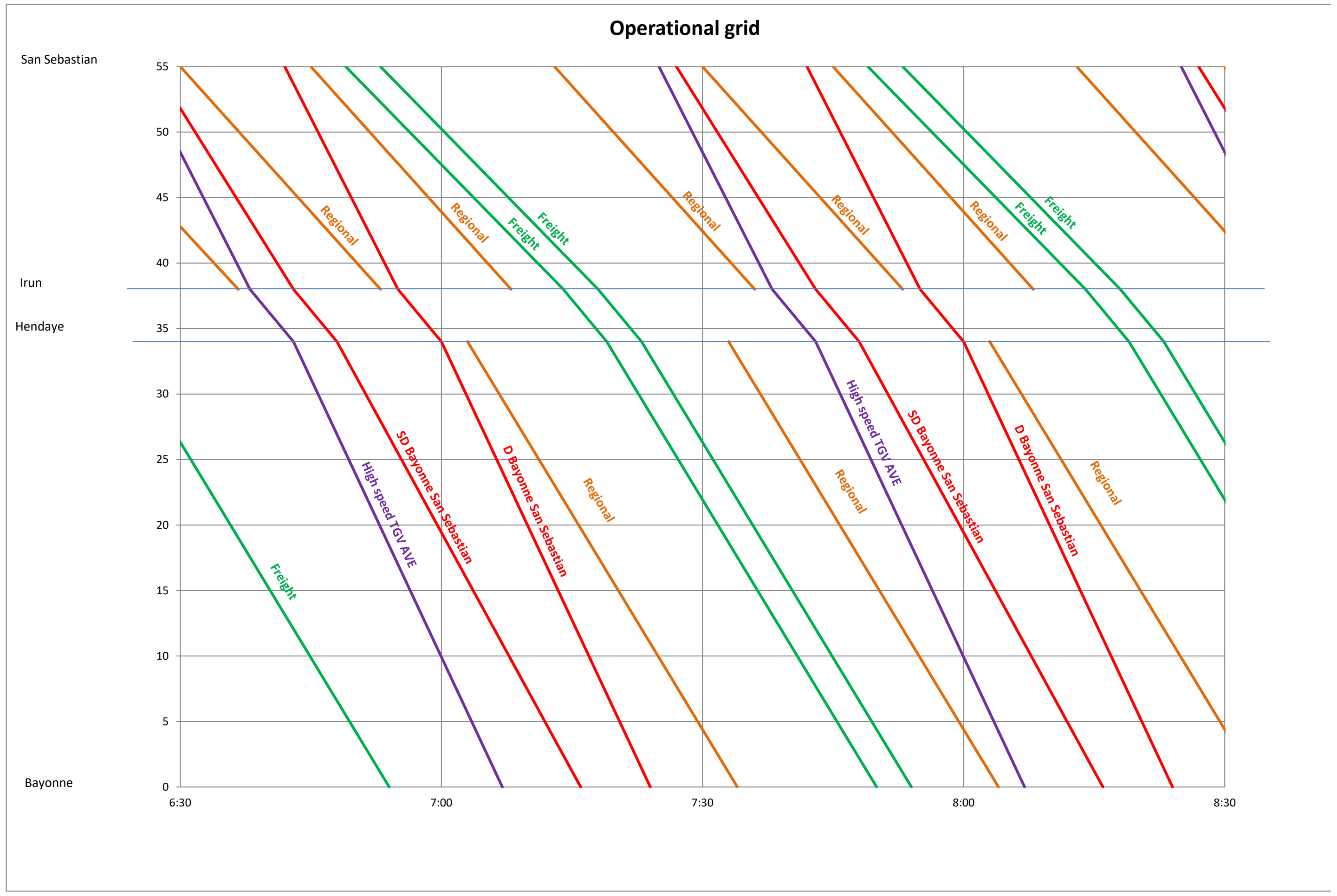
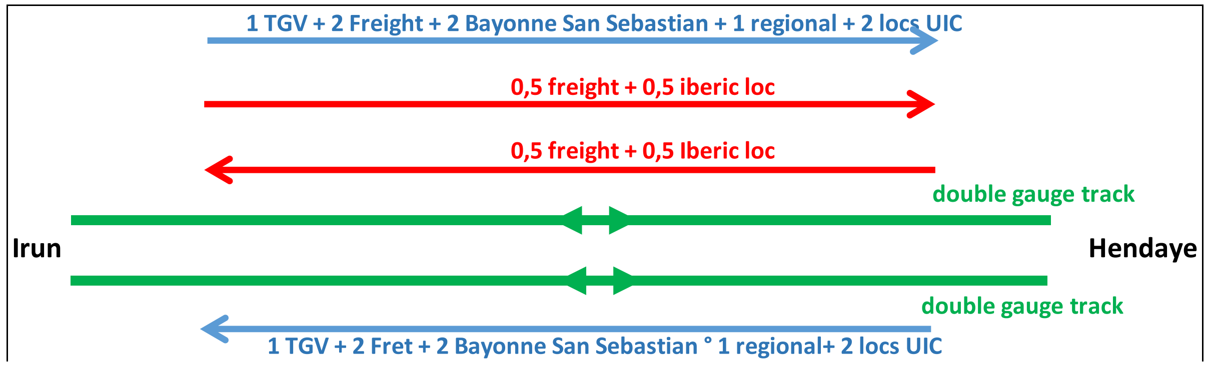



*Figure 28: Operational grid in 2030 on Bayonne San Sebastian section*

As analysed in different lines in Spain using the ERTMS impact assessment method on capacity based on the UIC 406 code, it has been shown that the use of ERTMS level 2 system compared to the use of lateral signals with ASFA signalling systems increases the line capacity by 70% even if the maximum operating speed in high-speed lines is 300 Km/h versus 200 Km/h in conventional / lateral signalling plus ASFA lines. This method has been applied to quantify the capacity of the different types of lines included in the Spanish implementation plan depending on the signalling system currently installed and the one that is expected to be installed, in order to evaluate whether it will be possible to assume all the current and future demand for these lines.

### 5.2.4 Application to border section Irun Hendaye

The transit times for trains paths and locomotive exchanges are convenient, even with new train paths crossing the border.



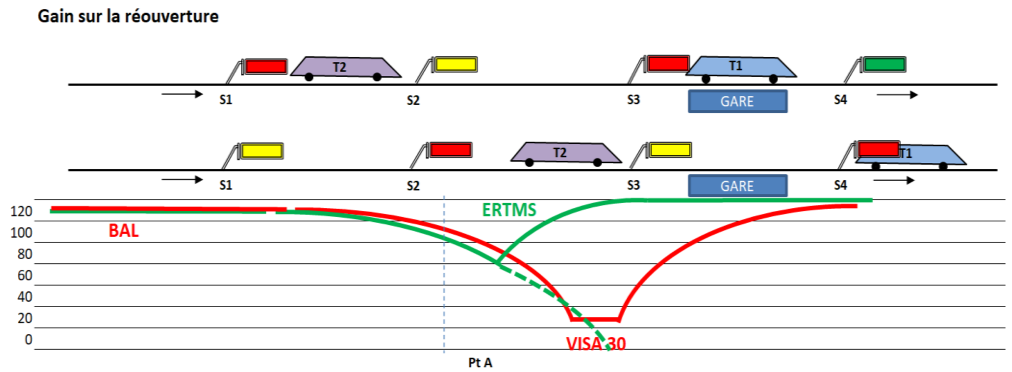

| | Temps d'occupation | |
|---|---|---|
| | Mix gauge track South => North | UIC Track North => South |
| 1 TGV UIC | 5mn | 5 mn |
| 2 freight UIC | 10 mn | 10 mn |
| Bayonne San Sebastian + regional | 15 mn | 15 mn |
| 2 locs UIC | 8 mn | 8 mn |
| Additional time North => South for crossing locs UIC | | 4 mn |
| 0,5 freight loc Iberic gauge | 5 mn | |
| 0,5 freight loc Iberic gauge | 4 mn | |
| TOTAL | 47 mn (78%) | 42 mn (70%) |

*Figure 29: Occupation chart on Bidassoa bridge for 2030*

In scenario 1, the occupation times will be notably reduced by the introduction of ERTMS L2. In scenario 2 with ERTMS L1 at the border, the situation will remain the same as BAL / ASFA situation.

### 5.2.5 Punctuality:

As it was previously exposed, ERTMS L2 implementation provides an advantage on the resolutions of disturbed situations and therefore on punctuality. The effect has been quantified in order to value the time saved on situations of chain delays.




Reopening at point A when train T1 has cleared signal S4:
BAL: the KVB requires the driver to respect the VISA until crossing open signal S3
ERMTS: the release information is transmitted to the train which can recover its speed before crossing the S3

*Figure 30 : better recuperation after a stop signal with ERTMS*

In the case of Vitoria Bordeaux section, as train paths have been added to meet demand in 2030, the gain in punctuality will not be maximum. By considering that the number of train paths has been increased by 30 to 50%, the gain in regularity will be minimal. However, it should be emphasized that the immense advantage provided will be to allow the addition of train paths without degrading the regularity or even improving it on certain sections.

The advantage offered by ERTMS L2 to be able to drive in the opposite direction without special provisions could be important for punctuality issues if there is obstruction on one track or to facilitate works on track. However, these reverse itineraries must be made possible by:

- the existence of points allowing these routes
- the creation of these routes in the interlocking installations

### 5.2.6 Travel time

The two main aspects that determine travel time are:

- The maximum speed, which directly influences the typical running of a line. The higher the speed allowed, the shorter the travel time on a line. One of the factors that influences the maximum speed of a line is the design of the infrastructure. However, infrastructure limitations or the type of trains operated may prevent a line from being operated at the maximum speed allowed by the signalling and train protection system.
- Impact on the regularity of traffic on lines with high demand. This high demand can have an impact on the typical running of a line, increasing travel time. Depending on the signalling system used, this high demand will have a greater or lesser impact on travel time.

This parameter is not a sensitive issue, despite it may appear in some situations. It is possible to save one or two minutes at the entrance of major stations such as Bordeaux or San Sebastian.

### 5.2.7 Reliability

Reducing the number of trackside equipment (signals and detectors) their regeneration improves the reliability of safety installations, which can be quantified.

We have already demonstrated on equivalent sections that the ERTMS L2 system would reduce the number of minutes lost for signalling incidents by 20 to 25%.

In Spain, as specified in section 4.2.1 of the ETI 2016/919 on control, command and signalling, during the useful life of the subsystems, the infrastructure managers and the railway operators supervise, the compliance of the reliability values used to define the procedures for the management of possible degraded situations. Directive 2016/797 in line with the TSI CCS 2016/919 indicates as a general requirement that the surveillance and maintenance of fixed and mobile elements that intervene in the movement of trains must be organized, carried out and quantified in a way that guarantees their operation under expected conditions. Any problem that the train has had due to a malfunction of the on-board equipment is considered an incident, and within these incidents, the so-called contractual incidents are those that have caused the train to be delayed more than 5 minutes.

Due to the fact that for each line the level of failures may be different, as an example an analysis is shown, included in the ERTMS National Strategic Plan of 2017, of the reliability values monitored in the Madrid commuter trains that operate in the 2 predominant signalling systems in the network

| Signaling system | Total distance travelled in 2016 (km) | No. impact incidents> 5 minutes in 2016 | No. impact incidents < 5 minutes in 2016 | Reliability value (Mean Kilomters Between Failures) |
|---|---|---|---|---|
| ERTMS | 18.159.269 | 5 | 15 | 907.963 |
| ASFA | 36.490.889 | 109 | 34 | 255.181 |

*Figure 31: Mean Kilometres Between Failures*

### 5.2.8 Safety

KVB system is a safety system with SIL 2 conception but without continuous control of the train.

ASFA Digital is a SIL4 in its on-board central unit but on the contrary it´s an analog system on its way of receiving the information from the track by punctual transmission (1 data per balise passed over). It provides semi continuous (static) on-board speed controls and protection against SPADS but requires the driver´s attention in combination with the lateral signalling. I.e. lost balises do not impact on the on-board equipment so the driver must always obey the signals. That is why ASFA is considered a driving support system and limited to a maximum operating speed of 200 Km/h.

Both ERTMS L1 and ERTMS L2 offer the great advantage of providing a continuous monitoring of ETCS braking control curve in SIL 4 process for the whole system track and train (dynamic braking curves and Movement Authority - MA). This continuous control of the train, since there is always radio communication (jn case of Level 2) with the train, allows each change of track to be sent to the train immediately, with an increase in funcitionality against the ASFA and KVB systems.

### 5.2.9 Operating costs of railway companies

Having locomotives with a single control and command system obviously allow to reduce costs. This element also reduces the need for drivers to change over due to a single driving mode between origin and destination, the only need relating to driving time.

But it should be remembered that the purchase of new interoperable locomotives induces an additional capital cost of 15 to 20% which must then be amortized within the framework of operating costs; therefore, the operation is almost neutral on the financial level.

### 5.2.10 Operational opportunities

The ERTMS system provides continuous monitoring of traffic, including the one between substation areas, and facilitating the centralization of regulation.

### 5.2.11 Operating and maintenance costs of infrastructure operators:

The savings made due to control station and command centralization, and maintenance savings have be valued (OPEX costs) in the previous chapter. The costs savings can be of 10 to 20 %.

### 5.3 CONCLUSION AND PROPOSITION OF IMPLEMENTATION SCENARIO

In scenario 1, the use of ERTMS L2 on a major part of the perimeter, compared to traditional signalling systems has great advantages, such as the increase in capacity on the lines, allowing it to respond to the growing transport demands. This means that being a system based on continuous communication reduces the range of the trains and therefore greatly increases the capacity of the line.

This scenario shows an economic advantage compared with the reference situation that corresponds to expenses to be incurred by the Infrastructure Managers ADIF and SNCF Réseau independently of ERTMS implementation.

Another of the most crucial parameters of the use of this technology is reliability, punctuality and safety, causing these to increase significantly and make the railway system have fewer incidents in the service and improve its quality.

Scenario 2 is economically worst in constant and discounted euros and for the sections on which ERTMS L1 is deployed for the first 30 years, none of the advantages provided in scenario 1 are benefited from.

**Therefore, we propose to retain the scenario 1 for ERTMS Level 2 implementation on the perimeter Vitoria Bordeaux.**

In constant €, this scenario represents an overall advantage of 129 M€ for infrastructure (compared to reference) and even with an additional expenditure of 107 M€ for Rolling stock retrofit, it remains positive of 46 M€ compared to the reference situation (compulsory network expenses for natural renovation).

In discounted euros, due to the economic weight of earlier expenses, the expenditure ascends to

- 98 M€ (NPV) for infrastructure (roughly equivalent to the extra cost of ERTMS – 68M€ in France and 31 M€ in Spain)
- and 69 M€ for rolling stock retrofit
- a total of 168 M€.