Final Report
November, 2016

Measuring and upgrading the clearance gauge of railway lines:

Market Study and Feasibility Study

Contract number – MOVE/B2/SER/2013-825

November - 2016
Ref. No. FR01T15B62/DCO/EU/34-16

EUROPEAN COMMISSION

Directorate-General for Mobility and Transport
Directorate B – European mobility network
Unit B2-Single European railway area

Contact: Frank Jost

E-mail: Frank.Jost@*ec.europa.eu*
MOVE-B2-SECRETARIAT@*ec.europa.eu*

European Commission
B-1049 Brussels

Document authorship and approval		
v. 1.0		
Author	Verification	Approval
Pierre Maizy (SYSTRA) Clément Ruel (SYSTRA)	Pierre-Etienne Gautier (SYSTRA) Pierre Maizy (SYSTRA)	Pierre-Etienne Gautier (SYSTRA)
v. 2.0		
Pierre Maizy (SYSTRA) Clément Ruel (SYSTRA)	Pierre-Etienne Gautier (SYSTRA) Pierre Maizy (SYSTRA)	Pierre-Etienne Gautier (SYSTRA)
v. 3.0		
Author	Verification	Approval

TABLE OF CONTENTS

The information and views set out in this document are those of the authors and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

1. INTRODUCTION

The current document is part of the final report for the Study on Measuring and Enlarging Railway Clearance Gauges. This study has been mandated by the European Commission, Directorate-General for Mobility and Transport, with the following primary objectives in mind:

- Create transparency on the access conditions of railway lines
- Attract additional freight traffic for rail according to real markets
- Open the rail freight market by removing unnecessary clearance gauge restrictions, and exploit economies of scale by giving wider network access to vehicles built to standard gauges
- Strengthen demand-oriented infrastructure development
- Identify the most profitable bottlenecks to act on
- Identify how current practice and standards with regards to gauge could be simplified/ revised for increase efficiency in solving gauge questions

The study works toward these objectives via the development of a best-practice guide with procedures for the revision of line codifications, with a view to upgrade line characteristics in a pilot program

The study activities are broken up into 6 distinct work packages (WP), as illustrated in the figure below.

	Description	WP Deliverables (integrated into contractual deliverables)
WP 1	Assessment of existing clearance gauge information systems	• Information on current data and procedures • Recommendations for EU policy makers
WP 2	Assessment of procedures to measure and enhance clearance gauge information	• Report including the state of the art and current rules and procedures to measure railway gauge, enlarge railway gauge, to revise the codification of railway
WP 3	Market study, resulting in selection of 2 to 6 gauge enlargement links	• Market study including the identification of flows and line sections where gauge is particularly problematic, the definition of the target commercial gauge for operators, and traffic forecasts
WP 4	Measurement campaign	• Report including the description of the tests conducted, the data collected and its analysis, the validation of the procedures to measure and enlarge railway gauge
WP 5	New gauge standard and Best practice guide	• Definition of new kinematic reference contour & infrastructure gauge • Best Practice Guide and report with the results of the previous tasks, proposed structures and harmonized rules • Identification of necessary modifications to UIC standards
WP 6	Feasibility study and cost benefit analysis (CBA)	• A report including a feasibility study and a Cost Benefit Analysis to prepare for the civil engineering works for enhancing the gauge on 2-3 selected sections identified in the market study

Figure 1 – Breakdown of the 6 work packages

The results of all the work produced within these 6 packages can presented in three major parts:

- An opportunity and feasibility of gauge enlargement operations, which corresponds to the WP 3, 4, 5 and 6
- Assessment of existing information systems and procedures for gauge measurement and enhancement, which corresponds to the WP 1 and 2
- A Best Practice Guide, which presents recommendations stemming from this whole study

The final report of this study consists of three documents, each of which is related to one of the parts above.

This document presents the results of the first part: the opportunity and feasibility study.

2. ABSTRACT AND EXECUTIVE SUMMARY

2.1. Abstract

NB: The following abstract covers the whole study.

2.1.1. English

This study deals with the question of rail freight clearance gauges in several ways.

A feasibility study identifies the bottlenecks of the European network where an enhancement in the gauge would make it possible to develop combined transport in the medium term, by increasing the modal share of rail in traffics. The appropriateness of such work has been studied through economic and financial evaluations. An increase in the permissible gauge on the Rhone Valley and on Perpignan-Barcelona then seems to present a very interesting potential in terms of development of rail freight activity.

An assessment also presents the practices of the infrastructure managers concerning their management of the clearance gauge: knowledge of the actual gauge using measurements, procedures implemented in response to requests from railway undertakings, monitoring of the infrastructure information and communication of this information to customers, in particular via the Network Statements.

Finally, a Best Practice Guide presents recommendations in terms of regulations, based on these assessments, in order to smoothen interactions between the different stakeholders, to facilitate access to the rail network by customers and ultimately to develop rail freight business.

2.1.2. French

Cette étude sur la question des gabarits pour le fret ferroviaire aborde le sujet sous plusieurs aspects.

Une étude de faisabilité identifie les points du réseau européen où une amélioration du gabarit permettrait de développer le transport combiné à moyen terme, en augmentant la part du rail dans les trafics. L'opportunité de tels travaux a été étudiée au moyen d'évaluations socio-économique et financière. Une augmentation du gabarit admissible sur la Vallée du Rhône et sur Perpignan-Barcelone semble alors présenter un potentiel très intéressant en termes de développement du fret ferroviaire.

Un état des lieux présente également les pratiques des gestionnaires d'infrastructure à propos de leur gestion du gabarit sur leurs réseaux : la connaissance du gabarit via des mesures, les procédures mises en œuvre en cas de sollicitation par une entreprise ferroviaire, la conservation de l'information et la communication de cette information aux clients, notamment via les Documents de Référence du Réseau.

Enfin, un Guide des Bonnes Pratiques présente des préconisations en termes de règlementation, partant des observations réalisées, afin de fluidifier les interactions entre les différents acteurs, faciliter l'accès au réseau ferré par les clients, et à terme développer le transport de marchandises sur rail.

2.2. Executive summary

NB: The following executive summary only covers this document.

2.2.1. English

The purpose of this feasibility study is to identify sections of the European rail network for which an upgrade of the maximum permissible gauge would permit a significant development of combined transport traffic at an international level.

The first step consists in a market study to pinpoint network's bottlenecks which require a gauge improvement to develop long-distance traffic. This approach was based on an analysis tracks' technical profiles provided by the Network Statements and through interviews with railway undertakings, infrastructure managers and rail freight corridor managers.

Several sections were selected after a preliminary analysis:

- Tunnels of the Vosges
- Meaux-Epernay line
- Dijon-Mulhouse line
- Rhône Valley line
- Perpignan-Barcelona line

Discussions with railway undertakings and combined transport operators also permitted to define the target gauge to reach which is the P400. It allows any type of combined transport (especially semi-trailers) and makes possible an important modal shift from road to rail.

After defining the sections to improve and identifying the target gauge, a new series of interviews with railway undertakings and operators led to assess the potential traffic growth resulting from these improvement projects.

The benefits generated by these deviations to rail (savings for shippers, reductions in truck traffic and its impact, in particular on environmental effects) have been taken into account for the economic and financial analysis.

Alongside with these expected benefits, the investment costs were estimated according to the following method.

3D measurements were carried out on the 5 lines selected, in order to describe precisely the geometry of the obstacles faced on the lines. This information made possible to determine which sections were compatible with the P400 and which were not. They were determined through virtual overlapping of the current contours of the infrastructure with the dynamic envelope of a trailer-wagon system. It resulted in the identification of the section parts with overlapping between the rolling stock profile and the infrastructure. This dynamic envelope was designed by applying the usual safety rules of SNCF engineering offices to the particular case of a 4 m-high trailer loaded on a 33 cm-high pocket wagon as the P400 is defined.

An analysis of the technical feasibility of the work was carried out focusing on the tunnel lengths concerned by these profile overlapping and according to the corresponding depth. The volume of infrastructure to be dealt with was deduced. For the work processes, two types of techniques have been proposed: working on the tunnel vault, to release volume at the overlapping areas (the upper corners of the trailers), or lowering of the roadbed. The investments estimated feed the socio-economic and financial evaluations.

Several scenarios have been designed for these assessments. They depends on the markets benefiting from the gauge upgrade on the chosen sections. It seemed appropriate in some cases to increase the permissible gauge on a batch of sections at the same time in order to open longer railway routes for wide-gauge transport.

The economic appraisal includes the costs of the project, its benefits by stakeholder but also the non-monetary effects, with first and foremost the environmental benefits. The purpose of it was to quantify the social and economic profitability of the each project component, in other words its interest, beyond the financial aspects, for the society as a whole.

A lower cost of the work and a more significant traffic captured defines labels an interesting project of permissible gauge upgrade. As a result, the joint treatment of the sections of the Rhone Valley and Perpignan-Barcelona appears to be the most profitable scenario, given the moderate amount of investment, and the high volume of traffic captured. Conversely, the Dijon-Mulhouse section appears to be the most expensive and the least interesting in terms of traffic growth.

The financial appraisal is limited to the monetary effects of the project and intends to assess the project's financial feasibility, its profitability and the ability of an investor to carry the project with or without a grant. Although the economic appraisal gives positive rate of return for several scenarios, the financial appraisal indicates that the revenues generated by the project (railway tolls earned by the infrastructure managers) are not sufficient to fund sustainably the investment. It points out a need for subsidies from the Member States combined with a grant from the European Commission. As the financial profitability is also directly linked to the volumes of traffic deviated to the rail sections studies, the scenario involving the Rhône Valley and Perpignan-Barcelona appears to be the most profitable in financial terms, requiring the least public participation in the funding structure.

2.2.2. French

Cette étude de faisabilité a pour but d’identifier des sections du réseau ferré européen pour lesquelles une augmentation du gabarit maximum autorisé permettrait de développer de façon significative les trafics de transport combiné, à l’échelle internationale.

La première étape consiste en une étude de marché recherchant les goulets d’étranglement du réseau, dont la suppression aurait pour conséquence une amélioration du gabarit dont bénéficieraient des trafics longue distance. Cette recherche s’est appuyée sur la connaissance du réseau apportée par les Documents de Référence des Réseaux, et s’est poursuivie via des entretiens avec des entreprises ferroviaires, des gestionnaires d’infrastructures et des managers de corridors frets.

Plusieurs sections ont été retenues après une première analyse :

- les Tunnels des Vosges
- Meaux-Epernay
- Dijon-Mulhouse
- la Vallée du Rhône
- Perpignan-Barcelone

Les discussions qui se sont tenues avec les entreprises ferroviaires et les opérateurs de transport combiné ont également permis de déterminer le gabarit cible qui devra être atteint. Il s’agit du P400, qui permet tout type de transport combiné (en particulier le transport de remorques) et rend ainsi possible un important report modal depuis la route vers le rail.

Après avoir défini les sections à améliorer et identifié le gabarit cible, une nouvelle série d’entretiens auprès des entreprises ferroviaires et des opérateurs a servi à évaluer les croissances de trafics résultants de ces éventuels projet d’amélioration.

Les avantages générés par ces reports de trafic vers le rail (économie pour les chargeurs, réductions des circulations de poids-lourd et leur impact, notamment d'un point de vue environnemental) ont été valorisé dans le cadre des analyses socio-économiques et financières.

A opposer à ces avantages, les coûts d'investissement nécessaires à l'augmentation du gabarit admissibles sur les sections d'études ont été évalués selon la méthode suivante.

Des mesures 3D ont été réalisées sur les 5 sections retenues, afin de connaitre avec précision la géométrie des obstacles (les tunnels) rencontrés sur les lignes. Cette information a permis de savoir quelles sections étaient compatibles avec le P400, et lesquelles ne l'étaient pas, en superposant virtuellement les contours réels de l'infrastructure avec l'enveloppe dynamique d'un ensemble remorque – wagon-poche, et en identifiant les linéaires pour lesquelles on observe une superposition du profil du matériel roulant et de l'infrastructure. Cette enveloppe dynamique a été conçue en appliquant les règles usuelles de sécurité des bureaux d'ingénierie de la SNCF au cas particulier d'une remorque de 4m de haut chargée sur un wagon-poche de 33 cm de haut (soit la définition du gabarit P400).

Une analyse de la faisabilité technique des travaux a ensuite été réalisée sur la base des linéaires de tunnels concernés par ces superpositions de profils et en fonction de la profondeur d'intrusion, et donc du volume d'infrastructure à traiter. Pour les travaux, deux types de techniques ont été étudiés : travail sur la voute du tunnel, pour dégager du volume au niveau des zones de superposition (les coins supérieurs des remorques) ou bien abaissement de la plate-forme de roulement. Les investissements ainsi estimés ont été intégrés aux évaluations socio-économique et financière.

Plusieurs scénarios ont été construits pour ces évaluations. Selon les marchés bénéficiant de l'amélioration du gabarit sur les sections retenues, il est parfois apparu opportun d'augmenter le gabarit admissible sur plusieurs de ces sections, afin d'ouvrir des routes ferroviaires plus longues pour des transports à haut gabarit.

L'évaluation socio-économique prend en compte les coûts des projets, les bénéfices économiques des acteurs impliqués mais également les effets non-monétaires du projet, avec en premier lieu les avantages environnementaux. Le but de cette évaluation et d'estimer la rentabilité socio-économique du projet, c'est-à-dire son intérêt, au-delà de l'aspect financier, pour l'ensemble des acteurs.

Il est d'autant plus intéressant d'augmenter le gabarit admissible sur une section si le coût des travaux est faible, et si le trafic généré et important. Il en résulte que le traitement conjoint des sections de la Vallée du Rhône et de Perpignan-Barcelone apparait comme le scénario à privilégier, étant donné le montant modéré d'investissement, et surtout le fort volume de trafic qui bénéficierait d'un tel développement. A l'inverse, la section Dijon-Mulhouse apparait comme la plus coûteuse à traiter et la moins impactante en termes de développement de trafic.

L'évaluation financière se limite pour sa part aux effets monétaires du projet, et a pour but d'évaluer la faisabilité économique du projet, sa rentabilité, et la capacité d'un investisseur à porter le projet avec ou sans subvention. Bien que l'évaluation socio-économique donne des résultats positifs pour plusieurs scénarios, l'évaluation financière indique que les revenus générés par le projet (les redevances ferroviaires perçues par le gestionnaire d'infrastructure) ne suffisent pas à financer l'investissement, et fait donc apparaitre un besoin de subventions venant des états ou de la Commission Européenne. La rentabilité financière étant elle aussi directement liée aux volumes de trafics gagnés sur le rail, le scénario impliquant la Vallée du Rhône et Perpignan-Barcelone apparait comme étant le plus rentable, et nécessitant la moindre participation publique au financement.

3. MARKET STUDY

3.1. Principles

3.1.1. Objectives

The objective of the market study is to identify the key gauge enlargement links that currently constitute bottlenecks and where enlargement of the clearance gauge would lead to significant development of rail freight traffic.

Among the information collected to date during the market study, the following are key elements for the other Work Packages:

- **Location of the key gauge enlargement links**: the initial results of the market study are the identification of the sections for which works to enlarge the clearance gauge would allow for development of the rail freight traffic along those links. A clearance gauge measurement campaign has been carried out along these key gauge enlargement links.

- **Desired clearance gauge:** the development of the rail freight traffic will be the result of a response to the needs of combined transport stakeholders, and in particular combined transport operators. The identification of their needs in terms of clearance gauge leads to the determination of the natures of the enlargement works to be carried, and whose cost will be taken into account in the cost benefit analysis (CBA) carried out in WP6. The measurement campaign carried out in WP4 has taken into account the target clearance gauges in order to test whether or not the measured sections, in their current state, provide the needed clearance gauge.

- **Traffic estimate**: the market study also seeks to estimate the degree to which new rail traffic may develop following elimination of the identified clearance gauge bottlenecks. The traffic estimate is both quantitative but also qualitative, identifying the origin and the destination of the traffic flux, the logistic chain put into place, as well as the route and mode of transport that is used if the enlargement works are not carried out. We identify gains both in terms of (a) modal shift from road to rail, and (b) shortening of current railway routes. The forecast changes in transport mode related to the removal of bottlenecks constitute the social-economic advantages that are being evaluated in the CBA of WP6.

3.1.2. Sources

Diverse sources of information have been used in this market study. In addition to contextual documents (Network Statements, White Paper, Green Paper, the series of "Core Network Corridor Studies", the series of "Corridor Information Documents"), existing databases contribute to the consolidation of assumptions on traffic.

The European Commission expects, however, a direct analysis of the real freight market, and for this reason most part of the data comes from a consultation campaign involving major rail freight stakeholders (European Freight Corridors Managers, Infrastructure Managers, Railway Undertakings and Combined operators*).

**As explained below, Combined Transport is the main target of this study, since it is by far the type of freight transport the most concerned by clearance gauge issues.*

This consultation includes:

- Questionnaire sent by email, accompanied by a presentation of the study and an introductory letter from the European Commission
- Telephone interviews
- Face to face interviews

The direct discussion with freight stakeholders provides a clear view of their expectations and is a particularly precious clarification of the current situation. Indeed, their knowledge of the context and of what is at stake goes much beyond the information available in the available documents. Furthermore, stakeholders are able to provide initial estimates (with varying degrees of precision) of potential rail freight traffic that could be captured thanks to gauge enlargement works.

3.2. About clearance gauges and profiles

In railway transport, the definition of clearance gauges is made following regulated codifications.

The nomenclatures used to describe the loading gauges are not the same for the description of the infrastructure and for the profile of the rolling stock, and may also vary in some countries that do not follow the international standards recommended by the UIC.

Codification of Infrastructure

The codified clearance gauge of a given section of the European railway network is defined according to the most limiting height and width profile encountered the length of the section. For a given section of line, the limiting profile may be related to a tunnel in the section, but it can also depend on features such as over-bridges, station platforms and overhead or lineside equipment. As such, a single local feature determines the clearance gauge of the surrounding line section.

The most commonly encountered clearance gauges in Europe are those defined by the UIC standards:

- The GA clearance gauge: the clearance gauge with the lowest height profile that can be found on lines that are open to freight traffic; today, sections with GA gauge are rare
- The GB clearance gauge: The minimum clearance gauge found on principle freight itineraries, this clearance gauge is found mostly in Western Europe; it allows “High-Cube” containers to pass

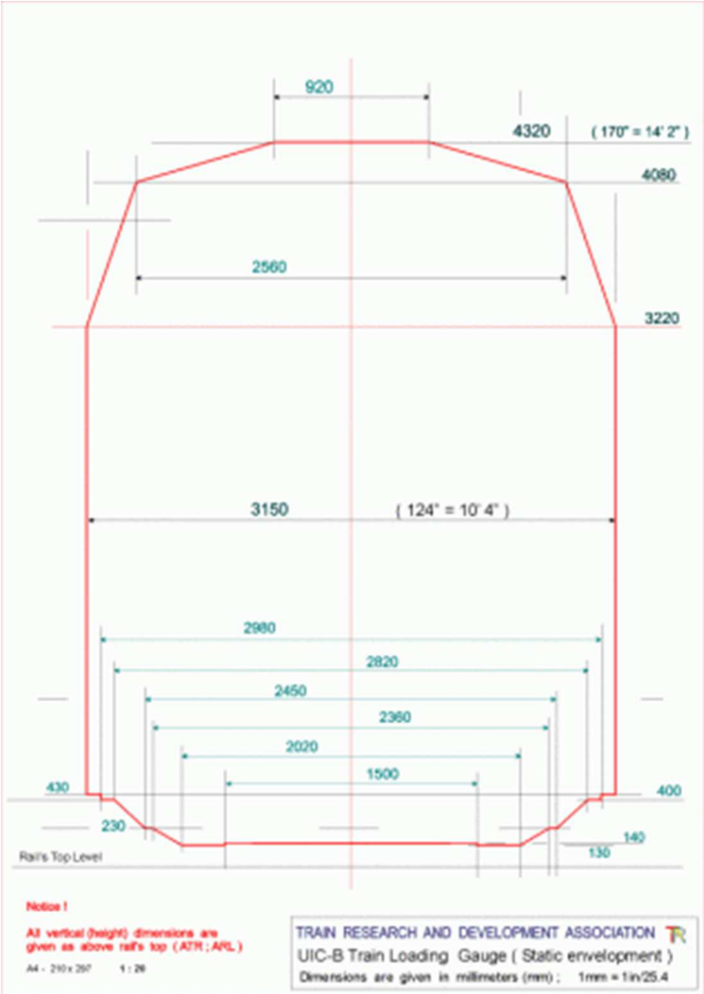


Figure 2 – GB Profile

- The GB1 clearance gauge: it is a larger version of the GB clearance gauge that allows the transportation of any type of containers and of some semi-trailers
- The GC clearance gauge: this gauge provides clearance for strictly all loading gauges and is also used for operation of trains at high speeds

There are also other kinds of codification for clearance gauges. For example, the IB gauge is defined in Spain, and the Ptb and Ptb+ gauges are defined in Portugal.

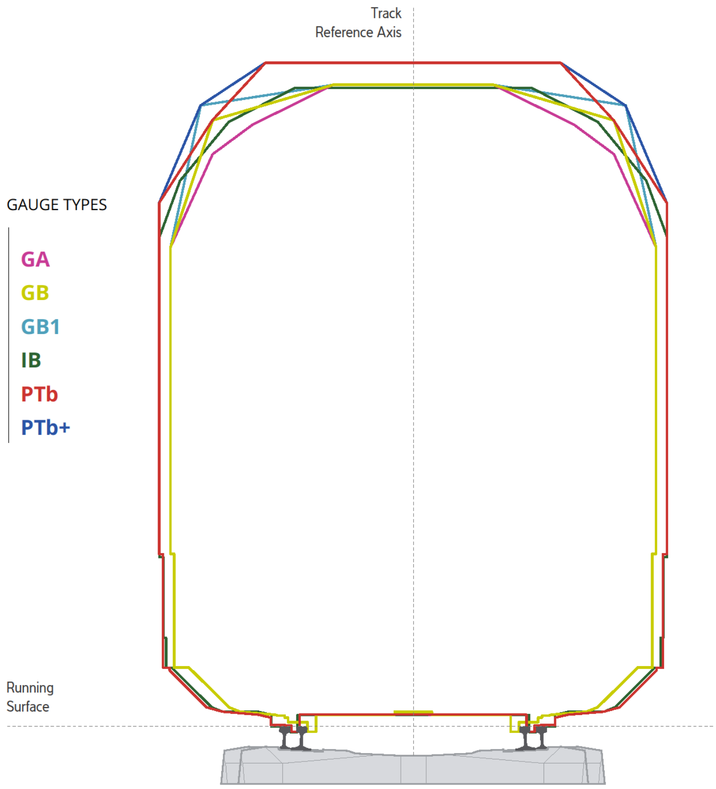


Figure 3 – Some UIC and Iberian gauge profiles

Note that the IB gauge, for example, is as high as GB1, but its rounded shape at the top does not allow bodies that are wide at the top to pass, whereas the GB1 has been designed to that purpose.

Codification of rolling stock

In the domain of rail freight, the subject of clearance gauge naturally concerns trains that are either particularly wide, particularly tall or both. Conventional freight traffic is not much concerned by clearance gauge restraints, as the wagons generally used are of moderate size. On the contrary, combined transport concerns merchandise that is stored in large objects such as containers, truck trailers, or even entire trucks in the case of rail highways, for example.

Research into the industrialization and the profitability of freight transport have led, for all transport modes, to an increase in the size of units transported, as well as a preponderance of plane-parallel forms:

- Maritime containers may reach up to 2.90 meters in height and 2.44 meters in width in the case of high cubes; the width is 2.59 meters in the case of super high cubes.
- Swap bodies are generally limited to a height of 3 meters, but go up to 3.2 in the case of Megacombi
- Trucks and semi-trailers are limited to a height of 4 meters

Due to the general standardization of the size and shape of containers and swap bodies (at least within the study perimeter), it has been possible to create a single codification system, as described below.

Codification of containers and swap bodies:

- The CXX type for widths less than 2.55 m, where XX is the height in centimeters to add to the reference height of 2.45 m

C45 represents a container with a height of 2.45m + 0.45 = 2.90 m, which is a high-cube container.

- The CXXX type for widths between 2.55 and 2.60 m, where xxx is the height of the container in centimeters, from which the reference height of 85 centimeters must be subtracted

A C341 container has a height of: 3.41 m – 0.85 = 2.56 m

Codification of semi-trailers:

- The PXX type for widths less than 2.50 m, where XX is the height in centimeters to add to the reference height of 3.30 m

A P22 semi-trailer has a height of: 0.22 + 3.30 = 3.52 m

- The PXXX type for widths between 2.50 and 2.60 m, where xxx is the height of the semi-trailer in cm

A P400 semi-trailer has a height of 4 meters.

Rail cars

- The reference rail car for the CXX codification has a floor height of 1.175 meters with respect to the top of the rail.
- The reference pocket wagon for the PXXX codification has a floor height of 33 cm with respect to the top of the rail.

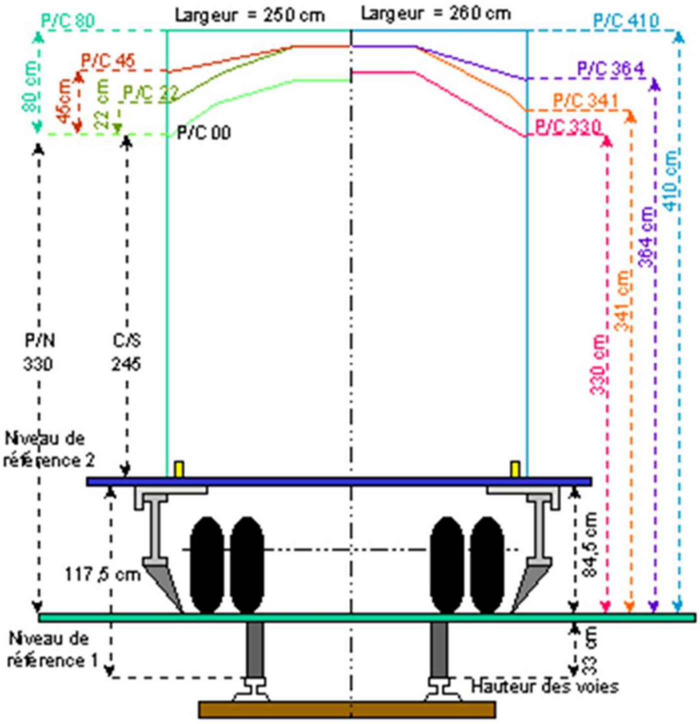


Figure 4 – Profiles for CXX, CXXX, PXX and PXXX bodies

Development of new low-floor wagons has changed the needs in terms of height for the complete trailer-piggy-backed-on-wagon system.

For instance, the following height of floor are commonly used:

- 0.27 m with a low-floor wagon
- 0.23 m with the Modalohr wagon

Thus, the top of a 4 meter high semi-trailer stands at 4.23 m if put on a Modalohr wagon, or at 4.27 m if put on another type of low-floor wagon.

Correspondence between codifications

In order to understand the expectations of combined transport operators in terms of infrastructure, it is necessary to know the equivalencies and the compatibility between the nomenclatures of the network (infrastructure) and of the rolling stock.

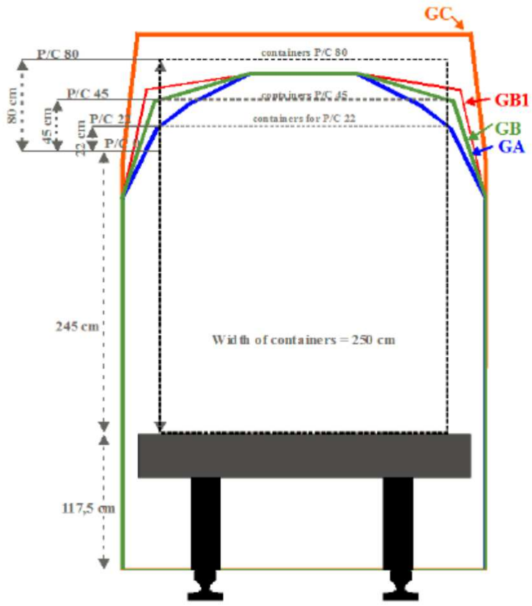


Figure 5 – Equivalence between infrastructure gauge and container profiles

The figure above show an example of correspondence between certain container profiles and the corresponding infrastructure clearance gauge as defined by the UIC.

According to the needs expressed by stakeholders who have been interviewed to date, the primary points of reference to take into account are the following:

- The transportation of "high cube" containers necessitates infrastructure with GB clearance gauge or larger.
- Transportation of semi-trailers is possible (1) with the GB1 clearance gauge if done with low-floor wagons or (2) with all gauges larger than GB1

In practice, and in function of who is communicating, the two types of codification are used to describe the clearance gauge of a network section. For example, a line segment can be described as providing the C45 clearance gauge.

3.3. Geographic scope

3.3.1. Rail Freight Corridors

Reflection carried out by the European Commission and by freight stakeholders has led to the definition of Rail Freight Corridors.

These corridors represent the major axes of circulation linking the major traffic-generating hubs in Europe (metropolitan areas, logistic platforms, ports). They propose an offer (train paths) that is conceived at international scale, for long-distance trips.

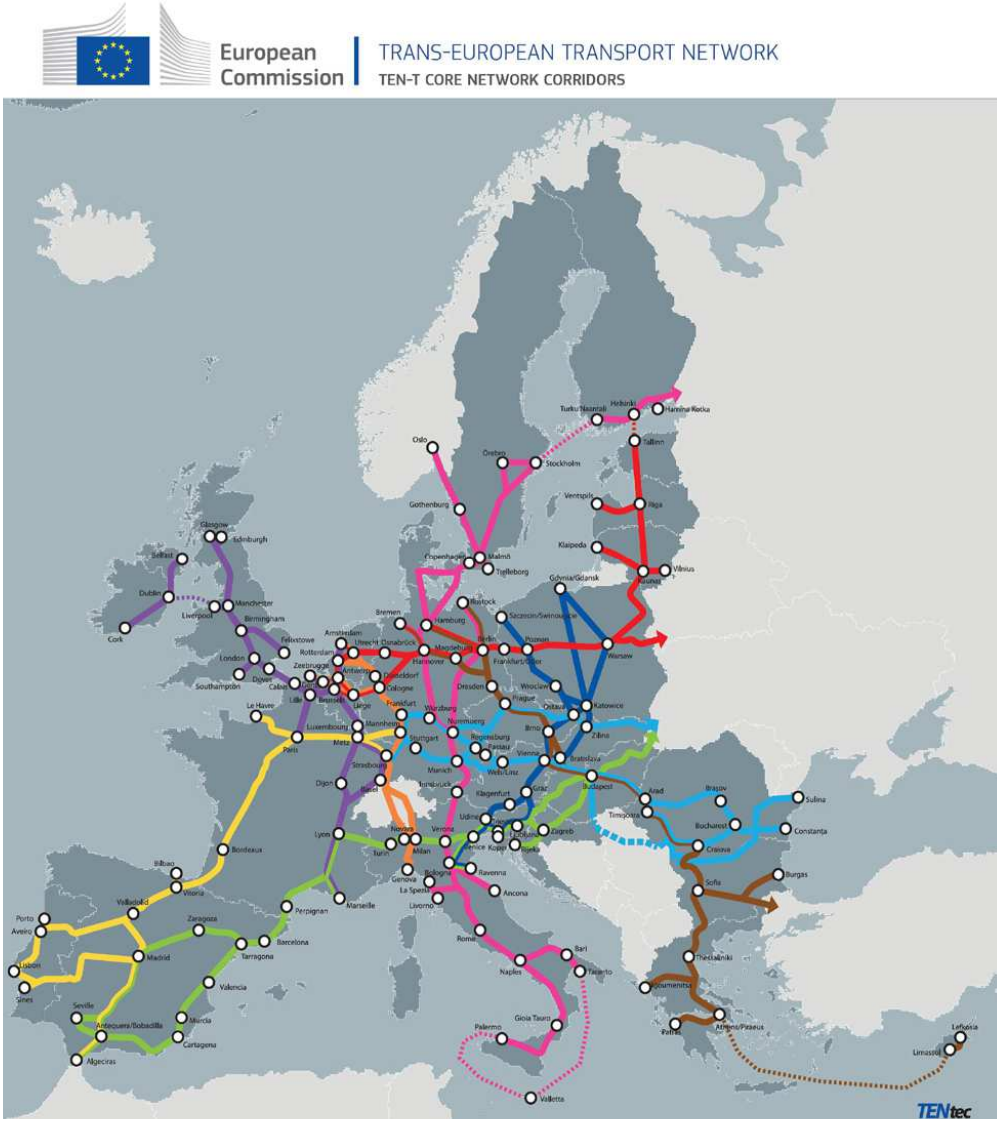


Figure 6 – The European rail freight corridors

The usefulness of projects to improve the European rail network can be evaluated in terms of the volumes of long-distance traffic that can be switched thanks to these projects from the road to rail. Therefore, the potential enhancements that are sought in this study are to be identified by following the same logic as the one that lead to the creation of the European Corridors.

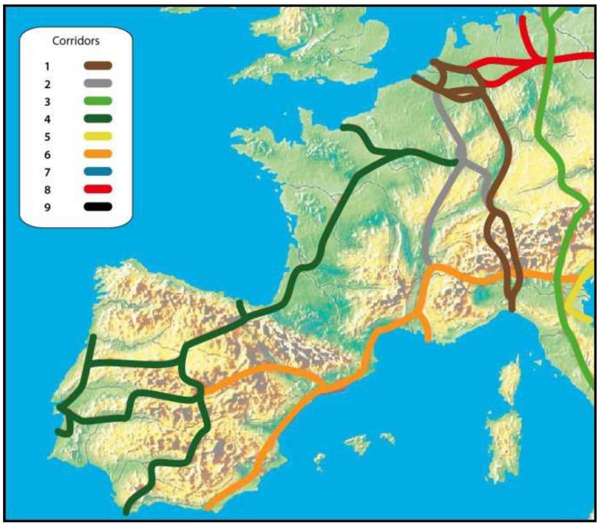
The analysis of the offer carried out in the market study depends on the definition of the corridors and on the continuity of the clearance gauge offered along these routes.

3.3.2. Focus on Western Europe

Though bottlenecks of various types may exist throughout European rail network (restricted train length, single track…), problems related to limited clearance gauge are most frequent in the mountainous regions around the Alps and the Pyrenees. In Eastern Europe, problems of limited clearance gauge are rather rare and do not have much impact, as indicated by most of the people interviewed and shown on the map below.

Figure 7 – Codification of lines for the transportation of semi-trailers (Infrabel – Interunit)

Thus in the current study, the search for those clearance gauge bottlenecks with the most impact on rail freight traffic concentrates on Western Europe, in particular mountainous zones and zones with strong development potential linked to maritime ports.



Referring to the rail freight corridors (RFC) that have already been mentioned above, corridors that are the target of the market study are the following:

- RFC 1: Rhine-Alpine
- RFC 2: North Sea-Mediterranean
- RFC 4: Atlantic
- RFC 6: Mediterranean

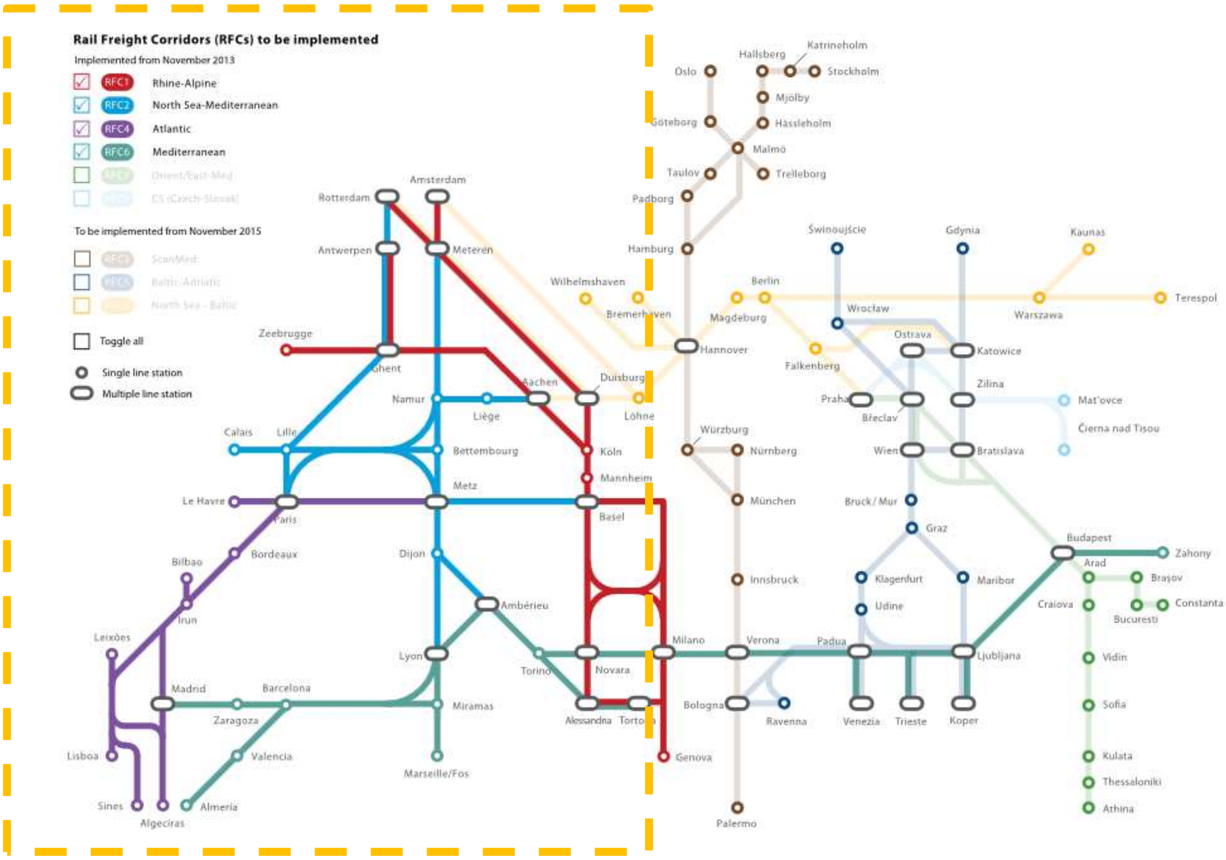


Figure 8 – The European RFC's and the focus on Western Europe

3.3.3. Special focus on gauge enlargement links

The objective of the analysis carried out within the above-defined perimeter of rail freight corridors 1, 2, 4 and 6 is to identify the gauge enlargement links for which clearance gauge enhancement should be a priority in order to develop a maximum amount of rail freight traffic.

Following the identification of the gauge enlargement links, the market study concentrates on the selected line sections in order to:

- identify the traffic flows on these sections,
- identify the stakeholders' expectations in terms of clearance gauge, and finally to
- estimate the potential rail freight traffic gains that could result from gauge enlargement.

This focused study will be carried out once the European Commission validates the selected gauge enlargement links.

3.4. Identification of key line sections

3.4.1. Methodology

At this stage in the study, the priority of the market study was to identify and to select the gauge enlargement links for which further study has been carried out:

- Additional interviews with the stakeholders concerned by these sections
- Identification of the desired clearance gauge
- Estimation of potential traffic
- Laser measurements of bottlenecks
- Feasibility study of enlargement works on the selected gauge enhancement links
- Cost Benefit Analysis

The choice of the gauge enlargement links follows the logic of the rail freight corridors, which were conceived by the European Commission with an eye to development of rail freight traffic. As such, we seek to identify gauge enlargement links that would reinforce the rail freight corridors.

The initial interviews that have been carried out target the heads of various corridors.

Reminder: the corridors targeted by the study are 1, 2, 4 and 6.

The interviews that have been carried out to date or that for the near future are listed below.

Corridor managers:

- Corridor 1: telephone interview with Stefan Wendel, Programme Director, on April 29th
- Corridor 2: interview in Paris with Guillaume Confais, Managing Director, and Eric Guenther, Operation Manager, on May 5th
- Corridor 4: interview in Paris with Jacques Coutou, Corridor Manager, on April 13th
- Corridor 6: telephone interview with Pierre Chauvin, One Stop Shop Leader, on April 27th

Other stakeholders: interviews have been conducted with Fret SNCF, Captrain Italia, RENFE Mercancias, COMSA Rail Transport, Kombiverkehr, DB, HUPAC, SNCF Réseau, Infrabel, ADIF, Generalitat de Catalunya, UIC, UIRR...

3.4.2. Analysis of studied corridors

The first concern of this market study was the identification of the gauge enlargement links that would be studied further. This identification started with a diagnosis of the infrastructure based on available documents but also on the Corridor Managers good knowledge of the railway network. Therefore, the choice of links is based primarily on interviews carried out with representatives for European rail freight corridors, so that the choice is supported by a global vision of the European territory, and not correlated with the special interests of a company or a country.

The information obtained in the other interviews is nonetheless taken advantage of the choice the gauge enlargement links.

Corridor 1

An interview was carried out with Stefan Wendel, the Corridor 1 Programme Director.

Corridor 1 connects the Northern Range to the Mediterranean, crossing:

- Belgium
- The Netherlands
- Germany
- Switzerland
- Italy

In terms of clearance gauge, Corridor 1's itineraries are almost all compatible with P400. This is the result of the fact that its IM members have for the most part adapted their network to P400 whenever lines were built or renovated.

The Gothard Tunnel is currently a known bottleneck in this corridor, with an authorized loading gauge that is smaller than P400. Works are currently scheduled on this section, and the tunnel will be compatible with P400 in the short term.

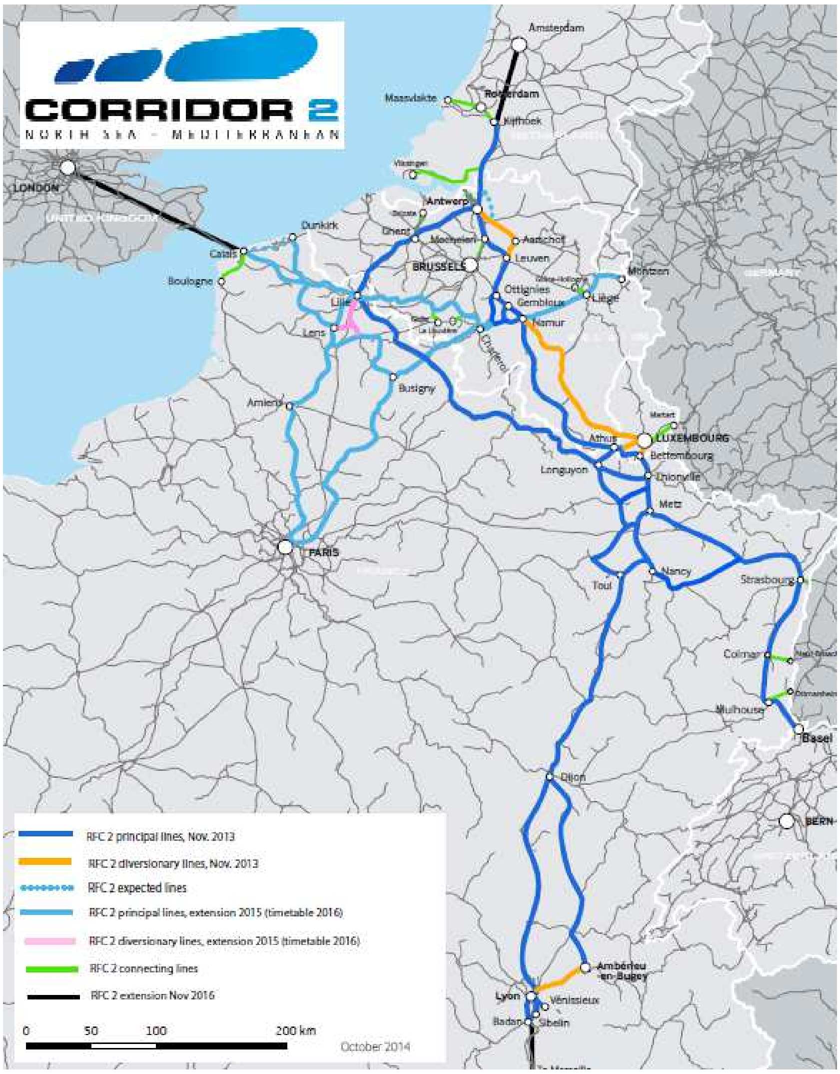
Otherwise, it is in Italy that the corridor 1 itineraries do not allow the P400 loading gauge, with the exception of the line to Novara from Switzerland. At the southern tip of the corridor, between Voghera and Genova, the maximum authorized loading gauge is even more limited: the C22 gauge. Nonetheless, a new line is currently under construction between Tortona and Genova. This new line will allow P/C 80 in the future. Removal of P/C22 to PC45 on the existing line is also not expected before 2020.

Figure 9 – Codification of lines for the transportation of semi-trailers (Infrabel – Interunit)

(C45 in blue, C22 in Red)

Corridor 2

Corridor 2 was the subject of an interview with Guillaume Confais, Managing Director, and Eric Guenther, Operation Manager, on May 5th.



Corridor 2 crosses the following countries:

- France
- Belgium
- The Netherlands
- Luxembourg
- Switzerland

At its creation, the corridor connected Flanders (Netherlands, Belgium, northern France) to Bale, via Luxembourg and northeast France. That is called the North-East section.

In addition, reached Lyon from Lorraine.

An extension of the corridor (2015) adds a connection between Paris and Belgium, and another foreseen in 2016 will extend to London and Amsterdam.

The corridor has relatively limited clearance gauges on multiple line sections and is rather uncompetitive, as compared to Corridor 1.

However, the most problematic areas are located on the eastern part of the north-east segment, where several tunnels are highly restrictive for transportation of trailers.

From North Sea to Luxembourg, trailer transport is complicated but still possible, with exceptional authorizations provided by the infrastructure managers.

Rail motorway are also currently in service from Bettembourg to Lyon, using Rail Freight Corridor 2.

But on the east side of Luxembourg, there is a series of six tunnels with GB limitation that represents an obstacle for high trains from Metz to Strasbourg. These are referred to as the Tunnels of the Vosges.

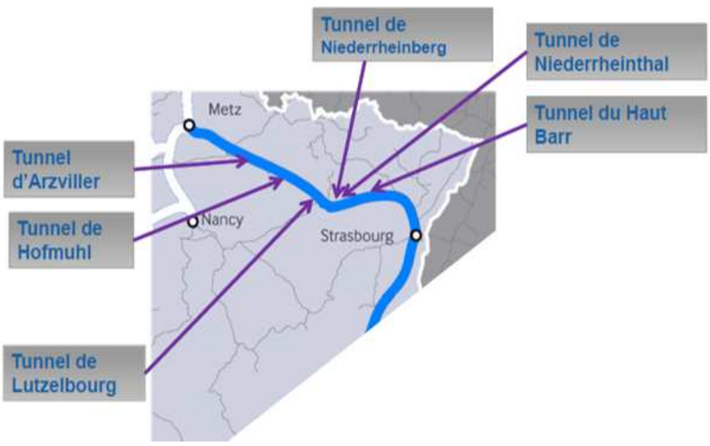
Market and feasibility studies have been carried out for Corridor 2 in order to explore possibilities of improving the offer via clearance gauge enlargement. According to these studies, the demand expressed by operators is clear: clearance to transport 4 m semi-trailers on long distances would lead to significant increase in rail freight traffic. Depending on the configuration of the infrastructure and the possible operations, the type of pocket wagon used to carry the semi-trailers could be chosen as an adjustment parameter.

Member of the Corridor 2 are also considering the possibility to proceed with the operations for gauge enlargement at the same time as heavy maintenance operations, so as to reduce the negative impact on traffic due to the works and the cost of the global operation.

Tunnel	Length	Current Gauge	Renewal planned
Arzviller	2678m	GB	2024
Haut Barr	304m		No
Lutzelbourg	439m		2019
Hofmuhl	248m / 328m		2019
Niederrheinberg	400m		2026
Niederrheinthal	493m		2032

Figure 10 – Renewal planning for the six tunnels of the Vosges

Besides, members of RFC 2 Management have identified an unsatisfied demand for container traffics willing to efficiently transit between Germany and Southern Europe. The section going from Mulhouse to Dijon is being considered as a missing link for potential international routes and might be part of the TEN-T if gauge was large enough to accommodate a significant volume of rail freight traffic. At this time, gauge is under GB and does not allow every kind of container to run from Dijon to Mulhouse.



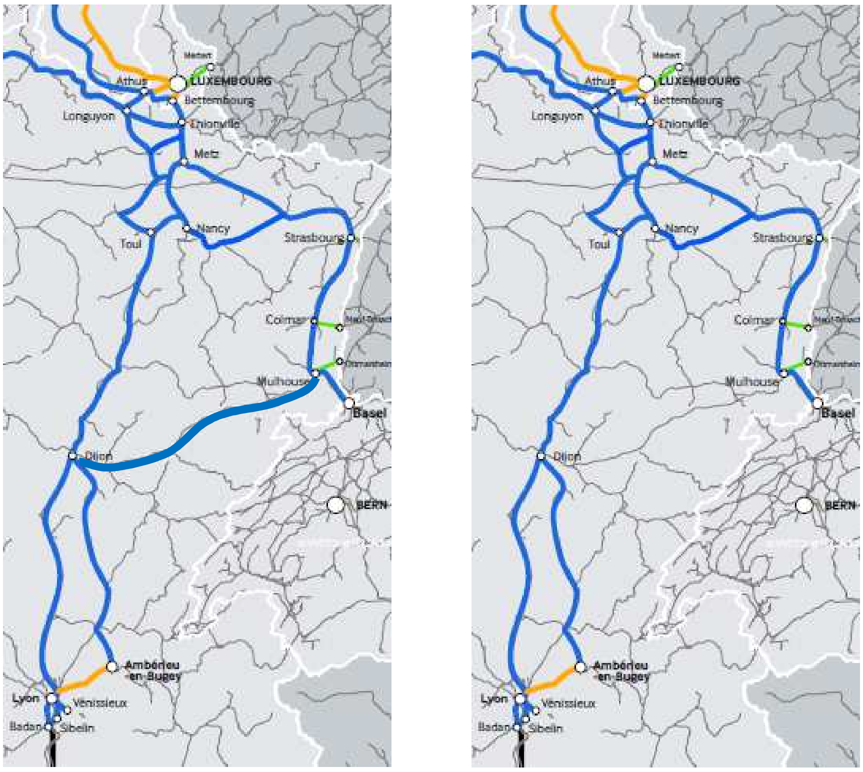


Figure 11 – RFC 2 with and without potential segment between Dijon and Mulhouse

Corridor 4 - Atlantic

Figure 12 – RFC4: The Atlantic Corridor

The Atlantic corridor stretches over Portugal (986 km), Spain (2128 km) and France (1418 km), and has recently been extended into western Germany.

In the southern part of the corridor, an initial observation on this corridor (and this is the case for the Mediterranean corridor, as well) is that numerous barriers exist that hinder cross-border rail freight traffic. The historic differences between Spanish railway standards and European standards extend the notion of bottleneck beyond issues of clearance gauge.

The disparities associated with crossing of the French-Spanish border include the following: (source: Corridor Information Document):

- the different track gauge between the Iberian peninsula and France, requiring the freight transfer across the border between France and Spain
- the maximum length of the trains limited to 500 m in Portugal, 550 m in Spain and 750 m in France
- the maximum grades reaching 18‰ and more in Spain and Portugal requiring additional traction south of Bayonne, depending on the gross load hauled
- the sections with single-track lines limiting the available capacity, and/or conditioning timetabling
- the sections with non electrified lines requiring, when appropriate, the exchange of the locomotive
- the disparity in the signalling systems requiring the exchange of machines and drivers at borders,

- the disparity of the power supply requiring rolling stock with dual voltage, triple voltage or diesel,
- the disparity of maintenance periods or works to be carried out on rail infrastructures depending on the country (by day, by night, on weekends) with partial or complete closure of a route.

In consequence, the rail itineraries of the corridor that present a competitive service level with respect to the road (that is, that provide long trips over rail with minimum changes in mode or vehicle) are those itineraries that go from the north of Spain to the northern half of France, essentially to Paris. This is possible thanks to progressive adoption of UIC standards for sections of the Spanish rail network near borders.

As for the future, the continuity of the UIC standard will permit trains to travel from France to Valladolid in 2020, and then on the majority of major axes in Spain and Portugal in 2030.

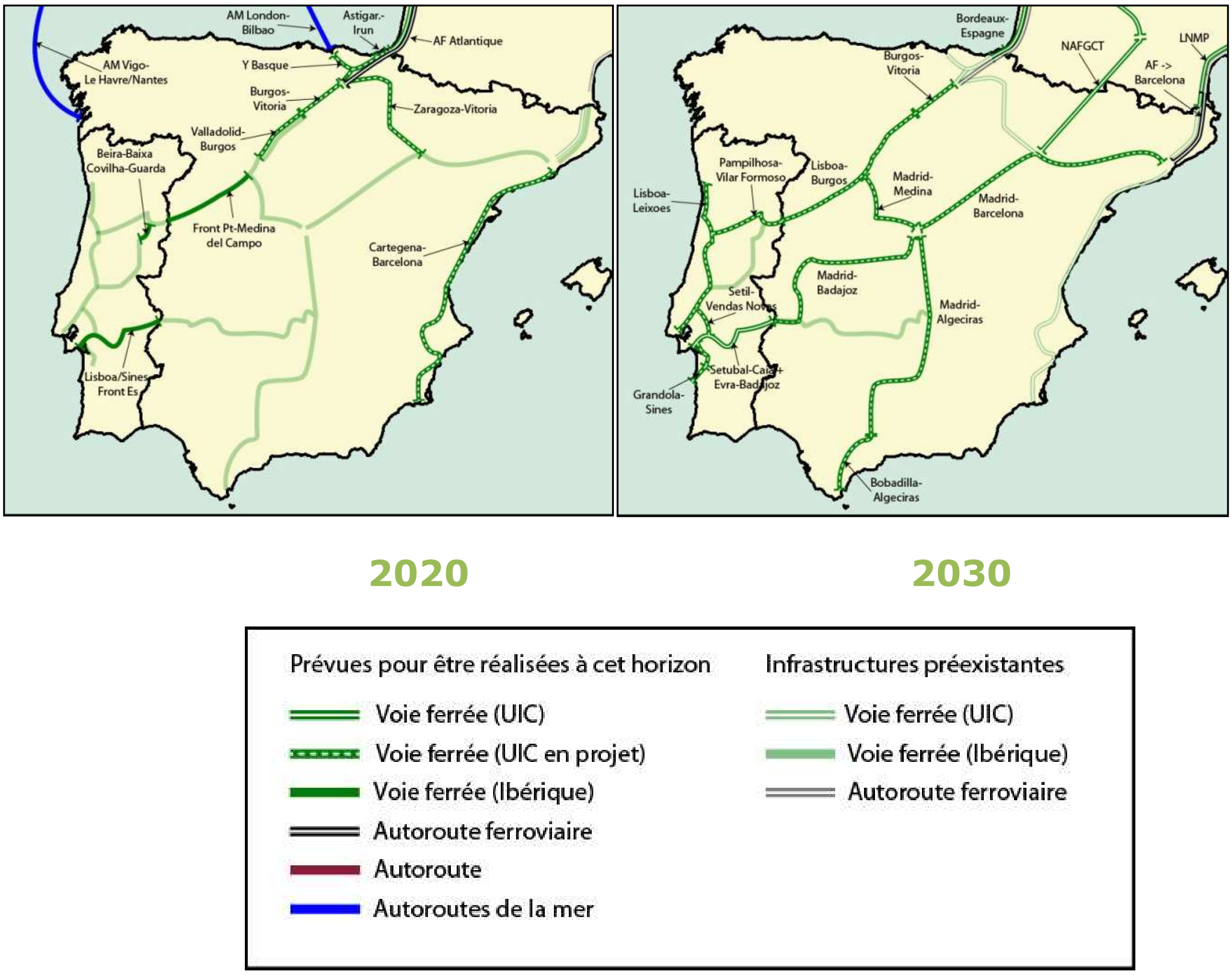


Figure 13 – Future configuration of the RFC4 (Corridor Information Document)

Thanks to this planned harmonization of rail network characteristics, we can consider that the transportation of large volumes cross-border would be technically feasible; thus we can now concentrate on questions of clearance gauge.

The illustration below represents the different infrastructure clearance gauges that exist along the corridor, with the UIC standards and Spanish and Portuguese standards.

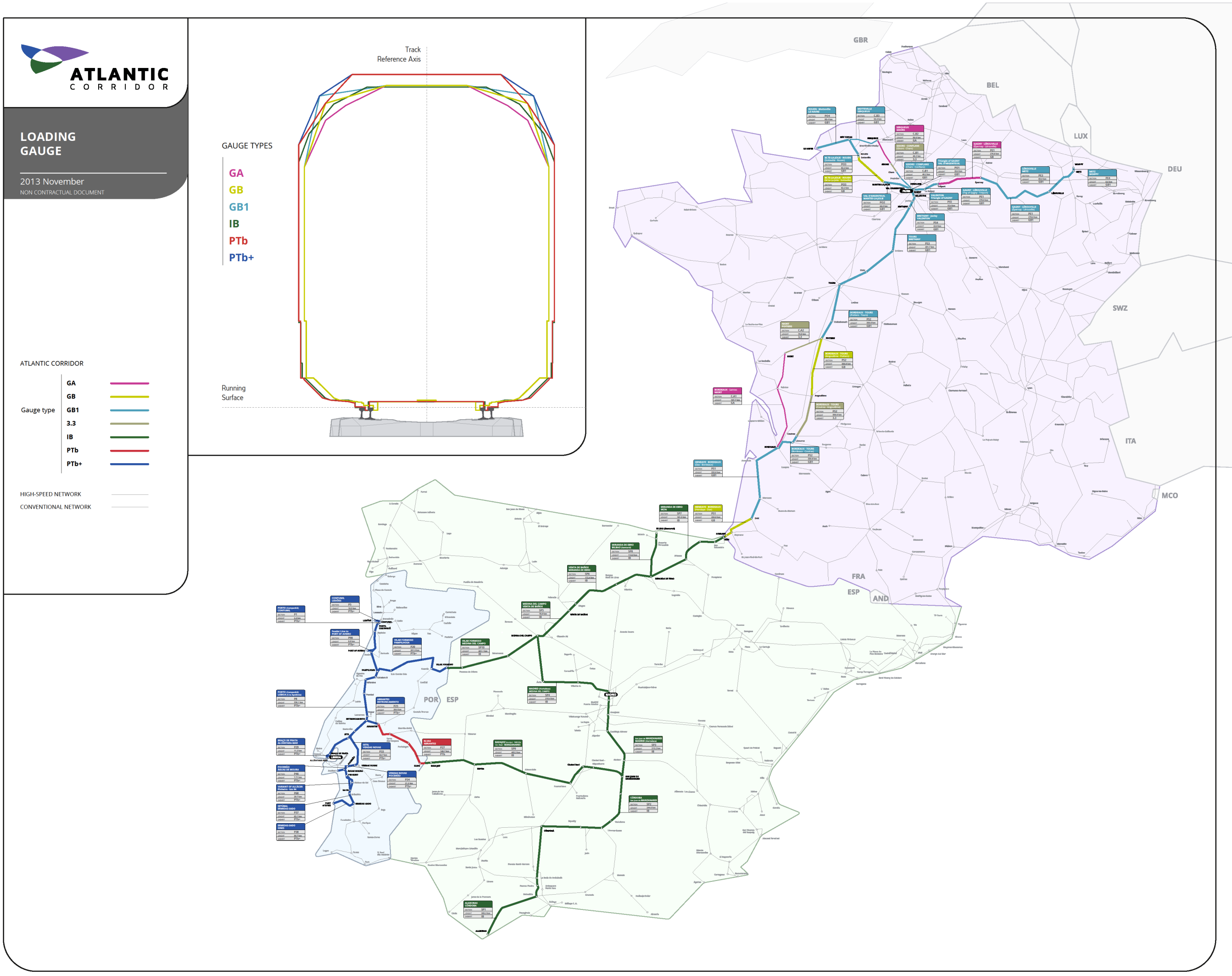


Figure 14 – Structure gauges on the Atlantic Corridor

The three countries have different clearance gauge profiles, leading to the following observations:

- In France: the corridor proposes the GB1 (compatible with P375) for a large part; some sections have a smaller clearance gauge (GB) between Poitiers and Bordeaux, as well as to the east of Paris
- In Spain: the IB is present along all axes of the corridor; its profile which is more rounded than the GB1 (though the height is equivalent) makes it incompatible with P400 and thus with the transportation of semi-trailers
- In Portugal: the Portuguese clearance gauges are quite large and are compatible with P400

As mentioned above, the current situation will evolve thanks to network improvement projects.

Caution: some of the following elements have been completely called into question, due to the cancellation of the Atlantic Rail Motorway project.

In France, transition to GB1 along the corridor is progressing with works planned on different sections between Poitiers and Bayonne (via Bordeaux):

- First, GB1 gauge on the detour route via Niort and Saintes (the future Rail Motorway will use this route)
- Then by 2030, GB1 gauge on the main route via Angoulême

European funding has been requested for the enlargement of the clearance gauge of the detour route in the context of the Atlantic Rail Motorway.

In Spain, projects for network compatibility include the enlargement of the clearance gauge in order to make it compatible with P400:

- Between Irun and the south of San Sebastian
- As an extension, the Basque Y project will propose a line at GC gauge from San Sebastian to Jundiz (near Vitoria)

European funds have also been requested for these Spanish projects.

If these future projects are taken into consideration, the Atlantic corridor will offer the GB1 gauge without interruption between Vitoria and Paris, with the exception of a short section going from Hendaye to Bayonne (about 35 km) at the GB gauge.

At the other end of the corridor, the 90-km section between Meaux and Epernay (also GB gauge) blocks an uninterrupted itinerary at GB1 between Vitoria and the border between France and Germany.

When these future works are taken into account, the Atlantic corridor will offer the continuity of the GB1 clearance gauge between Vitoria and Paris, except for a short sections between Hendaye and Bayonne (35 km) that is rated GB. In order to obtain continuity between Vitoria and the German border, another section presenting limited clearance gauge must be addressed; namely, the 90-km section between Meaux and Epernay, which is currently also rated GB.

Potential traffic grow along the Atlantic corridor has been identified in prior studies (for instance "Études Relatives au Développement de Services d'Autoroutes Ferroviaires sur la Péninsule Ibérique à l'horizon 2020" for GEIE Sud-Europe Atlantique Vitoria-Dax); the potential growth lies essentially with transport of semi-trailers. As mentioned above, a rail freight motorway (in which semi-trailers are loaded onto trains) is being created between Bayonne and Paris. This project is a sign that a demand for this type of transport exists.

In a first phase, the city of Vitoria, as the southern point of the Basque Y, could be the Spanish endpoint. The location of the site, at the convergence of Spanish motorways to the north, makes it a natural logistic hub, to which trucks would come in order to load their semi-trailers onto a train towards Paris.

Figure 15 – Location of Vitoria on the Spanish road network

A starting point at Madrid could also be possible, but at a later date, when a larger part of the Spanish rail network will have been brought to UIC standards.

As such, in view of the location of potential development of rail traffic along corridor 4, priority is given to those sections that allow continuity in the clearance gauge from Span to the north (to Paris and beyond).

The Hendaye – Bayonne section represents an obstacle to the development of transportation of semi-trailers and trucks to and from Spain. This short segment of about 30 km, in effect compromises the creation of an itinerary of at least 900km (to Paris). Furthermore, the clearance gauge limit appears to be due to metal armatures reinforcing the arch of the tunnel in the section (which would be compatible with most trailer gauges without the armatures). It is possible (though this point needs to be studied and confirmed) that, with a solution for compensation, the removal of the armatures would be less costly than a major intervention on the arch of a tunnel.

Update:

Because of the recent cancellation of the Atlantic Rail Motorway project, the related evolution of the French part of the RFC 4 that have been presented above can no longer be considered as a certain future.

Therefore, operations on the short segment between Hendaye and Bayonne cannot be expected to open a long road up to Paris and beyond, until the infrastructure projects from Bayonne to Paris have been reaffirmed.

The Rail Motorway project might be permanently cancelled, but might also be reconsidered and turned into a new one, going from Spain to Paris (and beyond). These possibilities are dealt with by a whole study recently launched by Corridor 4 Management.

For all these reasons, traffic forecasts cannot be reliably done on this area, and this network link between Hendaye and Bayonne shall not be included in the selection proposed below.

In the northern part of this corridor, on the other hand, gauge enlargement on the Meaux – Epernay section would still open a rail route for high profiles between Paris and Germany, whereas currently a long detour to the north of this section is necessary for P400. The section is rather long, however, and the type of works that would be necessary to enlarge the clearance gauge had to be evaluated.

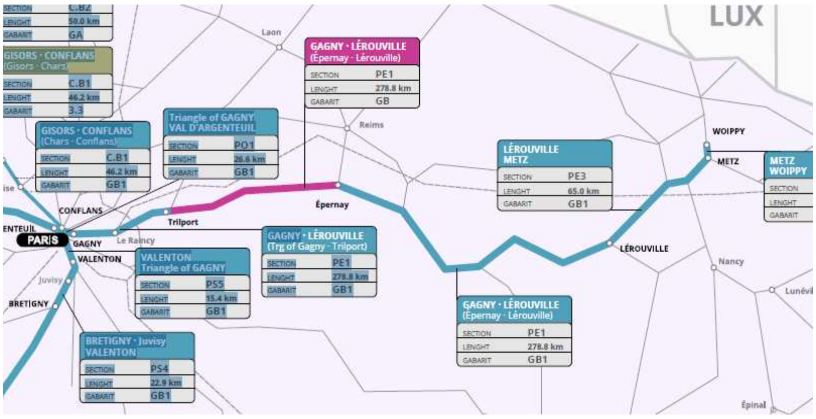


Figure 16 – Meaux – Epernay section, in pink (extract from the previous gauge map)

Corridor 6 - Mediterranean

The Mediterranean Corridor has been the topic of a telephone interview with Pierre Chauvin, One Stop Shop Leader for Corridor 6.

This corridor links Spain with Hungary via France, Italy and Slovenia. It will soon be extended to sections of lines in Croatia.

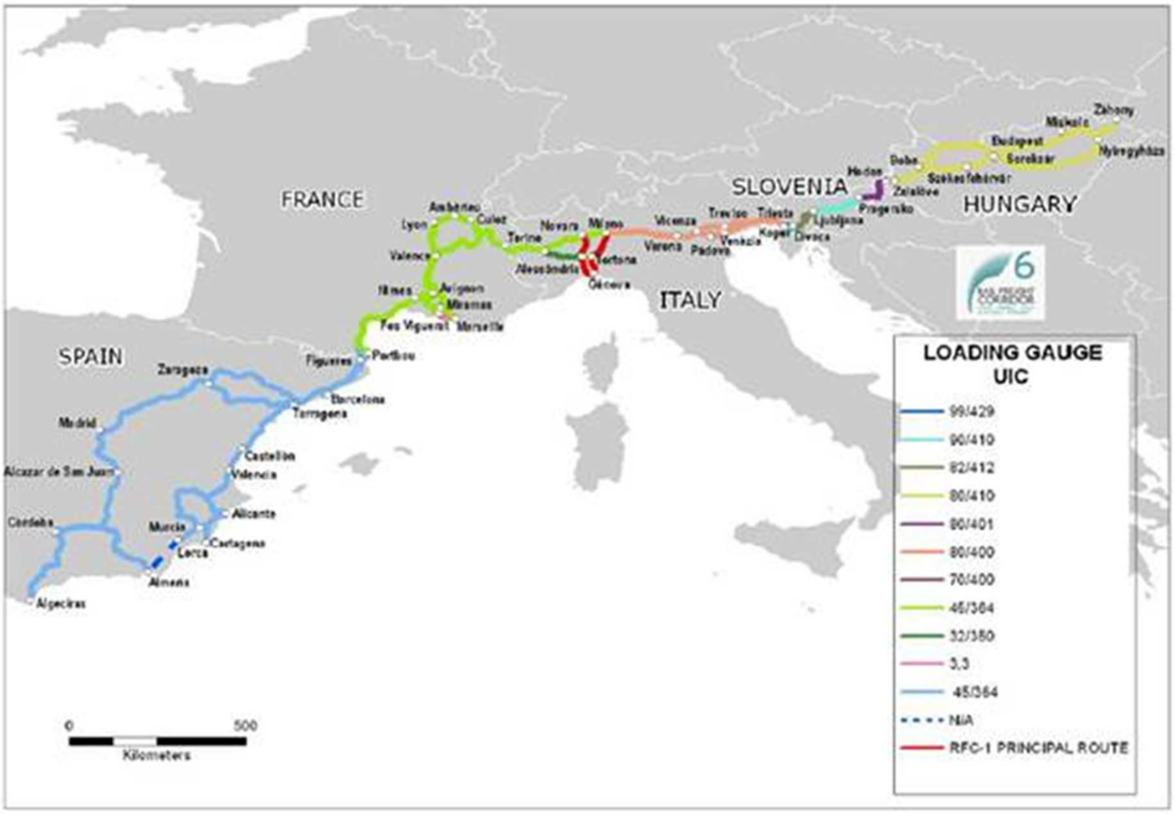


Figure 17 – Structure gauges on the Mediterranean Corridor

The different countries that this corridor crosses do not offer the same types of railway clearance gauges.

- In Spain, the rail network is designed for the IB clearance gauge presented above
- In France, multiple sections limit clearance gauge, and only C45 trains are guaranteed to be able to run in the corridor
- In Italy, RFI is undertaking clearance gauge enlargements in order to let P400 trains pass; this has already been done from Trieste to Milan and will also be undertaken between Milan and Turin
- In Slovenia and Hungary the rail infrastructure provides clearance for P400 trains

Thus clearance gauge limits are concentrated in the western part of the corridor.

The French-Italian border is limited to C45; furthermore steep grades necessitation reinforced traction. This Alpine crossing is currently the subject of several advanced studies aimed at creating a new tunnel linking Lyon and Turin. If we consider that the construction of this tunnel is indeed plausible, it is not pertinent to take into consideration in the current study the current crossing, via Modane.

In Spain, significant works have converted the Barcelona – Figueras section to UIC standards, in order to facilitation cross-border exchanges between Barcelona and France. Despite these investments, the line is not very heavily loaded, although the stakeholders who have been consulted to date unanimously agree that strong potential demand exists for the rail transport of trucks and semi-trailers. One obvious explanation for this situation would be the limited Spanish clearance gauge, which prevents development of rail transport of semi-trailers. A few tunnels seem to be the only obstacles to development of this market across the French-Spanish border, along the Mediterranean corridor:

- In Spain: a few tunnels have been identified as being problematic in the zone Castellbisbal-Rubi-Cerdanyola; this zone is used by trains serving the west of Barcelona (port), as well as the south of the Mediterranean coast (Tarragona and Valence)
- In France: south of Perpignan there is a tunnel that had not been measured and that can thus not be used by wide convoys

In France, the Rhone Valley line links the Pyrenees to the Alps, two zones where tunnels reduce the available clearance gauge. The current rules regardant the rail lines following the Rhone River (left bank line and right bank line) limit these sections to trains no larger than the C45 loading gauge. Though this limit may be consistent with the constraints of the surrounding sections, it is particularly discouraging to potential rail freight traffic between northern Europe (Netherlands, Germany) and the south of France or Spain (via corridors 2 and 6). On the right bank, specific bottlenecks have been identified; they are a series of tunnels between Lyon and Montélimar:

- between Irigny and Vernaison (km 546.532 to km 546.287)
- between Peyraud and Sarras (Tunnel d'Andance Km 580.083 to km 580.756)
- between Cruas and Le Teil (km 662.019 to km 662.043)
- the Verin tunnel

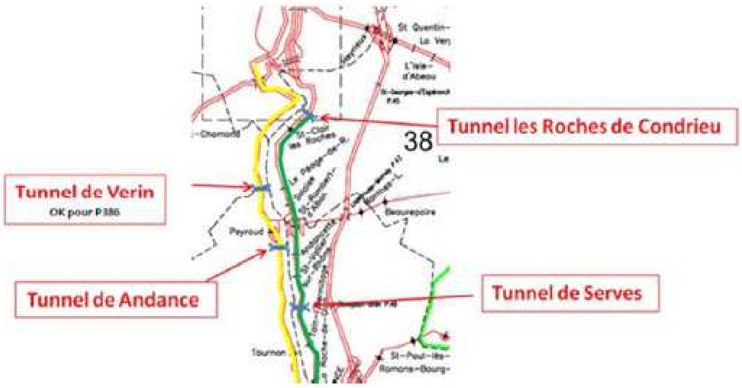


Figure 18 – Bottlenecks in the Rhone Valley

Clearance gauge enlargement allowing trains carrying semi-trailers (minimum P386 loading gauge) on one of the two banks could lead to an immediate increase in rail freight traffic on long rail itineraries.

The combined removal of bottlenecks in Catalonia and the Rhone Valley would facilitate the development of long distance rail transport between Barcelona and northern Europe (Allemagne, Belgium, Netherlands, and Luxemburg) and would also open an itinerary between corridors 2 and 6.

3.4.3. Selected key line sections

The market study has led to the identification of 5 key line sections that have then been specifically studied for the purpose of other work packages in this study.

Corridor / Section	Infrastructure Manager	Areas linked	
RFC2: North Sea - Mediterranean			
Tunnels of Vosges	RFF	North Sea Benelux	Germany Switzerland
Dijon – Mulhouse	RFF	Lyon Barcelona Mediterranean Corridor	Germany
RFC4: Atlantic			
Meaux - Epernay	RFF	Paris Atlantic Corridor	Germany
RFC6: Mediterranean			
Perpignan - Barcelona	ADIF TP Ferro RFF	Spain	Rhone Valley
Rhone Valley	RFF	Rhone Valley	Benelux Germany

Figure 19 – Selected Key Line Section

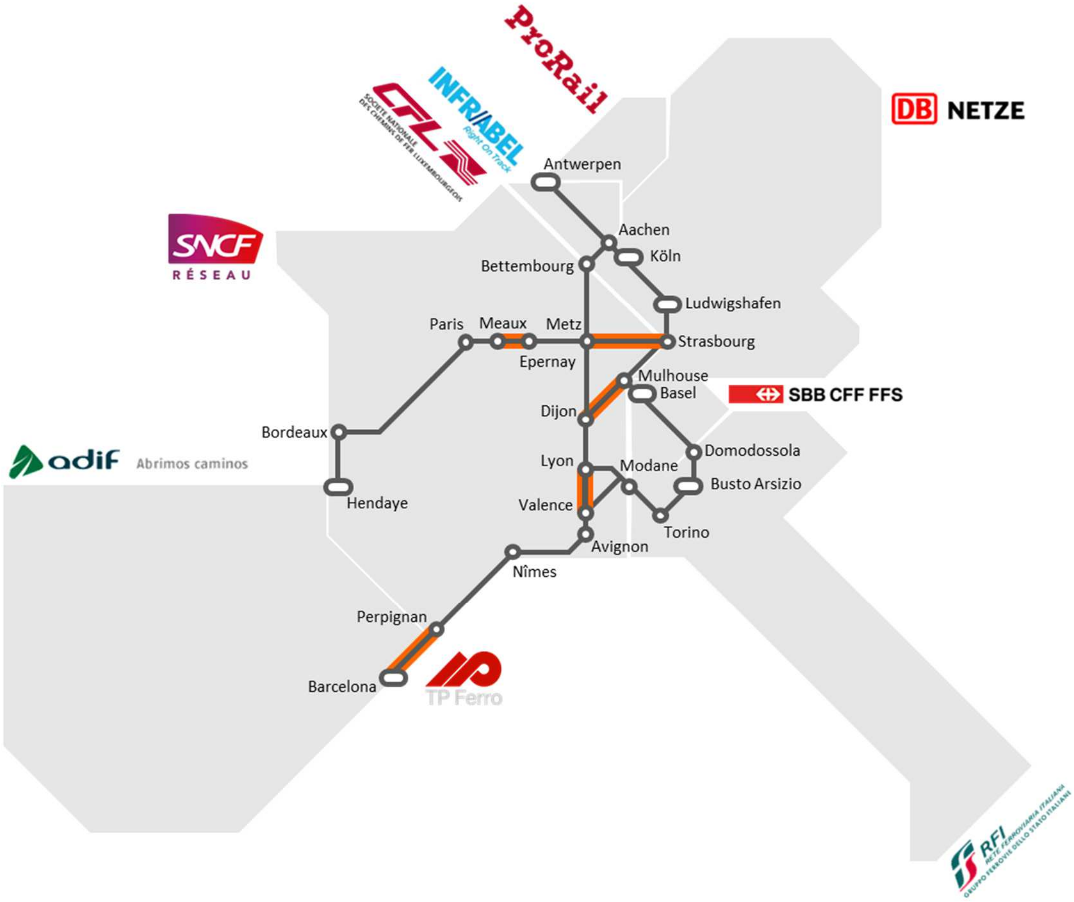


Figure 20 – Selected Key Line Section

Though the section of rail line between Bayonne and Hendaye was initially considered, this section has finally not been retained for the traffic forecasts or the analysis in Work Package 6. Indeed, enlarging the gauge on this section only makes sense if the Atlantic Rail Motorway project is undertaken, and this prospect is by no means certain.

3.5. Expected profiles

One of the objectives of the market study is to identify the loading gauges that operators would desire, in the case of lines that currently offer limited clearance gauges.

Though certain sections with very limited clearance gauge may see their traffic increase with a minor change in gauge (going from authorizing only C22 to authorizing C45, for example), the rail users are almost unanimously in agreement that they want the P400 loading gauge to be authorized over all itineraries. The P400 corresponds to the size of a 4-meter trailer loaded on a standard pocket wagon (which floor is 33cm high above the top of the rail).

This expectation is justified not only by the principle of maximum capacity (a P400-compatible line allows for all existing regular profiles), but also the nature of the potential traffic. Currently, the principal source of development of combined transport resides in the mode shift of semi-trailers and trucks, in particular via the concept of rail motorways, but also via the creation of mixed combined trains that carry both containers and semi-trailers. As such, the current study is almost unanimously considered to be an opportunity to convert the principle freight itineraries to P400.

Certain members of the European Union, like Belgium for example, systematically convert their rail infrastructure to allow clearance for the P400 loading gauge whenever works are carried out on a section of their network.

Currently, a large part of the TEN-T rail network is compatible with the P400 clearance gauge, in particular in Eastern Europe (see § 2.3.2). However, the railway clearance gauge in Spain, as well as on some sections in France and Italy is smaller.

Therefore, the enhancement of the identified line section toward a P400 compatible gauge would make some of the main continental routes available for a much wider market

This need for P400 can of course be satisfied with enlargement of the gauge to a P400 compatible infrastructure, but also by using lower pocket wagons in order to fit in lower tunnels.

While the “standard” pocket wagon’s floor is 33 cm above the top of the rail, giving a total height of 433 cm for the system wagon-trailer (P400 stands for this total height, from which the 33 cm of the wagon are deducted), 27 cm pocket wagons are quite commonly used for trailer transportation. Therefore, with these wagons, a P394 gauge would be enough to run 4m high trailers on trains.

For each selected line section WP6, two scenarios are studied: one in which the clearance gauge is enlarged to P400, and on in which clearance gauge is enlarged to P394.

The conversion of these key line section to a “P400” gauge is naturally the scenario most likely to increase significantly the rail traffic flows, since it would offer service continuity on greater distances for trailer transportation.

The P394 solution would reduce the possibilities for stakeholders because it would introduce a discriminating parameter, which the possibility to use of lower pocket wagons, able to fit 4m trailers into this specific profile.

However, P394 is studied in addition to P400 for two reasons:

- Such 27cm pocket wagons are getting more commonly used by combined operators and are nowadays being brought forward by manufacturers
- In case of a marked difference between these two option, in terms of cost, gauge enlargement toward a P394 profile would still be an enhancement while P400 could not be afforded

3.6. Traffic forecasts

The analysis that has been carried out, in particular in cooperation with corridor managers, has made it possible to identify this short list by identifying those sections where (1) the length of the infrastructure whose gauge shall be enlarged is small compared to the overall itineraries that would be impacted by the enlargement; and where (2) a localized gauge enlargement would produce a homogeneous authorized gauge throughout the corridor.

The potential traffic that could be generated by the enlargement of the clearance gauge on these sections has been estimated during the market study. Some rail freight stakeholders have mentioned development of their traffic, but this information cannot be communicated as-is due to confidentiality concerns. Indeed, a limited number of rail operators have been willing to participate in this study, and most of the information obtained is confidential. It has been agreed with the interviewees that the data shall be used as input to the definition of the gauge enlargement scenarios that are the subject of the feasibility study and the cost benefit analysis. However, it has also been agreed that the data will only be communicated in an aggregated fashion, together with all data received, in order to avoid providing explicit information on the market development projects of the companies providing the data.

All the results of these traffic forecast are presented within the results of the economic appraisal, in a later chapter of this report.

These stakeholders in the freight market have provided information on their current and future traffic, in light of the undertaking or not of gauge enlargement works on the studied links.

This potential traffic has been identified not only via the new traffic flows predicted in these interviews, but also in function of the reductions in transport cost due to the envisaged gauge enlargement works that could be achieved thanks to:

- Modal shift to rail
- Shortening or optimization of the rail itinerary
- Gain in capacity per transport unit, which would lower price per ton transported

Traffic forecasts have been made by gathering information from participating stakeholders. The questionnaire displayed below has been sent to stakeholders and received answers have led to the definition of traffic scenarios.

As some bottlenecks sections appears to provide joint benefits and address common markets (origin-destinations), the scenarios submitted to the economic and financial appraisal concerns groups of bottlenecks as detailed further below in this document.

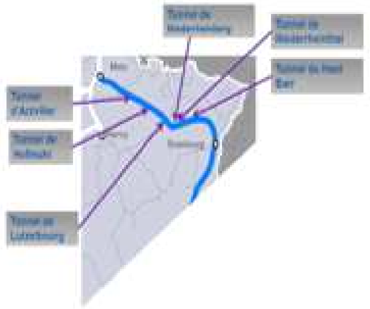
5 links selected for enhancement					
Link	Link 1 : Tunnels of the Vosges	Link 2 : Dijon - Mulhouse	Link 3 : East of Paris (Meaux - Epernay)	Link 4: Rhone Valley	Link 5: Perpignan - Barcelona
Location of the link					
Description of the expected enhancement	Operation on 6 tunnels to enhance their gauge to be compatible with P394 or P400 profiles	Upgrade of the rail link between Dijon and Mulhouse, to reach the GB profile.	GB1 is available on the line between Paris and Germany, except on a short section between Meaux and Epernay (the pink section on the map above), which is currently offering GB. Enhancement would provide GB1 on the whole line.	Train circulation is possible on both side of the Rhone river but with limitation due to 4 tunnels, 2 of them on each side of the river, located between Lyon and Montelimar. Upgrade on these tunnels would allow P394 or P400 on one or both sides of the river.	Operation on a tunnel near Perpignan and 3 tunnels near Barcelona would allow P394 or P400 profile to run on this whole link.
Your current activity on these line sections					
For each of these 5 links, please answer the following questions.					
Link	Link 1 : Tunnels of the Vosges	Link 2 : Dijon - Mulhouse	Link 3 : East of Paris (Meaux - Epernay)	Link 4: Rhone Valley	Link 5: Perpignan - Barcelona
Does your company currently run combined transport traffic on this link?					
If Yes – What are the origin(s) and destination(s) of these flows?					
If Yes – Which are the rail-road combined transport sites used to perform these traffics?					
If Yes – What volume of traffic? (trains per year, trailers/TEU per year)					
If Yes – What kind of containers, swap bodies, and/or trailers do you transport?					
If Yes – What kind of rolling stock is used for these traffics (rail cars, pocket wagons)?					
If Yes – What is the result in terms of PC codifcation? (C45, P380, etc...)					
If Yes – Which company (railway undertaking or combined transport operator) are you teaming with to operate these traffics?					

Figure 21 – Extract from the questionnaire for traffic forecast

4. COMPARISON BETWEEN EXISTING AND EXPECTED GAUGES

4.1. Measurement campaign

Data acquisition on the selected line sections has been completed in late 2015, from October 19th to October 30th. Six of these days were dedicated to measurement whereas the other were used to transport the device from a section to the next one.

Section	Length	Freight corridor	Day of measurement
Paris – Châlons-en-Champagne	170km	Atlantic	19/10/2015
Châlons-en-Champagne – Paris	170km	Atlantic	19/10/2015
Dijon – Mulhouse	235km	North Sea - Mediterranean	21/10/2015
Mulhouse – Dijon	235km	North Sea - Mediterranean	22/10/2015
Peyraud – Avignon	180km	North Sea - Mediterranean / Mediterranean	26/10/2015
Avignon – Givors	220km	North Sea - Mediterranean / Mediterranean	27/10/2015
Bayonne – Hendaye	35km	Atlantic	29/10/2015
Hendaye – Bayonne	35km	Atlantic	30/10/2015

Figure 22 – Measurement schedule

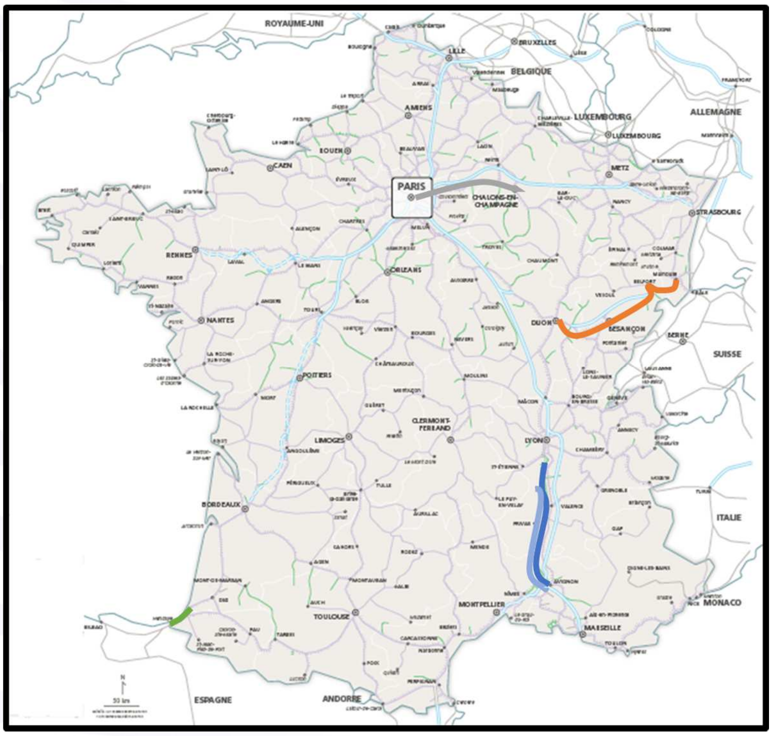


Figure 23 –Measured sections

Acquisitions have performed at a maximum speed of 80km/h.

The convoy was led by a diesel locomotive, followed by a train car containing the office for acquisition and registration, and followed at the end a wagon carrying the dynamic laser scanner device (Riegl VMX-450 Rail).

During the acquisition, several types information are collected, such as

- the path of the train is determined using GNSS and inertial data,
- measurements from the 3D scanner,
- photos and videos.

Figure 24 – During the measurement campaign

4.2. *Definition of target clearance gauge profiles*

SNCF has defined the rules to be used in order to identify infrastructure clearance gauge corresponding to rolling stock descriptions corresponding to the target P394 and P400 gauges.

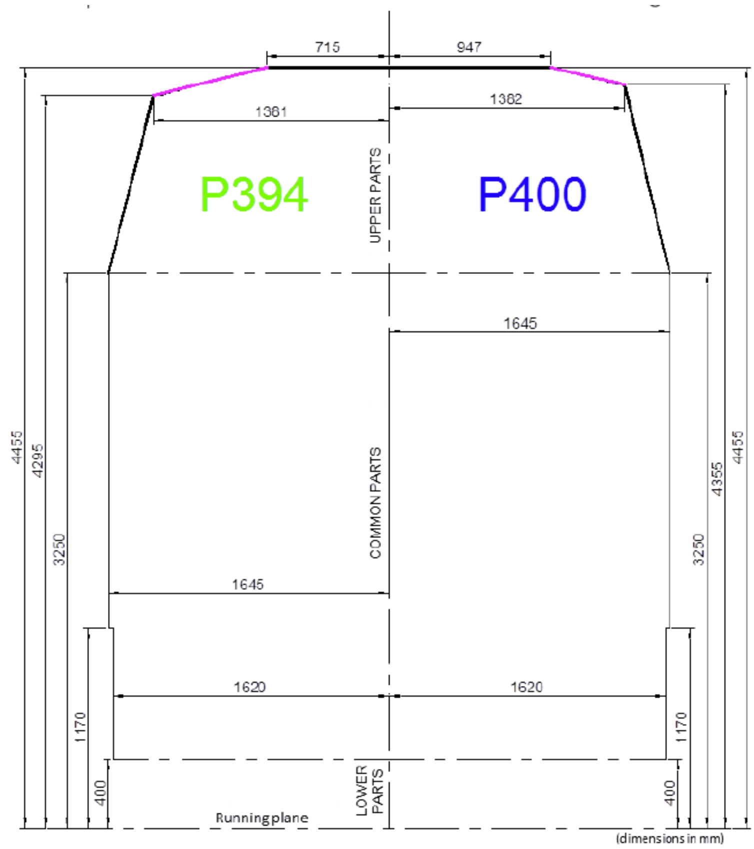


Figure 25 – Kinematic reference profile for codified contours P394 and P400

These calculation take as a basis a description of the actual space occupied by the rolling stock, and then adds the margins needed to take into account over swing on turns or changes in grade, as well as train movement on the tracks.

The principles of gauging calculations are the following:

- each gauge (GA, GB, GB1…) is based on a "kinematic reference contour" defined in EN 15273,
- for the definition of vehicle gauge, the relevant contour is reduced to take into account various phenomena,
- for the definition of infrastructure gauge, this contour is increased to take into account other phenomena,
- the effect of these phenomena (additional space needed for vehicle middle inside the curves and for vehicle ends outside the curves, space for vehicle inclination due to cant excess or cant deficiency, clearances between different vehicle parts, vehicle movements due to track irregularities…) is shared by convention between these vehicle reduction and infrastructure increment rules.

For the definition of a new gauge in response to a market demand, this process is adapted as follows:

- the desired (vehicle and payload) gauge is increased (by reversing the reduction rules usually applied for vehicle gauging) in order to define a new kinematic reference contour,
- this contour is then increased (same principle as usual) to obtain the corresponding new infrastructure gauge,
- this new infrastructure gauge (kinematic reference contour and relevant increment rules) is implemented in the software to be used by the offices in charge of detailed studies,
- the availability of this gauge on the targeted routes is checked with the help of this software, based on the results of field measurements performed along these routes.

The result of this process, with the addition of the necessary margins, is the Infrastructure Implantation Limit Gauge, which is compared to the available space inside the encountered tunnels or obstacles.

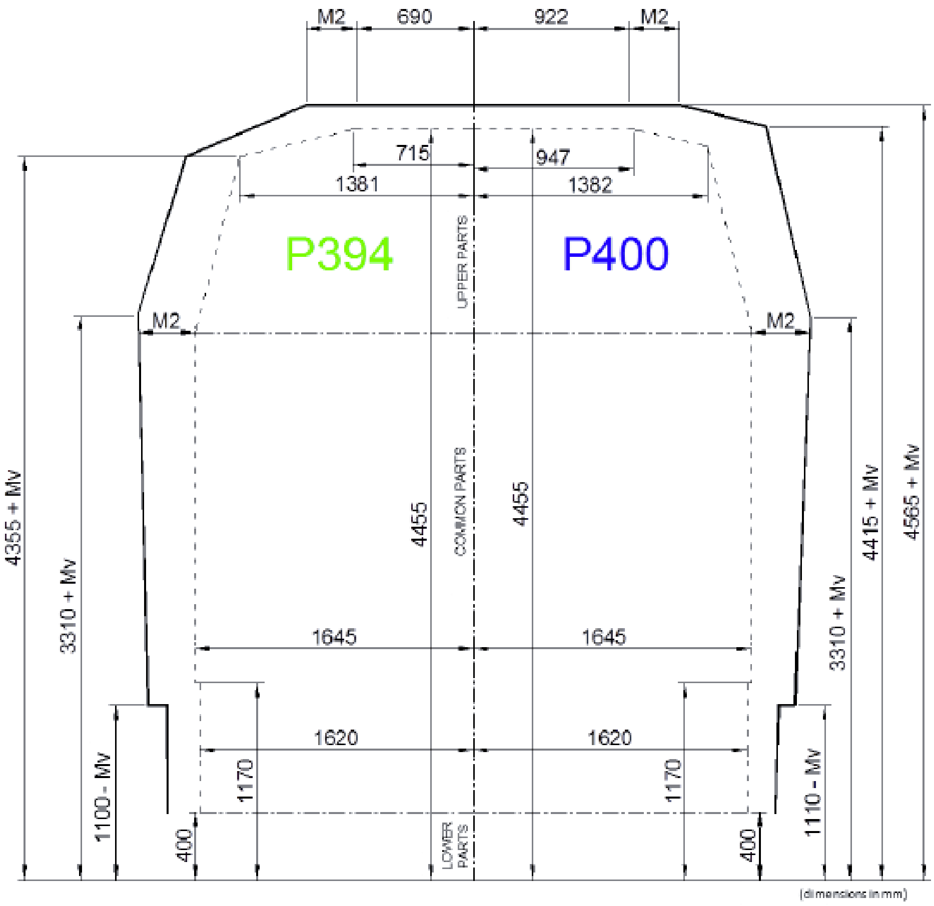


Figure 26 – Infrastructure Implantation Limit Gauges for P394 and P400

4.3. Comparison between infrastructure gauge and defined profiles

The measurement campaign has given a 3D represatation of the bottlenecks by a cloud of point.

Then superposition of these contours (the Infrastructure Implemantation Limit Gauges) and the infrastructure captured shape enables to detect and locate the risk of instrusion (mostly located in the upper corners of the transported trailers) for both P394 and P400.

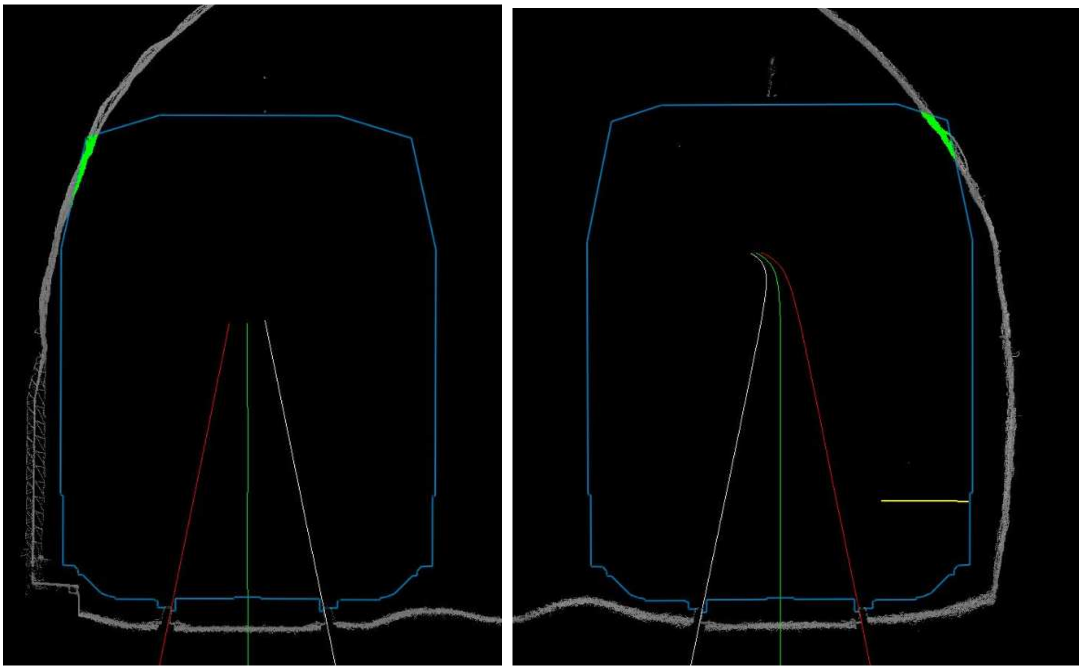


Figure 27 – Screenshots from the analysis software

The depths of intrusion along the tunnels have been estimated by reducing gradually the size of the contour and running it again through the point clouds: the occurrence of an intrusion with a reduce shape provide some information about the depth of the real intrusion.

For each tunnel from each studied line section, all the detected intrusion are registered, according to the subsection inside the tunnel and also to the depth of the detected intrusion, which will determine the type of work that would be necessary to upgrade the clearance gauge on the given tunnel.

Tunnel Section		Depth of intrusion				Contact area
Beginning	End	0 to 5cm	5 to 10cm	10 to 20cm	> 20cm	
580+152	580+298	81	20	43	2	Corner
580+318	580+389	34	31	6	0	Corner
580+401	580+476	39	25	11	0	Corner
580+553	580+602	25	13	11	0	Corner
580+647	580+667	13	7	0	0	Corner
580+677	580+685	6	2	0	0	Corner
580+690	580+727	12	21	4	0	Corner
580+756	580+761	5	0	0	0	Corner

Figure 28 – Depths of intrusion along one of the tunnels

These different level of depth determine the kinf of operation that has to be performed on each bottleneck and these cost estimates will provide investment scenarios to the cost-benefit analysis, which will determine if the upgrade of the studied line sections would be profitable, for each selected key line section.

5. FEASIBILITY STUDY

5.1. Introduction

Work Package 6 consists of two main parts, which are the Feasibility Study and the Cost Benefit Analysis.

The main inputs of this work package has been provided by the market study (Work Package 3) and the Measurement Campaign (Work Package 4). Additional assumptions has been taken to:

- Qualify and quantify the works of railway gauge upgrade for each bottleneck section;
- Evaluate the social, economic and financial impact of these investments;

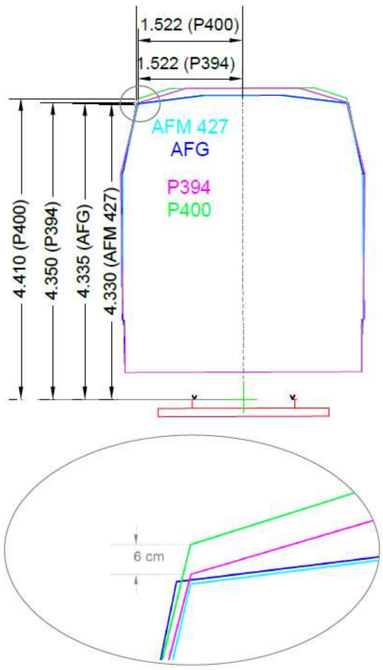
The feasibility study largely rely on the expertise of SNCF for similar works to define a standard typology of works operation and planning. The methodology of the Cost Benefit Analysis enforces the recommendations of the *Guide to Cost Benefit Analysis of Investment Projects, December 2014* from the European Commission.

5.2. Perimeter of the analysis

The Work Package 6 aims at qualifying, quantifying the works of railway gauge upgrade and appraising these investments regarding social, economic and financial impacts.

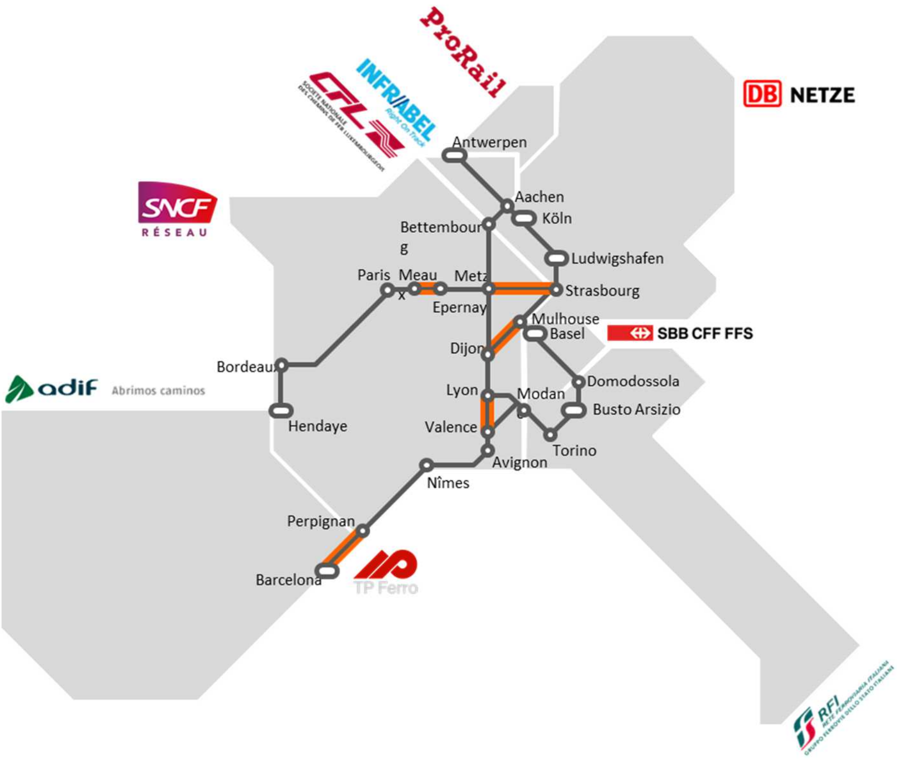
As a reminder, two clearance gauge standards are defined in this study, corresponding to the minimum envelopes being European standards for semi-trailers' transport on trains. Those standards are P394 and P400.

Figure 29 Geometric shapes of gauge envelopes for P394, P400, AFG and AFM 427



The Market Study performed previously has led to the identification and selection of 5 bottlenecks all over the European railway network in terms of clearance gauge. It has also triggered the beginning of a measurement campaign carried out from October 19th to October 30th 2015.

Figure 30 Bottleneck links identified in the market study



This measurement campaign concerns 47 tunnels representing a cumulated length of 22 km. These tunnels are part of 8 lines inscribed in 3 European Rail Freight Corridors which are the Atlantic Corridor, The Mediterranean Corridor and the North-Sea-Mediterranean Corridor.

Table 1 List and length of tunnels measured

Lines	Available data sources	Number and name of tunnels	Tunnel Length (km)
Paris/Metz (Meaux-Epergnay)	SNCF Réseau study	3 Armentières. Nanteuil. Chézy	2.22
Metz/Strasbourg (Tunnels des Vosges)	Previous data gathered for ETCS	6 Arzviller*. Hoffmuhl. Lutzerlbourg. Niederrheinberg. Niederrheilthal*. Haut Barr*	4.65
Dijon/Mulhouse	SNCF Réseau study	16 Champvans-les-Dole¤. Châlezeule. Laissey. Fourbanne¤. Champvans¤. Beaume-les-Dames*. Grange-Ravey n°1 et 2¤. Bois-la-Ville¤. Hyèvre-Paroisse. Passerelle d'Hyèvre¤. Branne. Clerval¤. Rang*. La Prêtrière. Montbéliard¤	6.55

Paris/Marseille (Vallée du Rhône)	Previous data gathered for TEPE	4 Verin¤. Andance¤. Les Roches de Condrieu*. Tunnel de Serves¤	1.41

The detail of these tunnels is specified below including already foreseen upgrade works and not depending on the project of clearance gauge.

Table 2 Vosges tunnels measured and ongoing or planned upgrade works

Line	Tunnel	Entrance PK value	Length (m)	Upgrade works
n° 070 000 from Noisy-le-Sec to Strasbourg-ville	Armentières	054+183	655 m	Works in 2016 – Reinforcement and repair of the slab
	Nanteuil	072+254	945 m	Works in 2019 – in the tunnel gallery which is already done
	Chézy	087+409	618 m	Works in 2017 – Refer to tender documents
	Arzviller	439+634	2690 m	Works in 2023 or after - 90 ml shotcrete shell
	Hoffmuhl	446+336	328 m	Works in 2019 - 35 ml shotcrete shell + sidewall reinforcement
	Lutzerlbourg	448+084	439 m	Shell and underpinning 2019: 35 ml shotcrete shell + sidewalls reinforcement
	Niederrheinberg	451+518	400 m	2019 - 30 ml shotcrete shell + sidewalls reinforcement
	Niederrheilthal	452+220	493 m	Regeneration 2026 – sidewalls reinforcement along 15 linear meter
	Haut Barr	455+180	304 m	Renewal 2032

Table 3 Dijon – Mulhouse tunnels measured and ongoing or planned upgrade works

Line	Tunnel	Entrance PK value	Length (m)	Upgrade works
n° 850 000 from Dijon to Vallorbe	Champvans-les-Dole	357+248	861 m	Not foreseen in upgrade program before 2023
n° 852 000 from Dole-Ville to Belfort	Châlezeule	408+320	1103 m	Gauge cleaning FR3.3 - Works in 2016-2017
	Laissey	425+549	40 m	Works in 2019 - 391 linear meter of shotcrete reinforcement

	Fourbanne	432+712	309 m	Works in 2023 – partial reinforcement of sidewalls along 30 linear meters
	Champvans	435+738	571 m	Works in 2023 – partial reinforcement of sidewalls along 50 linear meters
	Beaume-les-Dames	438+272	558 m	Works in 2020 - 447 ml additional liner
	Grange-Ravey N°1	440+303	51 m	Not foreseen in upgrade program before 2023
	Grange-Ravey N°2	440+412	42 m	Not foreseen in upgrade program before 2023
	Bois-la-ville	442+512	252 m	Not foreseen in upgrade program before 2023
	Hyèvre-Paroisse	443+753	264 m	Works in 2016 – Gauge cleaning FR3 .3 – Coating operation
	Passerelle d'Hyèvre	445+420	36 m	Not foreseen in upgrade program before 2023
	Branne	446+284	362 m	Works in 2016 – Gauge cleaning FR3 .3 – Shotcrete arch segments
	Clerval	453+032	102 m	Not foreseen in upgrade program before 2023
	Rang	461+086	1162 m	Not foreseen in upgrade program before 2023
	La Prêtrière	466+356	300 m	Works in 2016 – Gauge cleaning FR3 .3 - Coating operation
	Montbéliard	482+249	535 m	Not foreseen in upgrade program before 2023

Table 4 Rhône Valley tunnels measured and ongoing or planned upgrade works

Line	Tunnel	Entrance PK value	Length (m)	Upgrade works
n° 800 000 from Givors to Grezan	Verin	555+083	179 m	Not foreseen in upgrade program before 2023
	Andance	580+087	670 m	Not foreseen in upgrade program before 2023
n° 830 000 from Paris-Lyon to	Les Roches de Condrieu	553+818	181 m	Works in 2018-2022 - 150 ml additional waterproof vault coating
	Tunnel de Serves	590+210	382 m	Not foreseen in upgrade program before 2023

Marseille-St-Charles				

5.3. Methodology

5.3.1. Measurement campaign inputs processing

The measurement campaign has been carried out following methodology defined by SNCF I&P LVE. It consists in detecting obstacles, i.e. overlapping section of tunnel with P394 and P400 gauges envelope.

The intersection between the tunnel geometry and the P394 and P400 profiles have been calculated for each tunnel considering:

- A train speed of 120 km/h;
- A security margin of 1 cm to cover measurement devices inaccuracy;

The overlapping sections have been classified into 4 classes of depths which are:

- Under 5 cm
- From 5 to 10 cm
- From 10 to 20 cm
- Over 20 cm.

For each tunnel, tables of overlapping sections' length summarize the extent of sections to upgrade.

Table 5 Example of overlapping sections's length summary for the Andance tunnel

P 394 V1					
PK Début	PK Fin	Engagements (m)			
		0 à 5cm	5 à 10cm	10 à 20cm	> 20cm
580+086	580+148	42	18	2	0
580+204	580+211	7	0	0	0
580+218	580+220	2	0	0	0
580+222	580+422	77	93	30	0
580+489	580+496	5	0	2	0
580+496	580+506	0	0	10	0
580+506	580+529	13	10	0	0
580+594	580+624	3	25	2	0
580+630	580+652	20	2	0	0
580+657	580+659	2	0	0	0
580+695	580+717	11	11	0	0

5.3.2. Technical solutions

To realize the upgrade of tunnels, two types of work are feasible:

- Tunnel vault works
- Roadbed lowering.

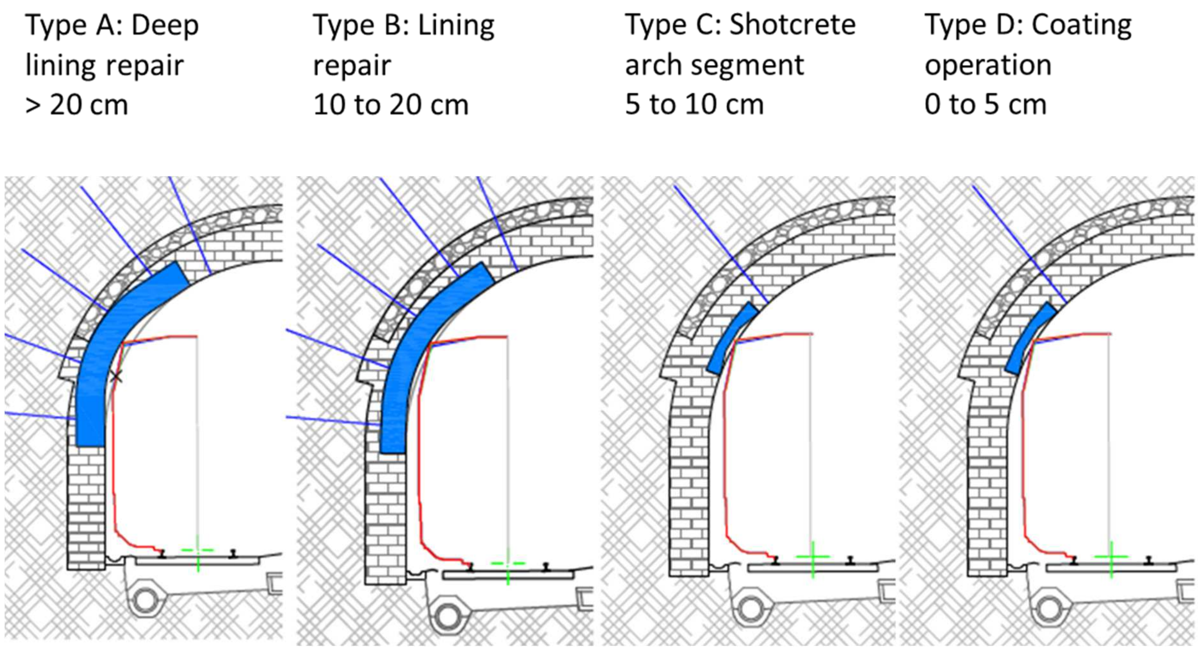
Tunnel vault works

In the case of tunnel vault works the choice, the deeper the overlapping, the costlier and complex are the works. A simplified typology of works has been proposed as follow:

Table 6 Vault works typology by overlapping depth

Overlapping depth	Type of works
Over 20 cm	Type A – Deep lining repair
From 10 to 20 cm	Type B – Lining repair
From 5 to 10 cm	Type C – Shotcrete arch segment
Under 5 cm	Type D – Coating operation

Types A, B and C require decreasingly complex lining repair whereas type D covers a thinner coating operation.



Support structure
(Source: SNCF)

Arch segment
(Source: SNCF)

Coating operation
(Source: Etandex)

Types A and B lining repairs will include:

- Installation of retaining anchorages
- Tunnel segment destruction

Type C works will include:

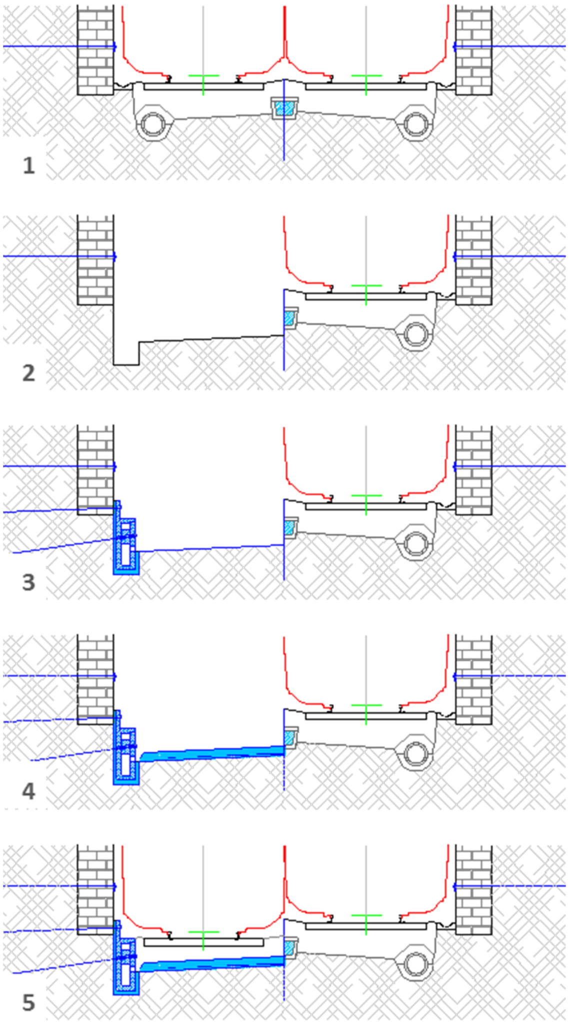
- Installation and fixation of a reinforcing cage
- Shotcrete projection on the tunnel segment.

Roadbed lowering

In the case of roadbed works, sewage and drainage systems modifications are required. In some cases, additional underpinning should be foreseen.

The process is split into 5 steps:

Figure 32 Roadbed lowering work description



In comparison with tunnel vault works, roadbed lowering typology is an interesting option for following situations:

- Short tunnels (< 500 m);
- Gauges overlapping for more than the half of tunnel length;
- Specific situation for which vault works are very expensive;
- No concrete apron to modify;
- No reinforced concrete sidewalls to modify;
- Partial service interruption by direction;

5.4. Provisional cost and planning of works

5.4.1. Work cost estimation

A cost estimation is given by tunnel, technical solution and process option of traffic management. Scenarios are proposed in another part later in this report to combine the best solutions for each tunnel.

Two options of traffic management are possible with various impact on the duration and cost of works:

- Option 1: partial traffic interruption
- Option 2: total traffic interruption by track (except signaling costs).

Unlike vault works, the traffic remains possible on one track during works duration. Therefore, only one process option (corresponding to option 1) is tested for this typology.

As a reminder, a deeper analysis of the option 2 is required to make sure of its compatibility with current operation.

Table 7 Costs estimation for each technical solution and options

M€ 2016	Vault works P394		Vault works P400		Roadbed Lowering works P400
	Option 1	Option 2	Option 1	Option 2	
Paris/Metz	32.4	19.2	52.3	30.1	21.0
Metz/Strasbourg	121.3	74.2	146.8	88.4	120.0
Dijon/Mulhouse	203.7	123.1	246.9	149.0	192.0
Paris/Marseille	14.5	8.9	26.6	16.0	45.0
TOTAL	371.9	225.4	472.6	283.5	378.0

Source: SNCF, 2016

Corresponding work planning estimations have been done on standard productivity ratios considering the extent and the type of work proposed.

The costs of these operations appear to be very specific to each tunnel that has been studied, and they can hardly be approximated using cost ratios. The figure below displays the investment costs for one meter of operation, for the studied tunnels, and shows a great disparity in the results.

Figure 33 Linear cost of investment

Impossible d'afficher l'image liée. Le fichier a peut-être été déplacé, renommé ou supprimé. Vérifiez que la liaison pointe vers le fichier et l'emplacement corrects.

5.4.2. Work planning estimation

Table 8 Work planning estimation

				P 394				Vault Works				P 400				Vault Works				Roadbed lowering		
				Impact			Dec 2015 Costs	Schedule		Dec 2015 Costs	Schedule	Impact			Dec 2015 Costs	Schedule		Dec 2015 Costs	Schedule	Janv. 2014 Costs	Schedule	
							P394_VAULTO1C	P394_VAULTO1S		P394_VAULTO2C	P394_VAULTO2S				P400_VAULTO1C	P400_VAULTO1S		P400_VAULTO2C	P400_VAULTO2S	P400_RBLOWC	P400_RBLOWS	
Line	Tunnel	Initial Kilometer Point	Length (m)	Work linear work V1 + V2	% tunnel impacted	K€/ml	Option 1 : Work with partial traffic interruption		K€/ml	Option 2 : Works with total traffic interruption by track (except signaling costs)		Work linear work V1 + V2	% tunnel impacted	K€/ml	Option 1 : Work with partial traffic interruption		K€/ml	Option 2 : Works with total traffic interruption by track (except signaling costs)		Option 2 : Works with total traffic interruption by track (except signaling costs)		K€/ml including branches
70 000 DE NOISY-LE-SEC A STRASBOURG VILLE	Armentières	054+183	655	660	50%	15	5,0 M€	4,5 months	9	3,0 M€	2,5 months	1034	79%	21	11,0 M€	5,5 months	12	6,0 M€	3,5 months	N.R Radier	N.R Radier	
	Nanteuil	072+254	945	1644	87%	25	20,7 M€	6,5 months	15	12,2 M€	3,2 months	1795	95%	35	31,0 M€	10,1 months	20	18,1 M€	4,8 months	N.R Radier	N.R Radier	
	Chézy	087+409	618	487	39%	28	6,7 M€	3,5 months	16	4,0 M€	1,8 months	594	48%	35	10,3 M€	4,8 months	20	6,0 M€	2,3 months	21,0 M€	5,6 months	18,8 k€
	Total sections Paris to Metz						**32,4 M€**	**14,5 months**		**19,2 M€**	**7,5 months**				**52,3 M€**	**20,4 months**		**30,1 M€**	**10,6 months**	**21,0 M€**	**5,6 months**	
	Arzviller	439+634	2690	2871	53%	41	58,9 M€	14,5 months	25	35,5 M€	8,7 months	3259	61%	44	71,6 M€	19,3 months	26	42,4 M€	10,1 months	65,0 M€	16,0 months	20,4 k€
	Hoffmuhl V1	446+336	328	66	10%	48	1,6 M€	1,2 months	39	1,3 M€	1,2 months	82	13%	51	2,1 M€	1,6 months	34	1,4 M€	1,2 months	N.P	N.P	
	Hoffmuhl V2	446+336	247	0	0%		-	-		-	-	0	0%		-	-		-	-	-	-	
	Lutzerlbourg	448+084	439	871	99%	51	22,4 M€	7,4 months	31	13,7 M€	4,8 months	873	99%	60	26,1 M€	9,2 months	36	15,8 M€	5,5 months	20,0 M€	6,2 months	23,8 k€
	Niederrheinberg	451+518	400	325	41%	17	2,8 M€	1,8 months	12	2,0 M€	1,6 months	466	58%	20	4,7 M€	2,8 months	14	3,2 M€	2,3 months	N.P	N.P	
	Niederrheilthal	452+220	493	914	93%	36	16,6 M€	5,5 months	22	10,1 M€	3,5 months	945	96%	44	20,9 M€	6,7 months	27	12,7 M€	4,1 months	17,0 M€	6,0 months	19,0 k€
	Haut Barr	455+180	304	608	100%	63	19,0 M€	6,7 months	38	11,6 M€	4,1 months	608	100%	70	21,4 M€	8,3 months	42	12,9 M€	5,1 months	18,0 M€	6,0 months	25,6 k€
	Total sections Metz to Strasbourg-Ville						**121,3 M€**	**37,1 months**		**74,2 M€**	**23,9 months**				**146,8 M€**	**47,9 months**		**88,4 M€**	**28,3 months**	**120,0 M€**	**34,2 months**	
n° 850 000 Dijon à Vallorbe	Champvans-les-Dole	357+248	861	1716	100%	41	35,3 M€	10,8 months	24	20,6 M€	5,1 months	1717	100%	49	42,4 M€	13,3 months	29	24,6 M€	6,0 months	N.R Reprises	N.R Reprises	
n° 852 000 Dole-Ville à Belfort	Châlezeule	408+320	1103	1421	64%	28	19,9 M€	6,7 months	17	12,1 M€	4,1 months	1730	78%	33	28,7 M€	9,2 months	20	17,5 M€	6,0 months	31,0 M€	8,2 months	20,6 k€
	Laissey	425+549	40	79	99%	86	3,4 M€	2,1 months	56	2,2 M€	1,4 months	79	99%	86	3,4 M€	2,1 months	56	2,2 M€	1,4 months	N.P	N.P	
	Fourbanne	432+712	309	614	99%	67	20,5 M€	7,8 months	41	12,5 M€	4,8 months	614	99%	69	21,1 M€	8,3 months	42	12,8 M€	5,1 months	23,0 M€	7,6 months	22,8 k€
	Champvans	435+738	571	195	17%	40	3,9 M€	2,3 months	25	2,4 M€	1,4 months	301	26%	53	8,0 M€	3,7 months	34	5,1 M€	2,8 months	N.P	N.P	
	Beaume-les-Dames	438+272	558	425	38%	21	4,4 M€	2,5 months	12	2,6 M€	1,4 months	551	49%	26	7,2 M€	3,2 months	16	4,4 M€	1,8 months	N.P	N.P	
	Grange-Ravey N°1	440+303	51	94	92%	79	3,7 M€	2,1 months	53	2,5 M€	1,6 months	94	92%	79	3,7 M€	2,1 months	53	2,5 M€	1,6 months	N.P	N.P	
	Grange-Ravey N°2	440+412	42	74	88%	86	3,2 M€	2,3 months	54	2,0 M€	1,4 months	84	100%	86	3,6 M€	2,8 months	52	2,2 M€	1,6 months	N.P	N.P	
	Bois-la-ville	442+512	252	390	77%	52	10,2 M€	4,6 months	31	6,0 M€	2,3 months	397	79%	57	11,3 M€	5,1 months	33	6,6 M€	2,5 months	21,0 M€	7,6 months	22,1 k€
	Hyèvre-Paroisse	443+753	264	419	79%	57	12,0 M€	5,5 months	34	7,1 M€	2,8 months	460	87%	57	13,1 M€	6,2 months	33	7,6 M€	3,0 months	21,0 M€	7,6 months	21,8 k€
	Passerelle d'Hyèvre	445+420	36	60	83%	73	2,2 M€	1,8 months	47	1,4 M€	1,2 months	64	89%	78	2,5 M€	2,1 months	47	1,5 M€	1,2 months	N.P	N.P	
	Branne	446+284	362	679	94%	51	17,3 M€	6,0 months	31	10,6 M€	3,9 months	703	97%	57	19,9 M€	6,9 months	35	12,2 M€	4,6 months	25,0 M€	8,2 months	23,5 k€
	Clerval	453+032	102	204	100%	41	4,2 M€	2,3 months	26	2,7 M€	1,6 months	204	100%	50	5,1 M€	2,5 months	32	3,3 M€	1,8 months	N.P	N.P	
	Rang	461+086	1162	1968	85%	44	43,7 M€	11,5 months	27	26,1 M€	6,4 months	2013	87%	53	53,1 M€	13,6 months	32	31,9 M€	8,1 months	50,0 M€	13,0 months	30,1 k€
	La Prêtrière	466+356	300	591	99%	60	17,6 M€	6,2 months	37	10,9 M€	4,1 months	591	99%	65	19,3 M€	7,4 months	40	11,8 M€	4,6 months	21,0 M€	7,6 months	23,3 k€
	Montbéliard	482+249	535	328	31%	13	2,2 M€	1,6 months	9	1,4 M€	0,9 months	550	51%	16	4,5 M€	2,8 months	10	2,8 M€	1,6 months	N.P	N.P	
	Total sections Dijon to Mulhouse						**203,7 M€**	**76,1 months**		**123,1 M€**	**44,4 months**				**246,9 M€**	**91,3 months**		**149,0 M€**	**53,7 months**	**192,0 M€**	**59,8 months**	
n° 800 000 Givors à Canal à Grezan	Verin	555+083	179	103	29%	41	2,1 M€	1,4 months	29	1,5 M€	1,2 months	161	45%	39	3,1 M€	1,8 months	27	2,2 M€	1,6 months	N.P	N.P	
	Andance	580+087	670	634	47%	19	6,1 M€	3,5 months	11	3,5 M€	1,6 months	868	65%	27	11,6 M€	5,1 months	16	6,8 M€	2,5 months	24,0 M€	7,0 months	17,5 k€
n° 830 000 Paris-Lyon à Marseille-St-Charles	Les Roches de Condrieu	553+818	181	64	18%	28	0,9 M€	0,9 months	22	0,7 M€	0,7 months	172	48%	28	2,4 M€	2,1 months	17	1,5 M€	1,2 months	N.P	N.P	
	Tunnel de Serves	590+210	382	658	86%	16	5,4 M€	3,2 months	10	3,2 M€	1,6 months	568	74%	33	9,5 M€	5,5 months	19	5,5 M€	2,5 months	21,0 M€	5,6 months	26,9 k€
	Total sections Paris to Marseille						**14,5 M€**	**9,0 months**		**8,9 M€**	**5,1 months**				**26,6 M€**	**14,5 months**		**16,0 M€**	**7,8 months**	**45,0 M€**	**12,6 months**	
	Total sections Perpignan to Barcelona																					
	TOTAL						371,9 M€	136,7 months		225,4 M€	80,9 months				472,6 M€	174,1 months		283,5 M€	100,4 months	378,0 M€	112,2 months	

6. COST BENEFIT ANALYSIS PRINCIPLES, SCENARIOS AND CONTEXT

The Cost Benefit Analysis applied to the railway gauge upgrade projects follows the methodology recommended by the European Commission in the Guide to Cost-Benefit Analysis of Investment Projects (Economic appraisal tool for Cohesion Policy 2014-2020), December 2014.

The main assumptions and specificities of the appraisal are detailed in the following paragraphs, the various scenarios appraised are also presented in terms of works combination and markets addressed.

6.1. Principles of the economic and financial appraisal

6.1.1. Methodological framework

The economic and financial analysis also called Cost Benefit Analysis (CBA) aims at evaluating the impact of an investment project in comparison with the most likely situation where the project is not realized. The project situation considers a set of railway gauge upgrades. The non-investment situation, namely counterfactual scenario considers every project yet incurred and having an impact on railway traffics in the scope of the study.

All the costs and benefits stem from the traffic and logistic costs variations and the investments related to each provisioned works.

6.1.2. Macro-economics

The appraisal period covers 30 years from the date of commissioning according to the EC recommendations. In accordance to the state of the art, all the monetary estimations are constant prices in 2015 Euros.

The Macro-economic framework of the appraisal is defined thanks to the following documents:

- The EU27 GDP, Population and GDP per capita permit to actualize the unit externalities costs, the historical values being extracted from EUROSTAT and the projected values coming from the Ageing report 2015, EC.
- The French public works index (TP01 index) is used to actualize the amounts of investments: a growth of 1.7% p.a in constant euros is estimated according to the average evolution for 1994-2014;

6.2. Scope and context of the appraisal

6.2.1. Perimeter of the appraisal

This appraisal covers the perimeter of traffic variations estimated in the market study for each bottleneck. It includes interalia road, railway and maritime short sea shipping freight traffics between Belgian/Dutch and Spanish/Italian seaports.

Traffic impact is split into classes as follow:

- Traffic deviation (road to rail, short sea shipping to rail);
- Route deviation (rail only)

Following the market study assumptions, no induction traffics is considered.

Traffics inputs are given by origin-destination and mode for the project and the counterfactual scenario. The zoning applied is equivalent to NUT3 as defined by the European Union.

The types of goods transported is not known, only the type of cargo is specified, namely semi-trailer or containers. For that reason, all volumes of traffics are given in TEU (Twenty feet Equivalent Unit).

6.2.2. Project and counterfactual scenarios

As detailed in the market study and the feasibility study, the appraisal applies to railway gauge upgrade works of 5 bottlenecks. The expected impact is estimated by the comparison of the project scenario and the counterfactual scenario.

The economic and financial appraisal includes the following stakeholders and aims to evaluating the impact for society as a whole:

Table 9 Stakeholders of the economic appraisal

STAKEHOLDERS	REVENUES	COSTS
Freight clients	-	Transport costs Goods and ITU immobilization
Investors	Residual value of investments	Investment costs
Port authorities	Port dues	Maintenance cost Taxes
Maritime operators	Terminal Handling Charges Freight Rates	Handling costs Operation costs Taxes
Railway operators	Transport costs	Operating costs Taxes
Road haulers	Transport costs	Operating costs Semi-Trailer immobilization Taxes
Port terminals' managers	Handling charges	Operating costs Taxes
Inland terminals' managers	Handling charges	Operating costs Taxes
Railway infrastructure manager	Track Access Charges State operating subsidies	Maintenance costs Renewal costs Taxes
Road infrastructure manager	Road tolls	Maintenance costs Taxes
Public authorities	Taxes	-
Third parties	-	Externalities

7. COST BENEFIT ANALYSIS INPUTS

The main Cost Benefit Analysis inputs are the investment costs, the level of services and the traffic forecast. For each, the following paragraphs provide an overview of the various components used to define the scenarios.

7.1. Investment costs

The investment costs of each bottleneck removal are detailed in the Feasibility study paragraph above. The EC Guide already mentioned recommends including an estimation of the residual value of the investments in the appraisal. The linear amortized value of the investments is thus considered via the assumption of an average physical life of 50 years applied to the tunnel works on the vaults or on the roadbed.

As a comparison, the Railway Project Appraisal Guidelines, 2005, EIB, indicates a life of 80-100 years for very large tunnel works and 40 years for Rail UIC ballasted track.

On a 30 years' appraisal period, the residual value calculated via a linear amortization will represent 40% of the initial investment amount. This value is added to the benefits of the last year of appraisal. In discounted value, it represents around 15% of the initial investment amounts.

7.2. Level of service

Modal and rail route deviation between the counterfactual and the project scenarios are estimated thanks to a detailed description of the level of services for each alternative including:

- **Transport distance** by mode extracted from:
    - National Geospatial Intelligence Agency, USA for the short sea shipping mode;
    - Charging Information System, RNE, for the rail mode;
    - ETIS PLUS for the road mode;
- **Average speed** of 60 km/h for the road and rail mode, and 20 knots (37 km/h) for the short sea shipping as indicated by Alpha Liner database for the selected lines;
- **Additional delays** by mode based on a benchmark of operational issues:
    - Train mode:
        - Manoeuver and preparation delay: 2h;
        - Caution delay before closing time: 2h;
        - Goods delivery delay after the train arrival: 1h
        - Border crossing delay: 6h for Spain (including bogies changing) and 2h otherwise
    - Road mode:

        - Rest period each 4.5h of driving: 15 min
        - Rest period each 9h of driving: 9h
    - Short Sea Shipping mode:
        - Caution delay before closing time: 1h;
        - Goods delivery delay after the train arrival: 1h
- **Road dispatch distance** around the platforms of origin-destination based on values commonly used in the literature in the absence of relevant survey:
    - Rail-road dispatch: 100 km
    - Ship-road dispatch: 200 km
    - Road-road dispatch: 50 km (covers the distance between the regional platform/centroid considered to calculate the level of service and the actual destination)

For each scenario, road infrastructures are supposed to have adequate investments to avoid saturation at a regional level. Shipping lines are supposed unchanged, given that the modal deviation do not represent a significant share of current maritime traffics.

7.3. Traffic forecast

7.3.1. Traffic scenarios

The traffic inputs are provided by the market study realized by the consortium (Work package 3) for each scenario and provides the volumes of goods by mode, origin-destination, route and the corresponding deviation between counterfactual and project scenarios.

Some bottlenecks sections appear to provide joint benefits and address common markets (origin-destinations) described below

Table 10 Market volumes

	Markets	K.TEU	M.TEU.km	Extent (km)
M1	Belgium-Swiss/Italy	25.6	17.5	700
M2	Spain-Belgium/Italy	9.4	12.7	1300
M3	South West France-Germany	16.0	22.4	1400
M4	Spain-South Germany	39.2	60.0	1600
M5	South France - South Germany	56.1	45.8	800

7.3.2. Traffic growth

The market study permitted to identify the volumes of traffic and route deviation based on the current economic situation. The economic and financial appraisal require projections all along the evaluation period, considering the changes of macro-economic situation in the future. For that purpose, we rely on the Rail Freight Corridors market studies or TEN-T work plans depending on the origin-destination involved:

Table 11 Market projection assumptions

Corridor	Markets	Traffic CAGR by 2030	Source
RFC 1 Rhine Alpine	M1 Belgium–Swiss/Italy	1.55 % p.a.	TEN-T interventions - Work Plan of the European Coordinator
RFC 2 North Sea Mediterranean	M2 Spain – Belgium M4 Spain – South Germany M5 South France – South Germany	2.00 % p.a.	Consultant estimation
RFC4 Atlantic	M3 South-West France – South Germany	2.56 % p.a.	RFC market study projection - CID Part 5 Implementation Plan 2017
RFC6 Mediterranean	M2 Spain – Italia	2.07 % p.a.	2030 corridor implemented scenario given by the work plan, road traffics only - Work Plan of the European Coordinator

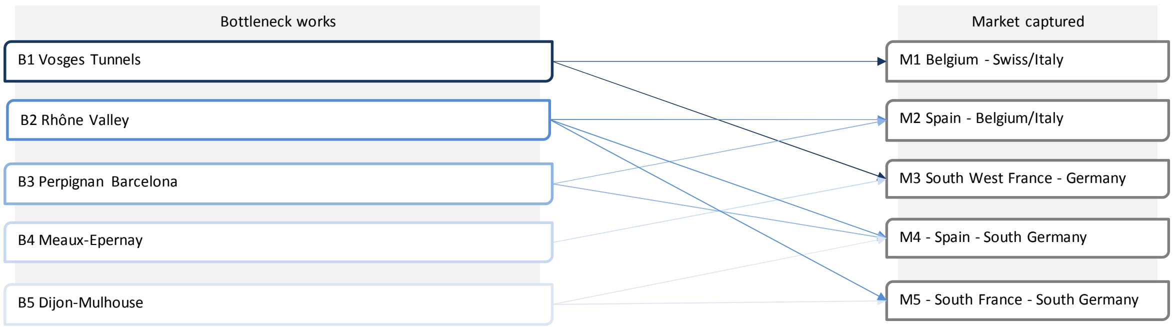
A build-up of traffics is considered as proportionate to the share of investment realized at a given date related to the total of investments planned. For instance, if the investment is planned by thirds over 3 years, the traffic build-up will be of 33% the first year, 66% the second and 100% the third year. It considers the fact that various railway gauge upgrade works are incurred in the same time and some of the origin-destination to be captured are already operated and could develop quickly thanks to a partial work realization (work by track, alternate routing etc…).

8. COST BENEFIT ANALYSIS SCENARIOS

8.1. Combination of works and markets captured

The various bottleneck removals permit to reach different markets: an adequate combination of them allows to reach them as detailed in the scheme bellow.

Figure 34 Combination of works and markets captured



To optimize the comprehensiveness of the appraisal, we propose to evaluate 5 service scenarios to highlight their own and cumulated benefits:

Table 12 Service scenarios definition

Sc.	Bottleneck works	Markets captured
A	**B1** Vosges Tunnels	**M1** Belgium – Swiss/Italy
B	**B1 & B4** Vosges Tunnels and Meaux-Epernay	**M1+M3** Belgium – Swiss/Italy and South West France - Germany
C	**B2 & B3** Rhône Valley and Perpignan Barcelona	**M2** Spain – Belgium/Italy
D	**B2 & B3 & B5** Rhône Valley, Perpignan Barcelona and Dijon-Mulhouse	**M4** Spain – South Germany
E	**B2 & B5** Rhône Valley and Dijon-Mulhouse	**M5** South France – South Germany

Among the tunnels in the Rhône Valley, we estimated the impact of investments on both banks even the right bank is currently a line dedicated to freight trains. Sensitivity tests are appraised hereafter to compare the effect of investing on the one bank or another.

Each of these scenarios shows its interest by comparing the lengths of the identified bottlenecks with those of the entire routes that will benefit from the enhancement operations.

Figure 35 Length (in km) comparison between bottlenecks and entire routes

8.2. Work typology and operations

The feasibility study shown that for most of the cases, there are various constraints among the technical solutions related to:

- The railway gauges' profiles (P394 and P400);
- The works' costs: lowering the roadbed may appear cheaper in some tunnels where an important share of the length is overlapping with the objective gauge profile;
- The operational impact: complete service interruption may appear as a threat to the railway undertakings with the challenge to recover the traffics lost during the work period;

Based on these considerations, we propose 4 work scenarios combined with the infrastructure scenarios which are:

- "Best Price": the cheapest solution is chosen among roadbed lowering and vault works disregarding the operational impact of the works for the P394 and P400 objective gauges;
- "Minimal Customer Loss": the cheapest solution is chosen among roadbed lowering and vault works, choosing if possible the solutions with partial traffic interruption;

The content of the technical scenarios is summarized in the table below.

Table 13 Work scenarios definition

Gauge	Scenario	Technical solution
P394	394.1 Best price	

P400	400.1 Best price	Vault works with total traffic interruption by track
P394	394.2 Minimal Customer Loss	Vault works with partial traffic interruption by track except roadbed lowering for the following tunnels: Arzviller, Lutzerlbourg, Niederrheilthal, Haut Barr (Vosges) and Rang (Dijon-Mulhouse)
P400	400.2 Minimal Customer Loss	Vault works with partial traffic interruption by track except roadbed lowering for the following tunnels: Lutzerlbourg, Haut Barr (Vosges)

Scale economies could potentially be done by grouping the gauge upgrade with maintenance or renewal works planned from 2020: a sensitivity test is proposed to appraise its impact on the economic performance of the project.

9. COST BENEFIT ANALYSIS ASSUMPTIONS

The Cost Benefit Analysis rely on various additional assumptions to estimate the economic and financial impact of the investment projects: it concerns financial unit flows and unit values of externalities permitting to calculate the surplus of each stakeholder.

9.1. Freight clients

For the shippers, the total logistic costs are composed of:

- **Goods immobilization costs**: this unit value theoretically applies to the time savings between counterfactual and project scenarios[1]. This principle assumes that the shippers have an interest in receiving the goods earlier. However, in some logistic schemes like just-in-time organization, the main interest of shippers is to receive the goods timely but not early, which would imply an over cost of storage. For that reason, the immobilization cost of goods is not considered in this study;

- Transport means immobilization costs of 1 €/ton.h considering the similarity between:

    - **Container immobilization costs**: the use of faster transport mode permit to limit the immobilisation of trailer or container and better their productivity with higher turnover. A rental cost of 1.2 $/TEU.day i.e. around 1.0 €/TEU.day is estimated via a benchmark of services proposed for 20' container rental. The container immobilization cost is related to 10 tons per TEU and 12h daily time of amortisement. It leads to an estimation up to **1 €/ton.h** of container immobilization cost.

    - **Trailer immobilization costs**: the Comité National Routier provides an estimation of 13.5 €/h for a trailer immobilization cost, i.e. around **0.9 €/ton.h** related to an average load of 15 tons per trailer;

- Road, railway and maritime transport services prices are detailed below by mode;

9.2. Road Hauliers

The Road Hauler costs estimations are based on the "Comité National Routier" cost model for the French Flag adjusted to obtain an average European value representing the main European Flags' traffics.

Relative values of cost component for each country are provided by the Cost comparison and cost developments in the European road haulage sector, 2014, NEA. Road Hauliers Flag shares are given by the most recent Eurostat database for international road transport.

Average costs can be deduced from the following traffic shares for each item:

- Fuel costs
- Labour costs
- Capital costs

[1] The French Instruction Cadre of 2014 for Infrastructure project appraisal gives a value of 0.60 €2010/t.h for high added values goods.

- Other costs.

Table 14Major flag share in international road transport

Flag (Eurostat 2012)	Millions of t.km	
Poland	147 274	32%
Spain	65 600	14%
Germany	49 022	11%
Netherland	40 311	9%
Czech Republic	39 500	8%
Portugal	26 783	6%
Hungary	26 572	6%
Slovakia	25 581	5%
Latvia	23 798	5%
Romania	21 522	5%

Compared with French values and with coefficients from the "Comité National Routier" it is possible to define average European coefficients:

Table 15 Road costs assumption for France

ITEM	VALUE	UNIT	EVOLUTION
Fuel cost	0.204	€2015/HGV-km	+2,6 % p.a.
Driver Hourly cost	23.11	€2015/HGV-h	+0,3 % p.a.
Daily capital cost	147.30	€2015/HGV-day	+0,0 % p.a.
Other costs	0.093	€2015/HGV-km	+0,0 % % p.a.

Table 16 Road cost assumption correction for European Hauliers

	Fuel cost (€/HGV.km) + taxes	Other cost (€/HGV.km)	Labour cost (€/HGV.h)	Capital cost (€/HGV.day)
10 Flags shares	1.4	83.6	68.9	83.6
France	1.59	93.0	92.8	93.0
Ratio	0.86	0.90	0.74	0.90

Road tolls are extracted from web services queries for each route, the following table present the corresponding unit costs per market.

Table 17 Road tolls and evolution assumptions

Markets	Road tolls €2015/TEU	EVOLUTION
Belgium–Swiss	30	+0.0 % p.a.
Belgium-Italy	80	
Spain – Belgium	160	
Spain – South Germany	150	
South-West France – South Germany	170	
Spain – Italy	340	
South East France – South Germany	N/C	

Road hauliers' revenues are estimated via an average operating margin up to 5 % as given by the sectorial accounts of the French Department for Statistics (INSEE).

9.3. Rail Operators

Railway operators' unit revenues are estimated via an analysis of the annual reports and traffic statistics given in the UIRR for various rail operators in the project perimeter which could be directly concerned by the traffic developments.

The average unit revenue is estimated up to 0.37 €2015/TEU.km with a steady evolution of 0.0 % per annum in constant euros. The following table present the average revenue by market depending from the length of the route used.

Table 18 Rail transport revenue assumptions

Markets	€2015/TEU		EVOLUTION
	Counterfactual	Project	
Belgium–Swiss	320	270	+0.0 % p.a.
Belgium-Italia	450	400	
Spain – Belgium	N/C	650	
Spain – South Germany	N/C	520	
South-West France – South Germany	N/C	470	
Spain – Italia	N/C	540	

South East France – South Germany	340	330	

The comparison of road and rail prices on the origin destination pairs permits to deduce the economic savings of the shippers. Rail Operators' costs (intermediate consumptions and taxes) are estimated via an average operating margin of 10 % according to the financial results of the rail operators studied.

9.4. Shipping Companies

Shipping companies transport prices are estimated thanks to worldfreightrates.com and directferries.com which provide quotations depending on the type and dimension of goods. Various operational alternatives are considered:

- Shipping lines more direct than road (Spain to Italia) are considered as Roll-on Roll-Off services with lower handling costs but higher trailer immobilization costs;
- Shipping lines less direct than road (Spain to Belgium) are considered as Lift-on Lift-off services with higher handling costs but lower container immobilisation costs;

Considering these assumptions, the maritime freight rates are the following:

Table 19 Maritime freight rates and handling charges assumptions

Market	Service	Freight Rate (€2015/TEU)	Handling Charges (€2015/TEU)	EVOLUTION
Barcelona - Genoa	RORO	500	30(1)	+0.0 % p.a.
Barcelona - Antwerp	LOLO	760	250(2)	

(1) Destacking trailer charges (Port of Barcelona Horizontal transport service, 2015), the corresponding services are free of charge in the Italian Ports as drivers are responsible of this operation

(2) Terminal Handling Charges, estimated with a share of 76% of 20' containers as given by EUROSTAT for Barcelona – Belgium in 2014

In addition, the Shipping Companies operating LOLO services collect Bunker Adjustment Factor (85 €2015/TEU), Low Sulphur Surcharge (20 €/TEU) and Currency Adjustment Factor (50 €/TEU) for each container load as for the 2016 CMA CGM Charges Tariffs.

The Shipping Companies' costs are split into operating costs, taxes, port dues and handling costs paid to the Stevedore Companies. As the maritime roundtrips per week are supposed steady, only the port fees variations proportionate to units handled are considered up to 7 €/TEU.movement.

9.5. Rail Infrastructure Manager

Railway infrastructure costs covers operational expenses, maintenance and renewal (including taxes) varying proportionally to the train circulations.

SNCF Réseau indicates maintenance costs' split as follow in their Socio-economic framework:

- Track maintenance: 0.5 €2012/Gross ton circulated i.e. 0.65 €2012/train.km
- Signalling maintenance: 0.27 €2012/train.km
- Electric distribution devices maintenance: 0.15 €2012/train.km

- Operation cost: 0.14 €2012/train.km

Maintenance and renewal are supposed to represent an equal share of the costs as for the French Court of Auditors[2].

The Track Access Charges (TAC) revenues are given by the Charging Information System of RailNetEurope for a Combined Transport electrified train with 2 locomotives, 30 wagons, 440 m long, 600 tons of load with 2 TEU per wagon and an average of 60 TEU per train.

The following table present the estimations of TAC by railway route.

Table 20 Track access charges assumptions

Markets	TAC €2015/TEU		EVOLUTION
	Counterfactual	Project	
Belgium–Swiss	60	30	+0.6% p.a.
Belgium-Italia	80	60	
Spain – Belgium	N/C	90	
Spain – South Germany	N/C	90	
South-West France – South Germany	N/C	100	
Spain – Italia	N/C	60	
South East France – South Germany	50	60	

9.6. Stevedores

Various Stevedore Companies are implied in the various logistic scheme considered. The order of magnitude of each handling revenue are given by:

- Port Transit Cost Observatory, MEDDE/DGITM, 2014
- Actions to promote intermodal transport, RECORDIT Final report, 2004, EC
- Sectorial accounts of the French Department for Statistics, INSEE, 2014

[2] L’entretien du réseau ferroviaire national – juillet 2012, Cour des Comptes

Table 21 Handling revenues and margin assumptions

Platform	Revenue (€2015/TEU.movement)	% Operating Margin	EVOLUTION
Rail-Road (inland)	40	5.0%	+0.0 % p.a.
Road-Road (inland)	20		

An important issue concerning handling tariffs is to enumerate the number of unit bulk breaking for each origin-destination pair, including dispatch (pre- and post-carriage).

9.7. Public authorities

Public Authorities revenues are based on taxes collection including Fuel taxes and corporate taxes. At this stage of feasibility study, an average European rate of taxes is considered based on the following sources:

- Fuel taxation: European Union Road Federation Yearbook 2014-2015
- Corporate income taxation: Taxation trend in the European Union, EUROSTAT, 2015

Table 22 Fuel and Corporate taxes assumptions

Country	Fuel Tax (€2010/l)	Corporate income Tax (% of EBITDA)
FR	0.61	38.0%
BE	0.57	34.0%
NL	0.67	25.0%
DE	0.65	30.2%
ES	0.43	28.0%
PT	0.58	29.5%
IT	0.56	31.4%
CH	0.49	8.5%
Assumption	**0.60**	**30.0%**

The tax rates applied are supposed to be steady during the period of appraisal.

9.8. Externalities

9.8.1. Congestion

Road congestion is not considered in the present study insofar its level of detail remains regional with few urban impact, the major part of the trips deviation being held by highways or major axis where road congestion is negligible.

9.8.2. Road Safety

An assessment of the avoided accidents thanks to road traffic diversion to rail is based on the values given by the Update of the Handbook on External Costs of Transports, 2014, RICARDO-AEA. This values stems from the CARE database (Community database on Accidents on the Roads in Europe) of the European Commission. Only French values are considered as the greatest part of the trips deviation is realized in this perimeter.

Table 23 Marginal road safety unit cost (Ricardo-AEA, 2014)

Mode	Value	Unit
HGV, motorway	0.4	€2010/HGV-km
Intermodal Train	0.0002	€2010/train-km

9.8.3. Air pollution

Air pollution avoided has a local impact on the health conditions and provides social benefits to the neighbourhood. The following values given by the Handbook on External Costs of Transports of 2014 enable to assess the gains induced by the project.

Table 24 Marginal unit costs for air pollution (Update of the Handbook on External Costs of Transports, 2011)

Mode	Value	Unit
HGV	0.004	€2010/HGV-km
Intermodal Train	0.422	€2010/train-km
Short Sea Shipping	0.00139	€2010/ton.km

9.8.4. Noise costs

The noise impact due to the road traffic diversion is estimated using the Handbook on the External Costs of Transport of 2014 (IMPACT Handbook) from CE Delft. We deemed prudent to use the lowest values for HGV, which is the values for day and dense traffic.

Table 25 HGV and train marginal noise unit costs (CE Delft, 2011)

Mode	Value	Unit
HGV, dense and rural conditions	0.7	€2010/1000 HGV-km
Rail, dense and rural conditions	0.0299	€2010/1000 trains-km

9.8.5. Climate change

Global impacts on climate change due to the road diversion to rail are evaluated using the Handbook on the External Costs of Transport of 2014 (IMPACT Handbook) from CE Delft.

Table 26 HGV and SSS climate change unit costs (CE Delft, 2011)

Mode	Value	Unit
HGV, > 32 t, Euro V, motorway	0.067	€2010/HGV-km
Sea Short Shipping, general cargo 5-10 kt, average load = 4kt	0.0015	€2010/ton-km

9.8.6. Up and down-stream processes

Up and down-stream processes integrate the impact of the energy consumption to build, maintain and recycle the vehicles. It can be evaluated thanks to the Handbook on the External Costs of Transport of 2014 (IMPACT Handbook) from CE Delft.

Table 27 HGV, Trains and SSS up and down-stream unit costs (CE Delft, 2011)

Mode	Value	Unit
HGV, > 32 t, Euro V, motorway	0.029	€2010/HGV-km
Freight, electric, locomotive	3.19	€2010/trains-km
Sea Short Shipping, General cargo 5-10 kt, average load = 4 kt, NE Atlantic	0.0006	€2010/tonnes.km

10. ECONOMIC APPRAISAL

10.1. Economic appraisal parameters

The economic appraisal is calculated for a period of 30 years after the beginning of investment and progressive commissioning from 2020 that is for the period 2020-2049.

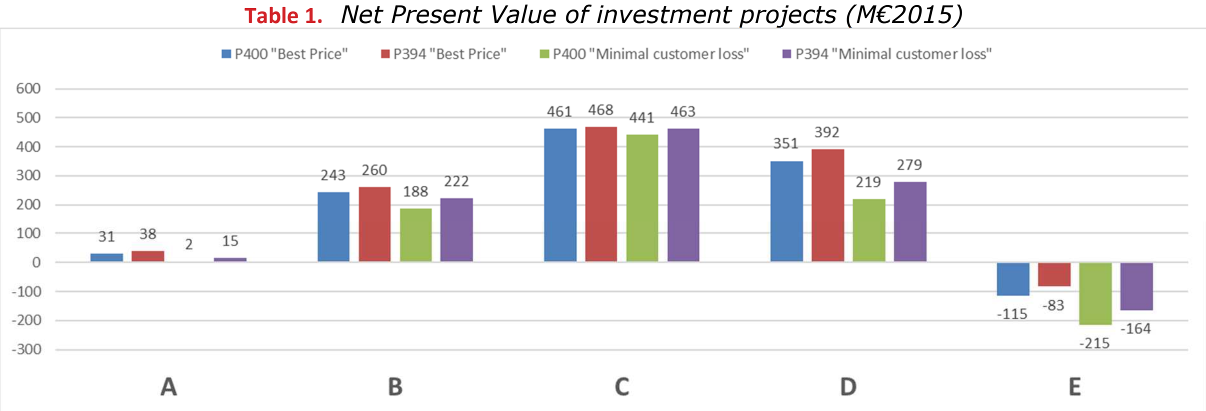
The social discount rate reflects the social view on how future benefits and costs should be valued against present ones. The coefficient used for this economic appraisal is 4 % as recommended by the European Commission for such project.

10.2. Main economic performance indicators

The economic performance indicators of the various scenarios present contrasted results:

- All the work solutions for scenario B (upgrade of Vosges Tunnels and Meaux-Epernay) provide high economic rate of return;
- The P400 and P394 Best prices own the highest economic performance but at a much lower level which need to be confirmed through sensitivity rates. The P400 Minimal customer loss work scenario present more costs than benefits due to the higher amount of investment the similar P394 work scenario permit to reach a positive surplus;
- All the work solutions for scenario E (upgrade of Rhône Valley and Dijon-Mulhouse) register more costs than benefits, mainly due to the high amount of investments on the Dijon-Mulhouse section regarding the gains of traffic it provides;
- The scenario C & D has not been appraised at this stage without the investment estimation for the Perpignan-Barcelona section which explain partly their significant benefits;

Table 1. *Net Present Value of investment projects (M€2015)*



B1 Vosges Tunnels	B1 & B4 Vosges Tunnels and Meaux-Epernay	B2 & B3 Rhône Valley and Perpignan Barcelona	B2 & B3 & B5 Rhône Valley, Perpignan Barcelona and Dijon-Mulhouse	B2 & B5 Rhône Valley and Dijon-Mulhouse
M1 Belgium – Swiss/Italy	M1+M3 Belgium – Swiss/Italy and South West France - Germany	M2 Spain – Belgium/Italy	M4 Spain – South Germany	M5 South France – South Germany

Table 2. *Economic rate of return of investment projects*

	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
A	7%	9%	2%	4%
B	23%	31%	12%	18%
C	NC	NC	NC	NC
D	17%	22%	8%	12%
E	-8%	-6%	-12%	-11%

The detailed economic indicators by project are provided in appendix 1.

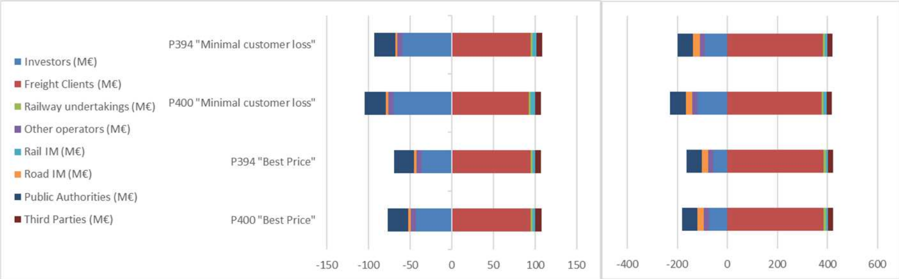
10.3. Surplus by actor

The global surplus permitted by the project is broken down between various stakeholders as follow:

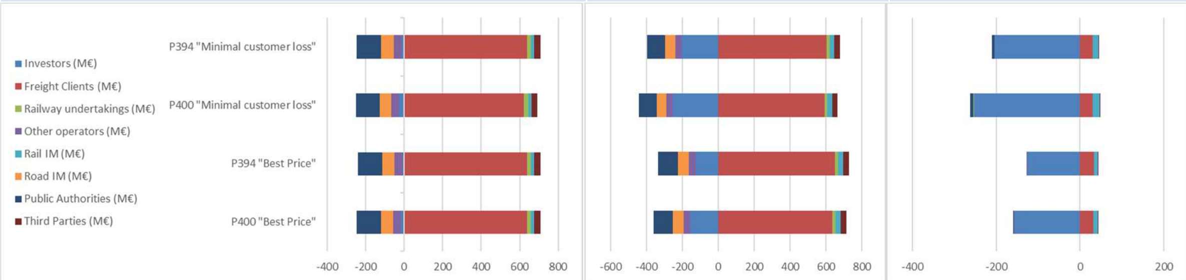
- The major benefit is gained by freight clients thanks to a significant decrease of transport costs;
- The investment amount is the major cost which determines mainly the economic sustainability of the project;
- The Public Authority register significant losses, mainly due to the avoidance of fuel tax payments related to the modal shift from road to rail;
- The Railway IM also own some gains linked to the combination of new track access charges revenues and subsidies to operate and maintain the network;
- Some economies of externalities are permitted by the projects to the third parties but do not justify the project per se.
- Scenario E is hampered by the weight of its investment costs, largely superior to the gains permitted to the freight clients: de facto, the unit gain per TEU is more than 10 times inferior to those of scenario A and B. These gains rely utterly on little favourable rail route deviation from Dijon-Metz to Dijon-Mulhouse to reach Ludwigshafen terminal in Germany.

Figure 36 Economic benefits per stakeholder

Scenario	A	B



Scenario	C	D	E



10.4. Freight client surplus

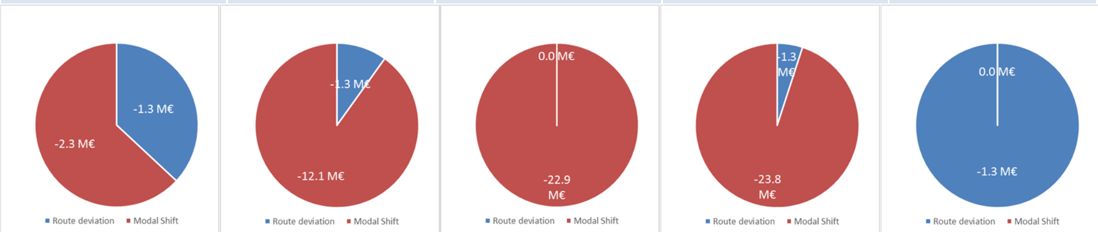
The economies realized by the freight clients thanks to the projects are based on an estimation of total logistic costs gains between the counterfactual and the project scenarios. The freight clients also benefit from time savings through economies of goods immobilization.

10.4.1. Total Logistic Costs savings

The weight of modal shift in the Total Logistic Costs savings depends from the market captured but is, in general, much superior to those of route deviation.

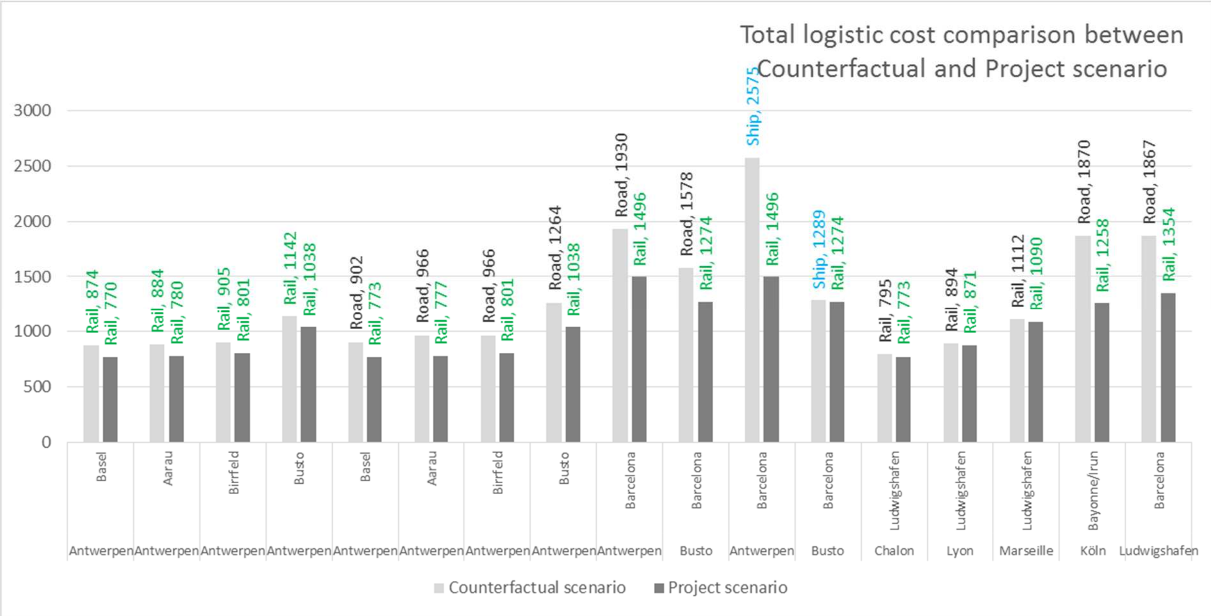
Figure 37 Total Logistic Cost gains by market

A	B	C	D	E



The Total Logistic Cost savings depends from the origin-destination and the mode/route changes as indicated in the table below for the whole markets considered in this study: the most significant gains are registered for the modal shift from short sea shipping to rail (Spain-Italy) even the corresponding volumes are not significant. The unit logistic cost gain remains much stronger in average for modal shift markets (-490 €/TEU) than for rail route deviation (-40 €/TEU) considering the weight of each origin-destination.

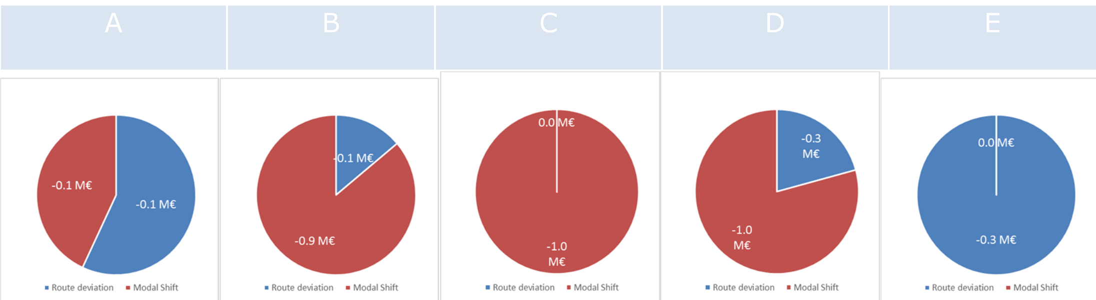
Figure 38 Total Logistic Cost gains by origin-destination



10.4.2. Goods Immobilization savings

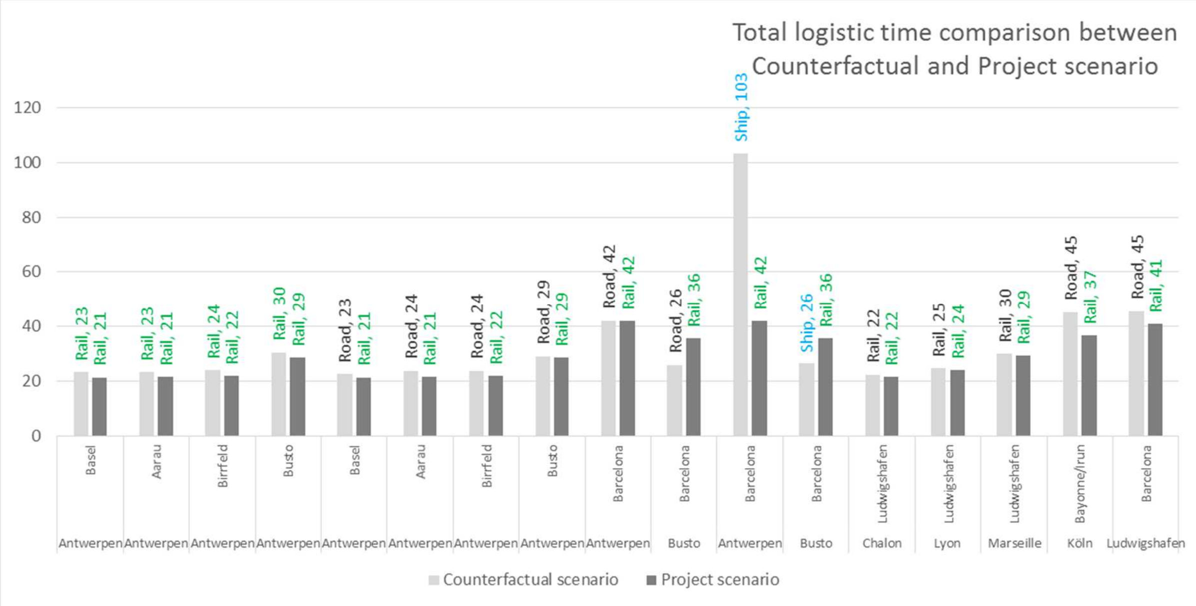
The weight of modal shift in the Goods Immobilization savings is still major but in a smaller proportion than Total Logistic Costs.

Figure 39 Total Goods Immobilization gains by market



The Goods Immobilization savings depends from the route chose in the counterfactual and project scenario for each origin-destination: consistently with the Total Logistic Costs savings based inter alia on the transport time, the most significant gains in terms of Good Immobilization are registered for the modal shift from short sea shipping and from the road on the long distance. The unit Goods Immobilization savings are significantly lower than Total Logistic Costs gains for both markets, being modal shift (-25 €/TEU) or route deviation (-6 €/TEU) considering the weight of each origin-destination.

Figure 40 Total Goods Immobilization gains by O/D



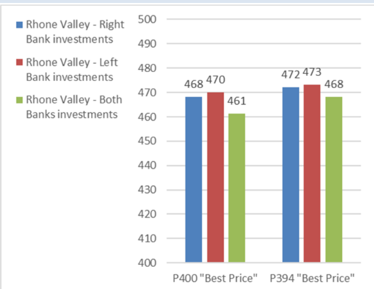
10.5. Sensitivity tests

10.5.1. Right/Left bank investments in the Rhône Valley

As investments of the Rhône Valley have been considered for both banks in the central scenarios, we present below a sensitivity test where the investments are realized successively:

- On the right bank only;
- On the left bank only;

Table 3. *Sensitivity test of Right/Left bank investment in the Rhône Valley (NPV in M€2015)*

C	D	E
		

The impact of shifting the investments from the right bank to the left bank of the Rhône Valley remain quite insensitive. The combination of both investments is more interesting for the Scenario E as it does not deteriorate significantly the Net Present Value (-6% for the P400 "Best Price" scenario and -4% for the P394 "Best Price" scenario): the weight of the investment costs for Dijon-Mulhouse explain this effect: in this context, the overcost for an alternative rail route on the left or right bank is acceptable.

10.5.2. Scale economy with maintenance

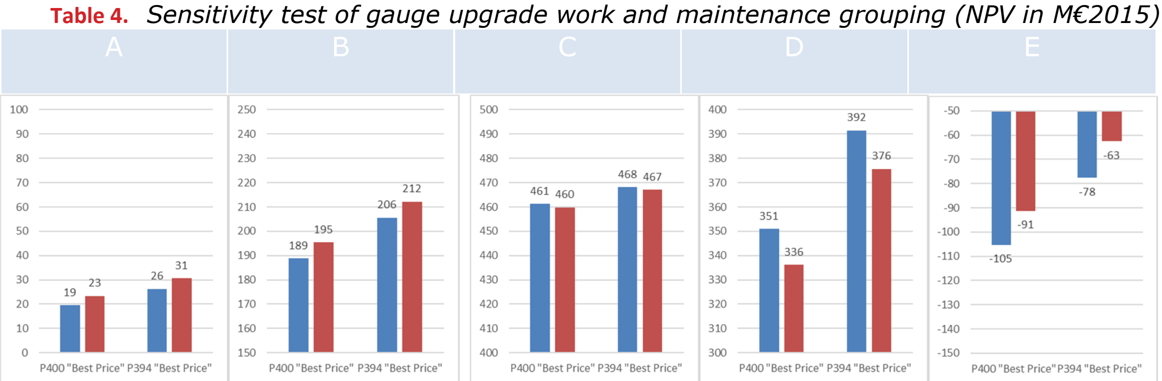
SNCF indicates that some maintenance operations are yet planned for the tunnels studied: grouping the operation of maintenance with the gauge upgrade would permit some economies of scale. Among all work costs' items, the site installation and logistics item could be potentially saved if the maintenance and gauge works are grouped.

The site installation and logistics represent for the example of the Andance Tunnel:

- Vault works:
  - P394:
    - Option 1: 0.775 M€ out of 6.1 M€ (12.7%);
    - Option 2: 0.415 M€ out of 3.5 M€ (11.8%);
  - P400:
    - Option 1: 1.09 M€ out of 11.6 M€ (9.3%)
    - Option 2: 0.595 M€ out of 6.8 M€ (8.7%)
- Roadbed lowering: 0.875 M€ out of 24 M€ (3.6%);

The sensitivity test is thus based on average assumptions of investments amounts economies of 12% for the P394 "Best Price" scenario and 9% for the P400 "Best Price" scenario.

Table 4. *Sensitivity test of gauge upgrade work and maintenance grouping (NPV in M€2015)*



The impact of grouping the maintenance and gauge upgrade works would permit to increase the profitability of scenarios yet interesting in economic terms but would not be sufficient to cover the losses of scenario E. It would represent a bettering of the net present value for scenario A (+20%) and B (+3%).

11. FINANCIAL APPRAISAL

11.1. Financial appraisal parameters

A consolidated financial analysis is conducted for the construction and the operation phases. This analysis focuses on the economic activity of freight operators. The financial discount rate is 5%, expressed in real terms in accordance with the European Commission recommendation for such project.

The reference year for discounting is the same as economic appraisal, i.e. 2019, one year before the first commissioning. Current prices are used in the analysis with a 1.8% inflation from constant 2015 prices.

The appraisal period is 30 years from 2020 to 2049.

11.2. Stakeholders and financial flows

The perimeter of the financial appraisal of the project is different from the economic appraisal: it focuses on the investor (IM), the operators (likewise) and the financiers of the project (IM, European Commission, States and Banks).

To have a reliable view of the financial performance of the project, we extracted from the economic appraisal:

- The initial investment amounts for each scenario;
- The residual values;
- The operating costs, that is the maintenance, renewal and operation cost of IM on the French and Spanish networks where the works are realized;
- The operating revenue, that is the track access charges on the same perimeter;
- The related taxes (CVAE and Corporate taxes);

At this stage of the project, no specific information is available concerning its funding: coherently with the Connecting Europe Facilities call for tender specifications, we supposed a co-financing rate of 85% fore every bottlenecks of the Core Network. For the remaining amount to finance, we consider 30% of National Public Grant, 40% of equity and a loan of 30% covering 30 years of maturity at 2.0% interest rate.

The European Commission Grant is calculated as the co-financing rate multiplied by the funding gap ratio. The funding gap ratio is equal to the difference of the discounted investment and the net operating revenue (including the residual value) divided by the discounted investment.

11.3. Main performance indicators

The financial performance indicators are the following for the scenario described

- **Financial return on investment** (from the point of view of the investor): Financial net present value on investment (FNPV(C)) and Financial rate of return on investment (FRR(C)) represent the financial interest of the investor to realize this investment. None of the scenario present real financial interest for the IM except scenario C which does not include the full work investment prices at this stage.

Figure 41 Financial net present value investment

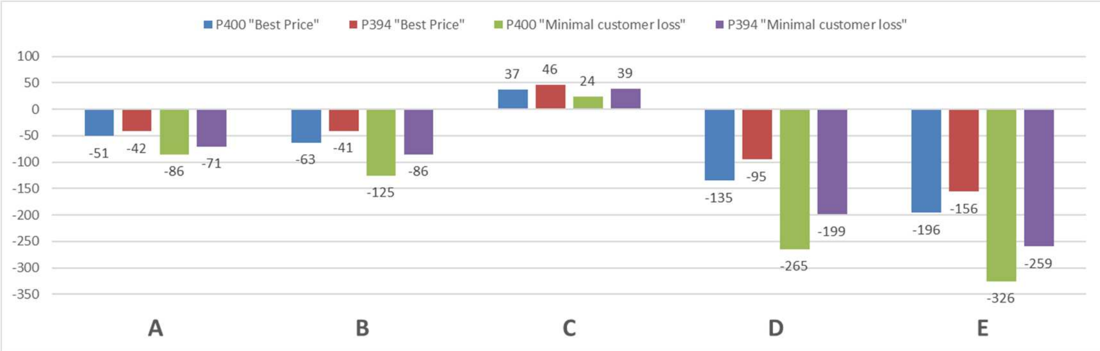


Table 28 Financial rate of return on investment

	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
A	-9%	-8%	-11%	-10%
B	-2%	0%	-5%	-3%
C	15%	26%	10%	17%
D	-2%	-1%	-6%	-4%
E	-13%	-12%	NC	-15%

- **Financial sustainability** (from the point of view of operator): Funding gap ratio (FGR) and Cumulated net cash flow (CNCF) provide information on the ability to cover the investment costs with the cash flow and the possibility for the operator to reach balance accounts at the end of the appraisal period. For each project, the funding gap ratio is high which means a large part of investment will require exogenous funding.

Table 29 Funding Gap Ratio

	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
A	75%	73%	78%	77%
B	51%	41%	64%	57%
C	0%	0%	0%	0%
D	50%	41%	62%	57%
E	80%	79%	81%	80%

Table 30 Cumulated Net Cash Flow (M€)

	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
A	1.6	2.1	0.4	0.9
B	30.1	32.0	24.5	28.0
C	80.7	83.1	76.8	81.2
D	65.0	69.3	50.0	56.9
E	0.0	0.0	0.0	0.0

To calculate the cumulated net cash flow, we assumed that the States will provide subsidies to cover the cash flow losses of the IM including their operating revenues, operating and financial costs.

- **Financial return on national capital** (from the point of view of public financiers): Financial net present value on capital (FNPV(K)) and Financial rate of return on capital (FRR(K)) represent the financial interest of the financiers to provide funds to realize this investment after having discounted the EC Grant from the investment. The scenario present average low financial interest for the financiers but at an expected level for such railway investment projects.

Figure 42 Financial net present value on capital

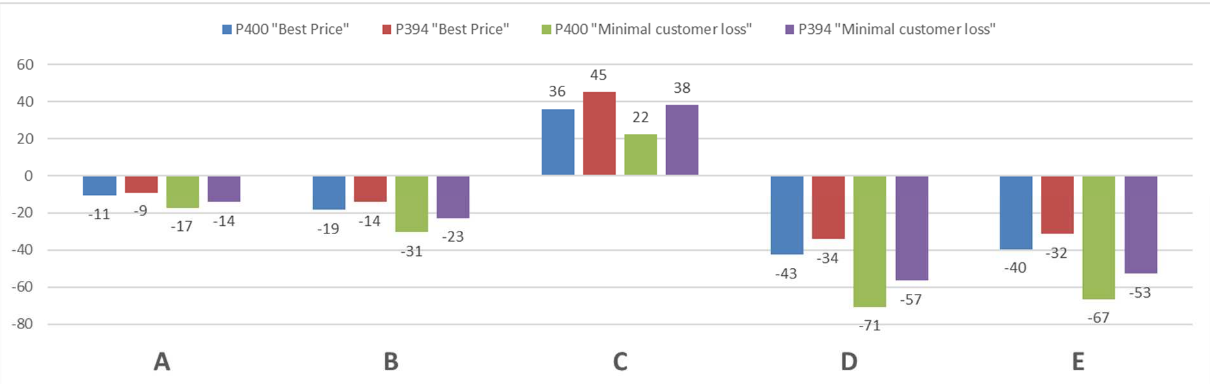


Table 31 Financial rate of return on capital

	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
A	2.4%	2.4%	2.2%	2.3%
B	3.0%	3.2%	2.7%	2.9%
C	14.0%	24.5%	8.8%	15.4%
D	2.8%	3.0%	2.3%	2.5%
E	2.0%	2.1%	1.8%	1.8%

12. APPENDIX

12.1. Appendix 1

Table 32 Detailed indicators of economic performance (Scenario A)

Scenario	A	A	A	A
Bottleneck	B1	B1	B1	B1
Market	M1	M1	M1	M1
Type of works	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
K.TEU (2020)	28	28	28	28
ERR	7%	9%	2%	4%
B/C Ratio	178%	215%	103%	127%
Investment (M€)	45	37	73	61
ENPV (M€)	31	38	2	15
Investors (M€)	-43	-36	-70	-59
Freight Clients (M€)	95	95	93	95
Railway undertakings (M€)	2	2	2	2
Other operators (M€)	-6	-6	-6	-6
Rail IM (M€)	3	3	5	4
Road IM (M€)	-3	-3	-3	-3
Public Authorities (M€)	-24	-24	-26	-25
Third Parties (M€)	7	7	7	7

Table 33 Detailed indicators of economic performance (Scenario B)

Scenario	B	B	B	B
Bottleneck	B1 & B4	B1 & B4	B1 & B4	B1 & B4
Market	M1+M3	M1+M3	M1+M3	M1+M3
Type of works	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
K.TEU (2020)	46	46	46	46
ERR	23%	31%	12%	18%
B/C Ratio	527%	763%	278%	398%
Investment (M€)	75	57	125	93
ENPV (M€)	243	260	188	222
Investors (M€)	-73	-55	-121	-90
Freight Clients (M€)	386	385	377	382
Railway undertakings (M€)	9	9	9	9
Other operators (M€)	-20	-20	-20	-20
Rail IM (M€)	9	8	12	10
Road IM (M€)	-26	-26	-25	-26
Public Authorities (M€)	-62	-61	-63	-62
Third Parties (M€)	20	20	20	20

Table 34 Detailed indicators of economic performance (Scenario C)

Scenario	C	C	C	C
Bottleneck	B2 B3	B2 B3	B2 B3	B2 B3
Market	M2 M6	M2 M6	M2 M6	M2 M6
Type of works	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
K.TEU (2020)	54	54	54	54
ERR	NC	NC	NC	NC
B/C Ratio	NC	NC	NC	NC
Investment (M€)	16	9	27	15
ENPV (M€)	461	468	441	463
Investors (M€)	-16	-9	-26	-14
Freight Clients (M€)	637	637	623	637
Railway undertakings (M€)	21	21	21	21
Other operators (M€)	-41	-41	-40	-41
Rail IM (M€)	18	18	17	18
Road IM (M€)	-64	-64	-62	-64
Public Authorities (M€)	-127	-127	-123	-127
Third Parties (M€)	32	32	31	32

Table 35 Detailed indicators of economic performance (Scenario D)

Scenario	D	D	D	D
Bottleneck	B2 B3 B5	B2 B3 B5	B2 B3 B5	B2 B3 B5
Market	M2 M4 M5	M2 M4 M5	M2 M4 M5	M2 M4 M5
Type of works	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
K.TEU (2020)	116	116	116	116
ERR	17%	22%	8%	12%
B/C Ratio	385%	526%	199%	263%
Investment (M€)	165	132	274	218
ENPV (M€)	351	392	219	279
Investors (M€)	-156	-126	-253	-204
Freight Clients (M€)	635	648	591	604
Railway undertakings (M€)	18	19	17	17
Other operators (M€)	-38	-38	-35	-36
Rail IM (M€)	28	29	27	27
Road IM (M€)	-58	-59	-54	-55
Public Authorities (M€)	-109	-112	-101	-103
Third Parties (M€)	31	32	28	29

Table 36 Detailed indicators of economic performance (Scenario E)

Scenario	E	E	E	E
Bottleneck	P400 "Best Price"	P394 "Best Price"	P400 "Minimal customer loss"	P394 "Minimal customer loss"
Market	62	62	62	62
Type of works	-8%	-6%	-12%	-11%
K.TEU (2020)	27%	34%	16%	20%
ERR	165	132	274	218
B/C Ratio	-115	-83	-215	-164
Investment (M€)	-156	-126	-253	-204
ENPV (M€)	32	33	30	30
Investors (M€)	-1	-1	-1	-1
Freight Clients (M€)	-1	-1	-1	-1
Railway undertakings (M€)	11	9	17	14
Other operators (M€)	0	0	0	0
Rail IM (M€)	-1	1	-8	-5
Road IM (M€)	2	2	2	2
Public Authorities (M€)	-196	-156	-326	-259
Third Parties (M€)	-13.4%	-12.2%	NC	-15.4%