ISCTE Business School
Instituto Universitário de Lisboa

HIGH-SPEED RAILROAD BETWEEN LISBON AND MADRID: YES OR NO? A REAL OPTIONS' VIEW

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Project submitted as partial requirement for the conferral of

Master in Finance

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October 2019

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Abstract

European Union has given more importance to transports and designed 30 priority projects to unify the European Union's territory and potentialize its economy. More than half of that priority projects include railroads, since this is considered an efficient transportation mode for passengers and freight.

One of those projects is the "High-speed railway axis of southwest Europe", that comprises the High-Speed Railroad between Lisbon and Madrid. In the past, this project was shut down for being considered non-viable. Nevertheless, the methods applied were static and did not account the flexibility of the project, while the goal of this project thesis is to determine the investment's value with flexibility through Real Options Valuation and discover if the project is truly viable or not.

JEL Codes: G11, G17 and L92.

Sumário executivo

A União Europeia tem vindo a dar cada vez mais importância ao sector dos transportes e concebeu 30 projetos prioritários para unificar o território da União Europeia e potencializar a sua economia. Mais de metade desses projetos prioritários inclui ferrovia, visto ser considerado um modo de transporte eficiente para passageiros e mercadorias.

Um desses projetos é o "Eixo ferroviário de alta velocidade do Sudoeste da Europa", que inclui a Linha Ferroviária de Alta Velocidade entre Lisboa e Madrid. No passado, este projeto foi cancelado por ser considerado inviável. No entanto, os métodos aplicados eram estáticos e não contabilizavam a flexibilidade do projeto, enquanto esta tese tem como objetivo a determinação do valor do investimento com flexibilidade através da avaliação de Opções Reais e descobrir se o projeto é verdadeiramente viável ou não.

JEL Codes: G11, G17 e L92.

Acknowledges

I would like to thank my mentor, professor José Carlos Dias, who taught me the course "Real Options" in ISCTE-IUL in a captivating way that was a crucial factor to have decided to develop a thesis using Real Options. His availability, comprehension, vote of confidence and constructive suggestions are also a reason to thank professor José Carlos Dias.

I feel extremely grateful for my parents' effort to support my academic life, in every way possible, and I would like to thank them along with my sister and my brother-in-law for the encourage that they gave me during the development of this thesis.

And to Adriana, Gonçalo and Ricardo, who motivated me and showed continuous interest in this process, a big thank you.

Table of contents

List of figures

List of tables

List of acronyms

ADIF - *Administrador de Infraestructuras Ferroviarias* (Administrator of Railway Infrastructures)

ADEF – *Associação Portuguesa de Desenvolvimento do Transporte Ferroviário* (Portuguese Railway Transport Development Association)

AVEP - *Alta Velocidade Espanha-Portugal* (High-Speed Spain-Portugal)

BTKm - Billion Tonne Kilometres

CAPEX - Capital Expenditure

CEF - Connecting Europe Facility

CO - Carbon Monoxide

CP – *Comboios de Portugal* (Portuguese Trains)

CTA - *Campo de Tiro de Alcochete* (Field Firing Range of Alcochete)

DCF - Discounted Cash Flow

DTA - Decision-Tree Analysis

EC- European Commission

ECB - European Central Bank

EEC - European Economic Community

ERTMS - European Rail Traffic Management System

EU - European Union

FDR – Financial Discount Rate

GDP – Gross Domestic Product

GVA - Gross Value Added

HICP - Harmonised Index of Consumer Prices

HSR – High-Speed Railroad

HST – High-Speed Train

IP – *Infraestruturas de Portugal*

IRR – Internal Rate of Return

ITM – In The Money

Km – Kilometre

NAL - *Novo Aeroporto de Lisboa* (New Lisbon Airport)

NO_x - Nitrogen oxides

NPV - Net Present Value

OTM – Out The Money

p.p. – percentage points

PI – Profitability Index

PP – Payback Period

PPP - Public–Private Partnership

PV – Present Value

RAVE – *Rede Ferroviária de Alta Velocidade*, S.A.

RENFE - *Red Nacional de los Ferrocarriles Españoles*

SO_2 - Sulfur dioxide

TEN - Trans-European networks

TEN-T - Trans-European Transport Network

TEU - Twenty Foot Equivalent Unit

tkm – tonne-kilometre

TTT – *Terceira Travessia do Tejo* (Third Tagus Crossing)

UIC - *Union Internationale des Chemins de fer* (International Union of Railways)

UK – United Kingdom

US – United States

VAT - Value Added Tax

VOC - Volatile organic compounds

WACC - Weighted Average Capital Cost

1. Introduction

Transports are getting more attention because it is believed that they can provide economic growths in the implemented areas and a special concern is being given to railways because of their efficient for passengers and loads, speed and low CO_2 emissions compared with roads.

European Commission wants to connect until 2050 all airports to railways, if possible, with High-Speed Railways, so it planned 21 priority projects involving railways throughout EU territory. Portugal is one of the countries involved in the priority projects, more specifically, in the "High-speed railway axis of southwest Europe", that aims to link Portugal, Spain, France and Germany.

This project thesis will only evaluate the first step of this European project, the connection between both Iberian capitals, this is, Lisbon and Madrid. Previously, those were made studies to examine its viability, however, the methods employed dismiss the flexibility of the investment. In other words, the managers' interventions based on information that arrive during the operation of the project was not measured.

Therefore, this project intends to make a new evaluation taking in account the flexibility using the Real Options Valuation and use the Discount Cash Flow methodology as a complementary tool.

After all inputs being detailed determined, it was computed the static NPV, the value of the project using the Black-Scholes and Merton model and a decision tree to denote the value of the project in every year if the investors decide to invest earlier, to recognize if the European project is profitable or not.

2. Contextualisation of the project

Portugal and Spain are countries located in Europe, more specifically in the Iberian Peninsula. In 1986, both countries joined the European Economic Community (EEC), nowadays designated as European Union (EU). Currently, this organization is formed by 28 countries.

As the name suggests, the EU tries to unify the country-members, helping to achieve cohesion between them, incentivizing countries' development and building a unique and strong market in this community.

As a result, the European Commission (EC) was originated to assure that the EU's interests are respected. One of this institution's programme is the Trans-European Transport Network (TEN-T) that has as its main goals build a network able to connect all country members, reinforce regional development, create access between the different areas of Europe, redistribute economic benefits to less development countries in the community and intensify the transportation's value to improve a Single Market (Vickerman, 1995).

According to Smit and Trigeorgis (2009), investing in infrastructures can support an economic development in a wider area, including investment beyond roads. To accomplish those ambitions, this programme designed 30 priority projects[1] with added-value to increment sustainable growth in the involved countries and to create transportation links throughout EU, as in figure 1.

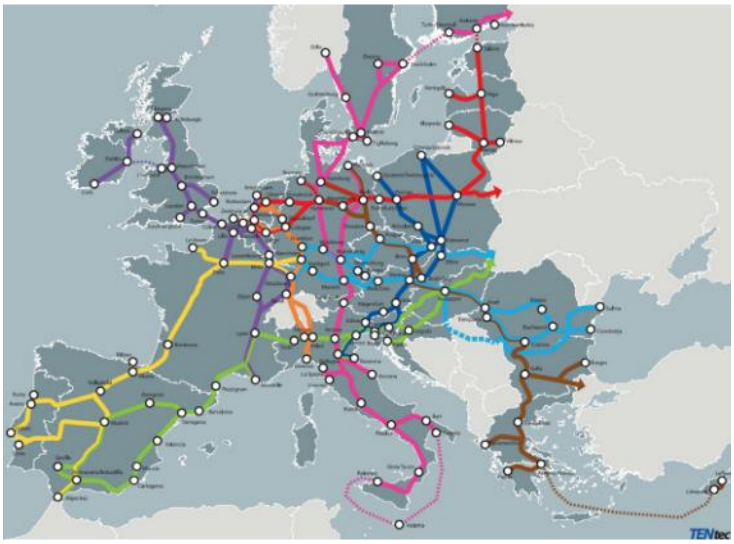

Figure 1 Core Network Corridors
Source: European Commission

[1] The 30 priority projects are exposed in the following link: https://ec.europa.eu/inea/ten-t/ten-t-projects/projects-by-priority-project

When analysing the 30 priority projects, there are 18 projects exclusively concerned with railroads and 3 other road-railroad projects. The 3rd TEN-T's Priority Project is designated as "High-speed railway axis of southwest Europe" or "Atlantic Corridor" and is composed by three sections, one of those is the Iberian sector that should connect Madrid-Lisbon-Oporto.

Remembering that a transportation investment is a significant large investment involving high uncertainty regarding the magnitude of the market and recognizing that there is a barrier to other players, since it demands specific and specialized knowledge and reputation regarding transportations' services (Pindyck, 1991), the Iberian sector of the Atlantic Corridor will benefit if segmented (Damodaran, 2000). Therefore, in this project, it will be analysed the financial viability of one specific segment of the previous mentioned sector, the connection between both Iberian Peninsula's capital.

3. Railroads

Historically, between 1995 and 2010, rail transport's demand rose a bit more than 16% in the EU27, while the EU15 had a more stable evolution with more than 30% increase (Banister and Givoni, 2013). In 2015, the rail sector contributed with 143 billion euros to the in EU's Gross Value Added (GVA) and provided 2.3 million jobs, where 577,000 jobs were directly originated by the sector (European Commission, 2015b).

The EC (2017a) expects an expressive growth in the rail transportation in the EU, even bigger that the road growth, with 1% growth per year in the passenger rail use between 2010 and 2030 and afterward a 2% until 2050, that would be translated in an increment of 44% in passenger rail use until 2030 and an increase of 84% until 2050. Regarding the freight rail use, it is anticipated a rise between 2010 and 2030 of 2% per year. This can be interpreted as a growth of 51%, and an 1% rise per year until 2050.

3.1. Railroads in Portugal

Programa Nacional de Investimentos 2030[2] (2018) reports that in Portugal, the railroad has 2558 km of length and more than half of this dimension is electrified, more specifically, 1646

[2] *Programa Nacional de Investementos 2030* is a programme that prioritizes structural investments with values above 75 million euros, with time horizon above 10 years located in Continental Portugal and in the Energy, Mobility and Transport and Environment sectors.

km. In terms of rail lines density, Portugal is below the EU average with approximately half of the performance, with 246 km/million habitants while the EU has 432 km/million habitants.

Along this distance, there are 438 stations for passengers and another 32 stations for freight transportation (*Programa Nacional de Investimentos 2030*, 2018). The localisation of this stations takes in consideration the high population density areas and their accesses, consequently, those locations will be characterized, as Portugal, by its bipolarisation and concentration of the stations sideways with the coastline.

In Portugal, rail infrastructures and roads are managed by IP (*Infrastruturas de Portugal*), a state-owned company that resulted of a merge between *Rede Ferroviária Nacional* -REFER and *Estradas de Portugal* - EP REFER, E.P.E., while the rail service is provided by CP (*Comboios de Portugal*).

During 2015, 88.5% of passenger dislocations were made by car, while the railway had a 4.1% of modal share, a value inferior to the EU's average of 7.6%. In the freight transport and in the same year, the road transportation was leader with 84.1% of tonne-kilometers made, meantime 13.9% of all cargo transport made in that year was done by railway (European Commission, 2017b).

In 2016, the rail transportation was operating with 354 traction machinery, 62 of which were used for cargo transportation, 102 carriers and 3042 wagons. The currently maximal load in the railway is 1400 tons, however only 26% of the rail system length can support this weight (*Programa Nacional de Investimentos 2030*, 2018).

IP (2018a) presents the numerous constraints in the Portuguese railroads, as for example, the short length of its carriers and wagons, the insufficiency of signalisation and electrisation in infrastructures, the deficiency in multimodal terminals, the low limit weight of transportation and many segments have only one track.

Additionally, the track gauge in Iberian Peninsula has a different measure from the European track. The Iberian gauge has 1,668 mm while the European has 1,435 mm (see Appendix 1). According to RAVE[3], the national rail system uses in 90% of their length the Iberian Gauge,

[3] Public Portuguese company created to investigate the implementation of High-Speed Railroads in Portugal that was integrated, in 2014, in REFER that nowadays is a part of IP.

which causes constraints in the goods flow between Iberian Peninsula and the rest of Europe, requiring a transhipping at the French border.

3.2. Railroads in Spain

The Spanish railway network has 15,301 km of extension, of which 9,699 km is electrified. In this network, near 75% of the length (11,333km) uses the Iberian gauge, while almost 17% (2,571 km) has the standard gauge installed (Ministerio de Fomento, 2019a). Similar to the Portuguese case, the rail network's density is also inferior to the EU average with 345.7 km/million habitants (European Commission, 2018c).

The Spanish railway infrastructures are administrated by ADIF (*Administrador de Infraestructuras Ferroviarias)*, a Spanish public firm that administer all railway infrastructures, including the stations and signalling, whilst the railway service is explored by RENFE (*Red Nacional de los Ferrocarriles Españoles)*, also a public firm of Spain.

In 2015, 6.6% of all passenger dislocations were made through railways, a small value compared to the car's share of 79.9%. Concerning the goods transports, 89.3% was perform by road and only 5.6% were done by railway (European Commission, 2018c).

Currently, there are 3 cross-border railways between Spain and Portugal, one between Valença do Minho and Tui; other one linking Vilar Formoso and Fuentes de Oñoro; and, finally, Elvas and Badajoz (Ministerio de Fomento, 2017).

The Spanish geomorphology, characterize by non-plane fields, restrain the rail's speed and creates difficulties during the planification and constructions of new paths. Other limitation to railway is the existence of large branches with single track (RAVE, 2011).

3.3.High-Speed Railroads

According to the official journal of the EU, a high-speed railway includes three types of railroad: a railroad that allows the tractive locomotive to move faster than 250 km/h; a conventional railroad that has the conditions for the equipment to be dislocated at a speed nearby 200 km/h; and railroads that are prepared for high-speeds considering specific and more challenging areas in terms of geographic characteristics.

Although the definition mentions speeds above 250 km/h, Banister and Givoni (2013) highlights that, nowadays, none of the HST has an average speed above 240 km/h, that is achieve by the most successful HST, the Tokyo-Osaka HST.

Campos and de Rus (2009) said, in their work, that worldwide there were 10,000 km of HSR under construction in 2008 and, in the same year, 20,000 km of the existing HSR were allocated to the passenger service. The same paper claims that passenger traffic in Europe for this transportation is around 50 million passengers every year.

The EC (2016a) made a forecast for the European high-speed railroads between 2010 and 2050 expecting to observe a 2.5% growth per year in the volume of high-speed rail. In the same period, it is projected an improvement in the high-speed rail passenger traffic of 11 p.p. to 32% and an evolution in the freight transportation correlated with the GDP rate, more specifically, a rise of 1.2% per year in the freight transportation, that would mean a total increase of 58%.

EC (2009a) defends that good candidates for the High-Speed Railroads should have between 200 and 800 km to be competitive against other transportation modes, and a distance between 300 and 600 km will be even more effective. Additionally, the demand should justify the investment and to help in this aspect be located near a high-density area to benefit a large community.

3.4. High-Speed Railway in Iberian Peninsula

In Portugal, there is not any High-Speed Railroad, however the *Alfa Pendular* is a service of high-speed trains with speeds above 200 km/h that circulate in 224 km of conventional tracks (European Commission, 2018c).

Conferred by ADIF (2019), the Spanish High-Speed Railway network started its operations in 1992 with the Madrid-Sevilla line and nowadays, is formed by 3,152 km. As it is showed in figure 2, not all system has the standard gauge, existing 567 km with exclusively Iberian gauge (ADIF, 2019). For the future, the strategic goal is to connect all provinces capitals, which would result in a distance inferior to 50 km to a High-Speed Railway station to 90% of the Spanish residents (RAVE, 2011).

Figure 2 Spanish High-Speed Railway network

3.5.High-Speed Railroad between Lisbon and Madrid

Spain is a major commercial partner for Portugal: 30% of the Portugal international exchanges are made with Spain (IP, 2018a). And according to IP (2018c), most of Portugal's freight importation and exportation by road are made with Spain, France and Germany, corresponding to 67%, 13% and 10%, respectively.

Starting in 2012 and ending in 2014, there was an attempt to connect Portugal and Germany, recurring to the Portuguese, Spanish and German's railroads operators. This route was made once a week for each direction. It was used wagons with 500m and with capacity of 32 mobile containers, that allowed carrying a volume of 60 TEU.

Nevertheless, the journey took 3 days and the different gauge between the Iberian Peninsula and France, obliged a stop in Irún, a Spanish border city, to make the transhipment of the mobile containers to wagon belonging to the DB Schenker delaying the process in 8 hours. This attempt was a commercial hit, but the numerous delays and the difficulties to assure the schedules with France forced the end of this initiative. It also compromised the lead time, more specifically, 40% of the merchandise with destination to German suffered more than 1 day of delay.

The goal with the implementation of the TEN-T's priority project is to consent longer wagons, 750m instead of 400m and reduce the currently time taken between the two cities through railroad in more than 7 hours, to 2h45m (RAVE, 2011).

According to RAVE (2011), the course in Portugal would require the construction of the Third Tagus Crossing (TTT) that would connect the two riverbanks, Chelas and Barreiro, see figures 3, 4, 5 and 6; a modification of the CP Waistline[4] to quadruple its capacity; an investment in signalisation and telecommunications throughout the course and, afterwards, an extension of the rail network to serve the new Lisbon Airport.

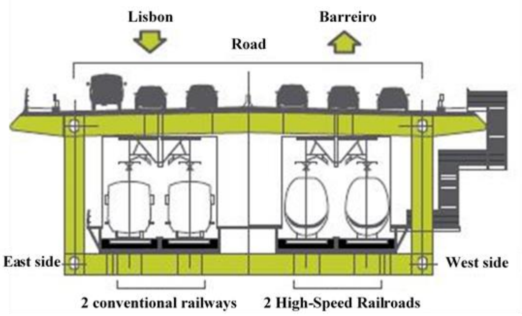

Figure 5 Transversal profile of TTT bridge
Source: RAVE (2008)

Figure 6 Photo montage of the North riverbank of TTT
Source: LNEC (2008)

Figure 4 Visual simulation - view from Miradouro da Cerca Moura
Source: RAVE (2008)

Figure 3 Visual simulation - view from Panteão Nacional
Source: RAVE (2009)

After environmental, geographic and demographic studies, both countries reached a path with 640km, which 203km would be constructed in Portugal (*Tribunal de Contas*, 2014). This trail is represented in figure 7 and, in Portugal, the High-Speed Railroad would stop in Lisboa-Oriente and Évora, while the Spanish stations would be in the International Station Elvas/Badajoz (in Caia), Mérida, Cáceres, Plasencia, Navalmoral, Talavera de la Reina and Madrid Atocha Station. The journey with the 7 stops would increase the trip time in 1 hour.

[4] CP Waistline is the name given to the main railroad network in the suburban Lisbon that has a semicircle design and connects the railroads from Sintra, West, Cascais, South and North.

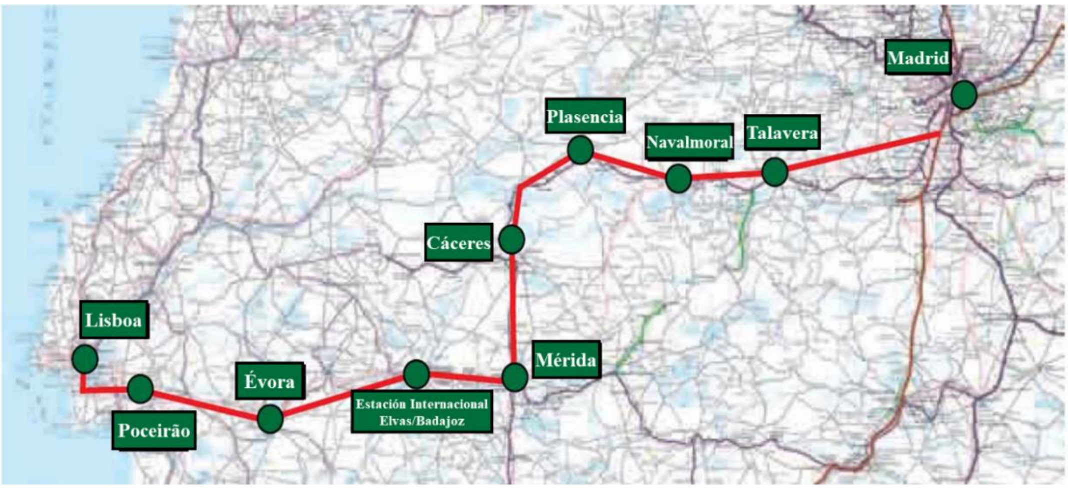

Figure 7 Planned High-Speed Railway between Lisbon and Madrid and its stops
Note: Poceirão it will not be a passenger station, but a logistic platform

Different services are expected to be performed in this HSR:

- Madrid-Lisbon (direct service);
- Madrid-Lisbon with stops in Plasencia, Mérida, Badajoz and Évora;
- Madrid-Lisbon with stops in Talavera, Cáceres, Badajoz and Évora;
- Madrid-Badajoz with stops Talavera, Navalmoral, Plasencia, Cáceres and Mérida;
- Madrid-Badajoz with stops Cáceres and Mérida;
- Madrid-Talavera;
- Lisbon-Évora.

The following two tables, table 1 and table 2, evidence the length of track that must be built between each rail station.

Station	Next Station	Length (Km)
Lisbon	Évora	120
Évora	Caia	87
Caia	Cáceres	115
Cáceres	Plasencia	66
Plasencia	Navalmoral	58
Navalmoral	Talavera de la Reina	64
Talavera de la Reina	Madrid	142
Total		**652**

Table 1 Length between stations in a direct service in the HSR between Lisbon and Madrid
Source: RAVE (2006)

Station	Next Station	Length (Km)
Lisbon	Évora	120
Évora	Caia	87
Caia	Mérida	62
Mérida	Cáceres	71
Cáceres	Plasencia	66
Plasencia	Navalmoral	58
Navalmoral	Talavera de la Reina	64
Talavera de la Reina	Madrid	142
Total		**670**

Table 2 Length between stations in service with stops in the HSR between Lisbon and Madrid
Source: RAVE (2006)

Furthermore, the structure between Lisbon and Madrid would gain value if the project to unite the High-Speed Railroad between Lisbon and Madrid to the High-Speed Railroads of France and Germany occur, as it is seen in the figure 8. This would demand a reclassification of the infrastructures existent that operates between Madrid and Barcelona, since currently it only does passenger services, while the connection between Barcelona and France is already for passenger and freight (IP, 2018a).

Figure 8 Atlantic Corridor
Source: European Commission

Additionally, the connection under analysis will be favourable if the Sines' high-speed railroad goes under construction because it is planned to connect Sines and Poceirão and then use the rail previous constructed for the linkage of both Iberian capitals. In figure 9, it is possible to observe that the length of the actual path and the projected one, would lower substantially the distance to the border. These would incentive the harbour traffic, possibly create a new logistic platform nearby Poceirão, that would be near a transportation knot, and therefore increase the utilization of a section of the Lisbon-Madrid's High-Speed Railroad.

Nowadays **With new connection to the border**

Figure 9 Current and new freight railway connection between Sines and the border
Source: Figure 2 of Tribunal de Contas (2014)

The combination of both routes would generate a demand of 12 freight transportations/day in the beginning of operations in the Évora-Caia area, that would rise for 36 freight transportations/day until 2049, that can be translated to 2.3 million tons/day in the launch and 8.5 million tons/day until 2049 (IP, 2018c).

4. Funding

An HSR project involves heavy investment and due to its importance to the quality of society, it is considered as a responsibility of the State. Nevertheless, these projects result in a tremendous financial effort in the national accounts, namely, sunk costs (Couto et al, 2012), while for investors, the exploration of this type of business is not attractive due to the high risk.

Vickerman (1995) recognizes that investments in Trans-European networks (TEN), that includes the TEN-T projects, have a growing difference between the investment cost and the amount from the private investors. At the same time, the financial help provided by EU contributions have been reduced in almost 40% (Banister and Givoni, 2013). The private sector is requiring more and more guarantee and/or possible government support. These requirements aim to increase the profitability for investors while decreasing the risk of the project, since they allow partial recover of possible losses (Brandão and Saraiva, 2008).

It has become harder and harder for the governments to find a way to finance these projects and to integrate them on national budgets (Vickerman, 1994). One way to contour this problem is through an alliance between both parties, the government and the private sector, to concretize the construction of an infrastructure project, called, Public-Private Partnership (PPP) (Chiara et al, 2007).

PPP's intention is to soften, in a long period of time, the financial impacts of costly projects and at the same time avoid large constrictions in the national budgets in the short-term (European Commission, 2018b). This form of partnerships is widely employed in the planning, construction of railway infrastructures as well its maintenance (RAVE, 2009).

The private sector becomes a concessionaire and executes and finances, partially, the construction and maintenance of structures and rolling stock, winning in return a user fee for its infrastructures and will have the maintenance and construction costs refunded by the national infrastructures managers and the State, respectively, as it is shown in the figure 10.

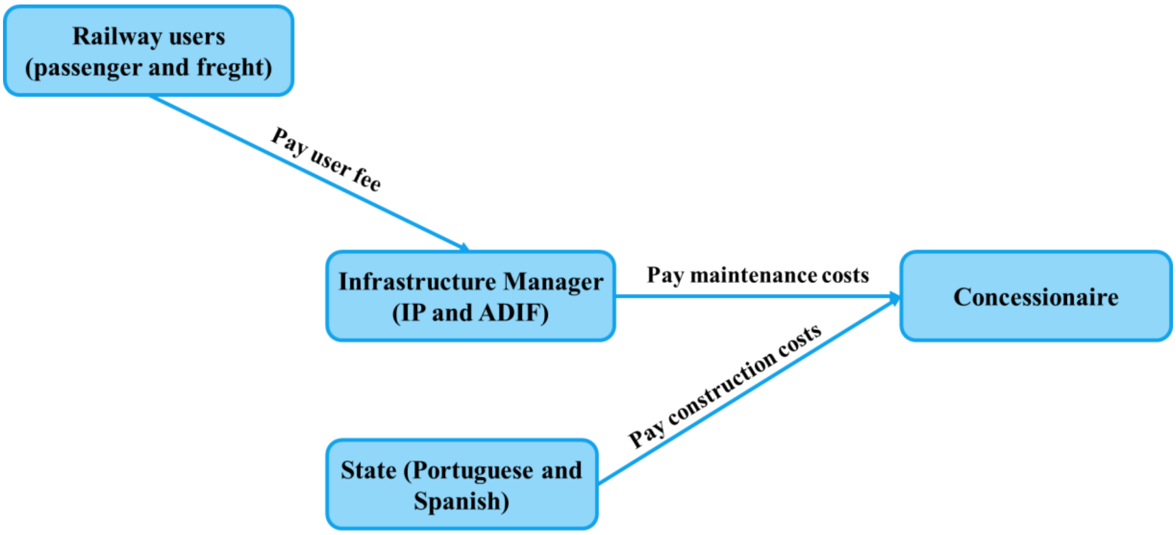

Figure 10 Cash flows between parties involved in the HSR between Lisbon and Madrid
Source: Author

Although this type of deal is more expensive for the governments, it is rewarded with gains in efficiency, in better quality in the service and generally the cost deviations regarding the expected cost is lower (RAVE, 2009c; Smit and Trigeorgis, 2009).

Smith and Trigeorgis (2009) proclaim that PPP allows more constant cash flows throughout the time, that facilitates high leveraging due to high debt ratios and that the participation of the private sector brings more discipline and rigor, reducing the costs more efficiently without compromising the quality.

5. Investment in transportation infrastructures

Jacques Barrot[5] states that "Modern economies cannot generate wealth and employment without highly efficient transport networks" (EC, 2005) and supporting to this statement is given in Pimentel et al. (2012) saying that transport infrastructure investments are fundamental and linked with sustainable economic growth.

Nowadays, companies compete in a worldwide range and each time with less and less protectionism measures. Consequently, to be competitive, countries must possess efficient and spread transport networks (Banister and Berechman, 2001). These infrastructures are even requested by the firms themselves, to agile their processes and operations and to engage more customers with lower costs and less leading times (Bontekoning, 2000).

[5] Former Vice president of the European Commission with responsibility for transport.

In the EU, transport infrastructures are mainly for road transportation, however in the White Paper on transport (2011), Siim Kallas[6], affirms that the EU's ambition is to shift 50% of the road services level to other transportations methods, with special attention to the railroad transportations, until 2050.

Berrittella (2010) adds that the EU wants to increase its intermodal transport[7] to reduce road transportation and seeks more sustainable methods of transportation, but that ambition is only feasible if the alternatives to road transportation become more advantageous for the consumers, being preferable by the increase in efficiency than by an increase in tax road or heavier regulations (Bontekoning, 2000). High-speed railroads can be a good alternative, being able to reduce the levels of road utilisation and avoiding congesting roads (Vickerman, 1995).

Another argument promoting alternatives to road transportation is an environmental one, increasing efficiency in intermodal transports' networks can reduce pollution, by using rationally the existent resources (Stead, 2001). The EC aims to reduce 30% of greenhouse gas emissions produced by transports and to diminish these gases in 40% until 2030 (EC, 2017a).

According to Campos and de Rus (2009), a private car consumes 6 litres of petrol/100 passengers-km and an air transport spends 7 litres of petrol/100 passengers-km, while an HSR only burn 2.5 litres of petrol/100 passengers-km, and, in terms of carbon dioxide emissions, HSR once again proves to be more environment friendly emitting 4 tonnes per 100 passengers-km, a lower result compared with the 17 tonnes released by airplanes and the 14 tonnes per 100 passengers-km produced by private cars.

Since 1970, rail transportation became an important concern for boosting economies, being nowadays consider an essential key (Couto et al, 2012). Also, since that period, the demand and revenues for high-speed railways, allowed the high-speed trains to be benefit for society, economy and their shareholders (Campos and de Rus, 2009).

Nevertheless, Couto et al (2012) emphasize that mistakes in high-speed railroads projects, as unrealistic assumptions or idealistic forecasts, can have the opposite effect and remember that the passengers will only adopt this method of transportation if they can gain more utility compared with other transportation's services.

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[6] Current Vice-President of the European Commission, Commissioner for Transport

[7] Intermodal transport is an integrated transport chain for goods composed by 2 or more methods of transport.

Supporting the previous statement are Banister and Givoni (2013) arguing that the economic growth may not occur, possibly because investments in High-Speed Railroads may not be enough or adequate to change the currently transportation mode of firms and passengers to this new type of transportation. Vickerman (1994) and Banister and Berechman (2001) accentuate that is the quality in transport infrastructure that is related with the economic development.

Correlated with High-Speed Railroads investments is the speed; however, it is not enough to ensure a good reception from the passenger's view. Banister and Givoni (2013) states that to reach economic growth, the project must follow some principles, such as: an average speed for distances bellow 500 km should be near 200 km/h; an exhaustive examination for the number and location of stations should be made to ensure the quality and a good network transportation, being preferable to minimise the number of stations and invest in good accesses to those stations; and it has to be reasonably priced to be a possible transportation for all population.

It is also pointed out by Banister and Berechman (2001) that it is required 3 sets of conditions to achieve economic increases, in particular, support for economic growth, namely good quantity and quality of labour; an integrated investment plan for the transport infrastructure with other projects and existent infrastructure; and regional, legal, organizational, financial and ambient support, as it is highlighted in Appendix 2.

6. Evaluation methods

Discounted Cash Flow (DCF) methods, such as Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI) and Payback Period (PP), evaluate projects by forecasting the cash flows during the life of the project and its residual or continuation value to discount at a proper rate to obtain a present value of the diverse cash flows (Alleman, 1999).

The NPV is the expected incremental value of a project for a firm and a manager only should invest in a project with a positive NPV (Damodaran, 2000). Nevertheless, this only makes sense in a static world or with perfect forecasts where the variance would be null, so, in the real world, the decision-maker should implement the project if it has a premium value (McDonald and Siegel, 1986).

The NPV is a popular tool among corporate finance's authors and in the academic framework because it respects crucial requirements: it is based on cash flows, tries to discount at a rate that represent adequate risk and is a multi-period analysis (Copeland and Philip, 1998). Although companies' awareness of this approval, in practice organisations rely more in the IRR, PP and PI (Berkovitch and Ronen, 2004).

The same authors exposed some of the downsides of the NPV, as the inability to expose the dispersion of cash flows throughout time and the incapacity to identify and deal with agency problems. According to Grenadier and Wang (2005), managers tend to choose projects with smaller PP, to reinforce their notoriety, and this is not captured by the NPV.

DCF methods are efficient for simple engineering investments, nevertheless, investments can generate future opportunities that must be considered during the assessment. However, this method is not able to represent future possibilities. (Garvin and Cheah, 2004).

Miller and Park (2002) present three other constraints of DCF tools, pointing that it is necessary to cast a "fitting" discount rate that should reflect risk and stays unchanged over time (Damodaran, 2000); that it only considers an investments as a "now or never" decision and not as mutually exclusive investments (McDonald and Siegel, 1986), ruling out the hypothesis of delaying the investment decision in order to collect more information or wait for a more favourable context; and, it ignores the management's flexibility to make adjustment decisions while pertinent information arrives to avoid risky situations or negative outcomes.

No management's flexibility means that managers cannot interfere or adjust their business. In the meantime, DCF methods consider that the forecasted cash flows are going to happen regardless of manager's decisions during the implementation and the life of the projects (Alleman, 1999; Block, 2007). Consequently, this type of analysis can mislead the managers' decisions (Copeland and Philip, 1998).

Although DCF methods are commonly used, they translated static viewpoints for the management, while managers should select dynamic methods to avoid and minimize the downside effect of uncertainty at the same time as they estimate and react to potential opportunities (Ford et al, 2002). For example, some projects, as infrastructure, can be developed in phases, allowing to understand and analyse them in an easier way. Since phases usually do not occur simultaneously, it also grants the possibility to obtain unknown information throughout the progress of the project, giving the managers ability to adapt their projects diminishing threats from new environment conditions (Garvin and Cheah, 2004).

Decision-tree analysis (DTA) is a methodology that gives a further step to capture the effects of managers' decisions (Alleman, 1999). This tool displays every conceivable scenario and the management's decisions associated to them. In each scenario, it is necessary to estimate the cash flow, the discount rate and the probability of occurrence and afterwards the expected value is computed (Block, 2007; Copeland and Philip, 1998). However, the same authors also pointed that this tool can guide managers to take wrong decisions, since there is no process to select the several discount rates that translate the different levels of risk in every branch of DTA.

Even though uncertainty is considered an adverse thing for managers and shareholders, this factor can improve the initial expected performance of an investment, but only if flexibility is included in the evaluation, because it reflects the possibility to explore future opportunities and avoid negative impacts (Cardin et al, 2007). Alleman (1999) even states that a DCF analysis can underestimate a project between 40 and 60%, because it neglects the flexibility value.

One way to reflect the flexibility and uncertainty of a project is through Real Options that measures physical assets as an American call option on the investment project. Accordingly, it is possible to use financial options' tools to determine the optimal time to invest, this means, exercise the option (Alleman, 1999; Grenadier and Wang, 2005).

Black and Scholes (1973) stated that "Stockholders have the equivalent of an option on their company's assets", then the DCF present limitation in contemplating the different firms' project as options, meaning that the projects cannot be reshaped in terms of dimension or timeline (Damodaran, 2000).

Although Real Options have similarities with Financial Options, the 6 inputs applied in Financial Options must be adjusted to reflect the reality of an investment in a business. In table 3, it is made the connection between the terms used in both modalities.

Financial Options	Real Options
Stock price	Present value of expected Cash Flows
Strike price	Investment value
Time to maturity	Time the decision can be postponed
Stock's volatility	Project uncertainty
Risk-free interest rate	Risk-free interest rate
Dividend yield	Rate of return shortfall

Table 3 Analogy between Financial Options' inputs and Real Options' inputs
Source: Taş and Ersen (2012)

Despite the high application of options in securities markets, Real Options is not a popular tool when assessing corporate investments, as a result of its mathematical complexity. Nonetheless, the complexity helps avoid agency problems in comparison to DCF approaches (Berkovitch and Ronen, 2004).

A useful instrument to represent Real Options during all stages is the previously mentioned decision tree, but it applies a higher discount rate that permutes in every branch of the decision tree to reflect the probability of the option ending up ITM or OTM that is subjective to every manager and the likelihoods are also subjective (Copeland and Philip, 1998).

A Real Option approach differs mostly from the NPV, when there is high uncertainty and managers can analyse new information to make more accurate decisions (Couto et al, 2012) and when the value of a project that does not account flexibility is near the threshold (Copeland and Philip, 1998). Alleman (1999) and Pimentel et al. (2012) said that flexibility should be accounted, because management's interventions skew the distribution of payoffs, restricting the potential losses associated at extreme events.

The benefit from applying Real Options is the elimination of a "subjective" discount rate. Instead it employs a density function to translate the uncertainty (Alleman, 1999).

When assessing transportation investment, Real Options is not often applied (Couto et al, 2012). Nevertheless, this methodology presents special advantages for this sort of investment. It is important to remember that a transportation investment is irreversible and if a firm goes through a bad scenario, it will try to get a residual value from its assets by selling them, but other companies will be exposed to the same adverse scenario and therefore will avoid investments (Abel et al, 1996). Additionally, there are options, like in the transportation sector, that are firm-specific, where the option only has value for a limit number of companies or a specialized sector, because only them possess reputation, experience, technic know-how and/or market share.

In spite of the irreversibility of transportation project, the decision to delay the investment is feasible, being analogous to a call option (McDonald and Siegel, 1986). Consequently, the investment stops being seen as a "now or never" decision and begins the concern to discover when is the optimal time to invest, this will be an important factor for the success of projects and their profitability (Couto et al, 2012).

Real Options can be employed in different sorts of valuation: investment, expand, contract, shutdown and restart, abandon the project and switch projects (Alleman, 1999; Copeland and Philip, 1998). During an analysis of an investment or expand option, the firm should wait for its optimal timing to invest in the project, because if it anticipates the investment, it will lose value from new information that arrives to the company (Couto et al, 2012).

The main disadvantage of Real Options is manager's reluctance to adopt this methodology, since they see it as a loss in their power, fearing that corporation's decisions will be made by scientists or mathematicians. According to Block (2007), it exists a connection between the use of Real Options and the background, academic and professional, of decision-makers.

Three models are popular for applying Real Options: a multimodal model, the Black-Scholes model and simulations. In the multimodal model, options are priced according to a lattice where each up and down move occurs in a discrete period and are pre-known (Tas and Ersen, 2012).

Black-Scholes model was introduced in Black and Scholes (1973) to price European options on stocks without dividends, being a specific case of a continuous multimodal model (Tas and Ersen, 2012). Since the Black-Scholes Model only prices European options, one of its limitations is the impossibility to value an earlier exercise (Damodaran, 2000).

Furthermore, it assumes no restriction in short-selling securities and that these ones are perfectly divisible; asset price that moves as a Geometric Brownian Motion with constant parameters (Wang and de Neufville, 2005), a certain and unchanged risk-free rate and volatility (Black, 1975), a lognormal distribution in the returns of the stock and an efficient market without transaction or taxes costs to price the option (Tas and Ersen, 2012).

Regarding to simulations, they value options based on every likely scenario and paths (Tas and Ersen, 2012). When exploiting it, it is typical to resort to Monte Carlo simulation, because it has less assumptions that the Black-Scholes model, it is versatile and can handle complexity and exotic payoffs (Wang and de Neufville, 2005). Nonetheless, it is a slow process and requires reasonable paths and stochastic models for unknown variables (Wang and de Neufville, 2005). The outcomes can be misleading, and they do not give any insights from where the value comes from or the impact and connection between the crucial variables (Wang and de Neufville, 2005).

7. Methodology

In the past, there were made viability studies for the implementation of the High-Speed Railroad between Lisbon and Madrid that applied DCF methods, like the one elaborated by Tribunal de Contas (2014), however this project will implement the Real Options Approach to achieve the project's value with flexibility.

All the criticism towards DCF methods may tempt managers to reject or ignore this methodology, however, they should be used as a complementary tool to Real Options and, since both approaches share inputs, the DCF should be computed first (Miller and Park, 2002).

The following chapters will show how the 6 inputs to compute the Real Option, mentioned in the previous section, were achieved. It is important to refer that the values throughout the project do not include VAT, this is an important fact due to different fiscal and tax laws in the two countries involved.

When it was necessary to discount the conjectured values, it was employed a rate of 7.5%, since it was considered to be a reasonable rate to discount public transport data according to "EU Reference Scenario 2016 Energy, transport and GHG emissions - Trends to 2050" (European Commission, 2016a).

In 1999, Portugal and Spain, along with other 9 countries, helped to found the Eurozone. One of convergence criteria to enter in the Eurozone were and still is price stability, that are monitor through the annual HICP inflation. The ECB restricts the annual HICP inflation to a rate of 2% in a medium term (ECB, 2019), accordingly, that was the rate used after 2019 to inflation the fares and the costs.

Subsequently, it will be presented how much is it worth the project including flexibility exploiting the Black-Scholes Model and, forthwith, a binomial approach that requires less assumptions and gives a result more realistic.

Afterwards, it is aimed to determine which should be the demand level to maximize the value of this investment and with that boundary computed, the managers should compare regularly the boundary and the environmental conditions to verify if it was attained, and therefore, if it is optimal to invest. If this is not observed, the managers should continue to make comparison and wait for the present cash flows be equal to the cash flow of exercising the option (Chiara et al, 2007; McDonald and Siegel, 1986).

8. Time

There are 3 different important time lines to analyse and consider throughout the project, namely: the time devoted to the operation of the new HSR line; the time required to build the mentioned HSR line; and the period of time that the decision of exercising the option or not can be postponed.

8.1 Operating time

In the transportation sector, it is frequent to observe concession agreements between governments and companies that will operate the business. The period concerned in the concession is typically between 30 and 50 years (European Commission, 2009a).

According to EU Guide (2014), transport infrastructure investments should be under scrutiny at least 30 years of cash flows and considering that this project requires super-infrastructures, like the TTT, the assessment must be examined between 30 and 40 years (RAVE, 2009a).

In 2008, Portugal launched a public tender for the concession between Poceirão and Caia and, in 2009, it opened a second public tender, this time, for a concession between Lisbon and Poceirão that would include the TTT. Both contracts were presented for public competition granting 40 years of operations (Tribunal de Contas, 2014). However, the public tender for Lisbon and Poceirão was cancelled and the already signed concession between Poceirão and Caia was shutdown, as a consequence of the financial crisis of 2008 (Tribunal de Contas, 2014).

Taking in account the mentioned advices and facts, this evaluation will use an operation time frame of 40 years.

8.2 Construction time

Regarding the construction time until it is possible to start operating it was considered 4 years, a value approved by Tribunal de Contas (2014), RAVE (2004) and European Commission (2008).

8.3 Life time of option

The White Paper on Transport (European Commission, 2011) serves as a guide in the matter of transport and elucidates strategies to consolidate the transport network in the EU. One of the main goals for the EU is to complete the high-speed rail network, including the 30 priority projects mentioned previously, until 2050. With the same time limit, it is expected to connect the main airports to the European rail system, specially the high-speed network.

Assuming that this HSR has to be functioning by 2050 and remembering that to build all the required infrastructures it is need 4 years, then the option can only be exercised between 2020 and 2046, this means that this option has a lifetime of 27 years.

9. Risk-free interest rate

As previously stated, one advantage of using Real Options is the elimination of a subjective discount rate, but this does not mean that time value should be ignored. Instead, it is applied a risk-free interest rate.

Since the 2 European countries actively involved in the implementation of the project belong to the Eurozone and the plan has a European character, the risk-free interest rate used was from AAA-rate euro area central government bonds. To assure the minimal risk possible to approximate to a no-risk scenario, it was considered government bonds with 10 years of maturity, similarity to the study made to assess the HSR between Lisbon and Oporto (RAVE, 2009b). Therefore, the risk-free interest rate used was 0.114725% corresponding to the spot rate in 12th March 2019 (European Central Bank, 2019).

10. Investment value

The investment value in this project is composed by the two different costs that must occur in the initial phase to able the provision of services. The first cost is related with infrastructure costs that include the construction of tracks with all infrastructures associated and the cost with the European Rail Traffic Management System (ERTMS[8]); and, the second cost is connect to the acquisition of rolling stock.

10.1 Infrastructure costs

UIC (2015) states that the European average cost for a construct 1km of new HSR is in a range of 15 and 40 million euros. Nevertheless, Campos and de Rus (2009) stated that this cost in the Spanish HSR is below the European average. According to these authors, until 2005, 1km of a new HSR costed between 7.8 and 20 million euros, while the on-going constructions had a cost oscillating from 8.9 to 17.5 million euros (see Appendix 3).

RAVE (2006) affirms that the Portuguese HSR will benefit from its geomorphology and will present lower cost in construction in face with European average.

[8] In high-speed is impossible to observe static signalisation, therefore it is required to adopt in-cab signalisation (UIC, 2015). The ERTMS emerge to standardise the railway signalisation in Europe and eradicate non-compliant signalisation and results in higher security in this type of transport and allows a higher average speed (European Commission, 2009b).

In Spain, there are some rail segments that have already built an ERTMS, as the section between Badajoz and Plasencia and between Toledo and Madrid (ERTMS, 2019), but it is missing the equipment between Caia and Badajoz and between Plasencia and Toledo. The cost for these two zones was estimated according to the distance between stations presents in table 2, and the cost to build ERTMS, that was assumed to be 165,000€, a simple average cost for ERTMS construction cost that ranges from 30,000 and 300,000€/km (European Commission, 2005). The results are exposed in table 4.

To assemble the ERTMS between Lisbon and Caia it is expected to do so through a PPP that according to the European Commission (2014a) it would cost 30.9M€.

It is also anticipated that in Portuguese solo there will be done 2 PPP to conduct the railway between Lisbon and Caia. The first segment will be between Lisbon and Poceirão with a cost of 928M€, while the second section will be located between Lisbon and Caia and will cost 1,411M€ (DGTF, 2009). These two values are only concerned with the HSR and ignore the costs regarding the conventional railway and with the road that will be a part of the TTT.

As shown in table 4, the branches between Mérida and Badajoz and Toledo and Madrid have a null cost, since they are already made European Commission (2015a). The HSR between Toledo and Madrid is currently in functions as it is exhibited in figure 2 since 2006 as a part of Madrid-Seville HSR service.

The construction cost from Caia and Mérida was accomplished by the subtraction of the cost to build an HSR between Évora and the border (Caia) (IP, 2018a) to the cost of building an HSR that connects Évora and Mérida (European Commission, 2013).

The cost regarding the segment between Badajoz and Navalmoral, in table 4, was collected from European Commission (2014a).

As previously stated, the cost to construct 1km of HSR in Spain is lower than the European average. In 2006, the HSR that connects Toledo and Madrid was in their finish line and therefore had a cost ranging from 8.9 to 17.5 million euros/km (Campos and de Rus, 2009). To forecast the cost to build an HSR from Navalmoral to Talavera de la Reina and from Talavera de la Reina, that are adjacent and have similar geomorphology to Toledo (see Appendix 4), it was considered that the cost would be 13.2M€, a simple average from the results expressed by Campos and de Rus (2009). After reaching the average cost/km, it was multiplied by the distance between stations that are stated in table 2.

Infrastructure costs	Section	Costs (million €)
ERTMS		
Portugal	Lisbon-Caia	30.9
Spain	Caia-Badajoz	5.775
	Badajoz-Plasencia	0
	Plasencia-Toledo	31.35
	Toledo-Madrid Atocha Station	0
Total		**68.03**
Construction		
Portugal	Lisbon-Poceirão	928
	Poceirão-Caia	1411
Spain	Caia-Mérida	173.548885
	Mérida-Badajoz	0
	Badajoz-Cáceres-Plasencia	237.81
	Plasencia-Navalmoral	416.9
	Navalmoral-Talavera de la Reina	844.8
	Talavera de la Reina-Toledo	897.6
	Toledo-Madrid Atocha Station	0
Total		**4,909.66**
Total infrastructure costs		**4,977.68**

Table 4 Infrastructure costs
Note: Distance between Madrid and Toledo – 74km; Distance between Caia and Badajoz -35km
Source: Author
Data Source: DGTF (2009); ERTMS (2019); European Commission (2005); European Commission (2013); European Commission (2014a); European Commission (2015a); IP (2018a)

Although the infrastructure investment has been already determined, it will not be done in just one payment, but throughout the 4 years of construction. It was considered that the infrastructure investment will be split according to the percentual average of the Portuguese Infrastructure Investment Schedule, presented in LNEC (2008). Therefore, in the 1st year of construction it will be dispend 18% of the budget, regarding the infrastructure investment, while in the 2nd, the 3rd and in the 4th year, it will be dispended 36%, 40% and 6%, respectively.

After applying the respective percentage for each construction year, it was reached the values demonstrated in table 5. Subsequently, each year was discounted at a rate of 7.5%, the same discount rate employed in the public transport data in "EU Reference Scenario 2016 Energy, transport and GHG emissions - Trends to 2050" (European Commission, 2016a). The sum of the 4 discounted cash flows generate the present value of the infrastructure investment, 4,598.21M€.

	Construction period			
Year	**1**	**2**	**3**	**4**
Infrastructure Investment (in M€)	885.3597489	1,779.009366	2,012.004	822.1205
Discounted Cash Flow (in M€)	823.5904641	1,539.434822	1,619.584	1,005.587
PV of infrastructure investment (in M€)	**4,598.21311**			

Table 5 Present Value of infrastructure investment (in M€)
Source: Author

10.2 Rolling stock acquisition

In order to deliver the service, in an initial stage, it will be required to purchase rolling stock to transport the passengers and to carry cargo.

Among different proposals to operate in the new HSR, it was selected to work in long distance the Serie-102 Talgo-Bombardier and to do shuttle services, a Serie-104 CAF-Alstom, for more details of these two rolling stocks analyse Appendix 5 and Appendix 6 (AVEP, 2011).

Considering the journey time required to complete a travel between Madrid and Lisbon and the vice versa trip with and without stops, see Appendix 7, it will be necessary to purchase 12 trains, however, it should be acquire extra units to replace the operating ones during maintenance, therefore 15 units should be acquired as it is showed in table 6 (RAVE, 2006).

In terms of cargo, according to RAVE (2004), for the first years it should be purchase 13 locomotives.

Rolling stock	Cost/unit (in M€)	Units to acquire	Cost (in M€)	Cost (in M€$_{2019}$)
Serie-102 Talgo-Bombardier	24.572 [1]	15	368.58 [1]	401.37
Serie-104 CAF-Alstom	14.872 [1]	5	74.36 [1]	80.97
Locomotive (for cargo)	2.3 [2]	13	29.9 [2]	38.47
Total	**----**	**33**	**----**	**520.81**

[1] Value from 2011
[2] Value from 2004

Table 6 Rolling stock needs and cost
Source: Author
Data source: AVEP (2011); RAVE (2004)

The data regarding the price of each passenger rolling stock was gather from AVEP (2011) and it is date back to 2011, while the locomotive price was obtained from RAVE (2004) and it is respected to 2004. Consequently, it was necessary to determine the present value of the rolling stock price. To do that, it was compile, in table 7, the annual inflation rate observed in UE 28 between 2005 and 2018 (OECD database, 2019).

Inflation rate	2005	2006	2007	2008	2009	2010	2011	2012
EU 28	2,30%	2,30%	2,40%	3,70%	1,00%	2,10%	3,10%	2,60%
	2013	2014	2015	2016	2017	2018	2005-2018	2012-2018
EU 28	1,50%	0,60%	0,10%	0,20%	1,70%	1,90%	28,66%	8,90%

Table 7 Average inflation in EU 28 between 2005 and 2018
Source: OECD database (2019)

This first investment in rolling stock will be made in the 4th year, in other words, in the year precedent to the beginning of operations, to avoid depreciation of the material and, for this reason and analogous to the infrastructure investment, this investment had to be discounted 4 years.

In table 8, it is added the cost of acquiring a new fleet of rolling stock to the construction cost of the new infrastructures. The sum of these 2 costs is then discounted, which gives a present value for the whole investment during the construction period of 4,988.20 M€.

	Construction period			
Year	**1**	**2**	**3**	**4**
Infrastructure Investment (in M€)	885.36	1,779.01	2,012.00	822.12
Rolling stock investment (in M€)				520.81
Discounted Cash Flow (in M€)	823.59	1,539.43	1,619.58	1,005.59
PV of investment (in M€)	**4,988.20**			

Table 8 Present Value of initial investment (in M€)

11. Present value of expected Cash Flows

During the exploration of a High-Speed rail service, the company will receive revenues from the passenger and the freight service, however, to determine those values, it is imperative to forecast a demand for each service and, afterwards, multiply it by the passenger and freight fares, respectively. On the other hand, it is also required to make expenses to realize the core activities, the commonly known, operational costs.

Additionally, in the end of the concession time, the company will expect to receive a value for the remaining assets of the company, a residual value.

The following subchapters will demonstrate how the mentioned components were achieved.

11.1 Demand

Although the project has not started within the expected timeframe, it was assumed that the schedule and the number of services per day would follow the same evolution then phase II of

AVEP (2011), in this phase, all operation will function totally in the HSR. Table 9 compile the information regarding the evolution of number of services per day for the different routes offer in this HSR and its corresponding time in minutes (AVEP, 2011). From Appendix 7 to Appendix 23 is more detailed information regarding this topic.

	Number of services/day				Time of trip (min)
	year 5-10	**year 10-15**	**year 15-30**	**year 30-45**	
Madrid-Lisbon (without stops)	8	8	8	12	159
Madrid-Lisbon (with stops in Plasencia, Mérida, Badajoz and Évora)	12	14	14	18	182
Madrid-Lisbon (with stops in Talavera, Cáceres, Badajoz and Évora)	12	14	14	18	187
Madrid-Badajoz (with stops Talavera, Navalmoral, Plasencia, Cáceres and Mérida)	6	8	10	12	149
Madrid-Badajoz (with stops Cáceres and Mérida)	4	6	4	4	127
Madrid-Talavera	18	18	20	24	44
Lisbon-Évora	10	12	12	14	30

Table 9 Services performed per day
Source: Author
Data source: AVEP (2011)

Using the same data from AVEP (2011), showed from Appendix 8 to Appendix 23, it was elaborated table 10 were it was stablished how units of rolling stock is required throughout the project.

	year 5-10	year 10-15	year 15-30	year 30-45
Serie-102 needed	10	12	12	15
Serie-104 needed	3	3	3	3

Table 10 Rolling stock required for passenger transport
Source: Author
Data source: AVEP (2011)

Observing table 10 and knowing that the rolling stock only has 25 years of useful life, this means, that in the year 30, it will be necessary to replace the rolling stock bought in the beginning of operations and even acquiring more units of rolling stock to fulfil the new schedule that will be implemented between the 30th and the 45th year. However, the company should not acquire the number of units strictly necessary but acquire 18 units of Serie-102 Talgo-Bombardier and 5 units of Serie-104 CAF-Alstom, as it is represented in table 11, since the firm should possess reserve units, that correspond to a total cost of 562.61 M€.

	Cost/unit ($M€_{2019}$)	Units to acquire in year 30	Cost ($M€_{2019}$)
Serie-102 Talgo-Bombardier	26.75770284	18	481.6386511
Serie-104 CAF-Alstom	16.19487859	5	80.97439293
Total		**23**	**562.61**

Table 11 Units of rolling stock to acquire and respectively cost
Source: Author

This sector of activity is subjected, in the beginning of its exercise, to a ramp-up effect. Ramp-up is the period when the new service is taking market share and attracting consumers for the new delivery service (RAVE, 2006). During this period, it is normal to see high rate of growth, since the demand did not reach, yet, its expected potential. Until 2006, there was not a European HSR with a ramp-up superior to 5 years and in the case of the Hanover – Berlin and the TGV Med (Valence–Marselha/Nimes) they did not even experience a ramp-up period (RAVE, 2006).

In this Iberian case, RAVE (2004) estimated that it will take 2 years for clients adopt the new delivery service: in the 1st year of operations the demand will correspond to 85% of the forecast value and in the 2nd year in functions the demand will be 95% of the conjecture value.

A large number of factors influences the transport sector, namely, economic, social, and demographic factors, being strongly correlated to the socio-economic development (European Commission, 2018a; European Commission, 2018c). According to European Commission (2018c), it is expected an increment of inhabitants in the larger cities, as in the case of Lisbon and Madrid, which can increase the potential market for this HSR.

The European Commission also forecast that, until 2030, the transport sector will reflect the GDP rate growth, specially the freight transport that will develop at closer rates to the GDP rate growth and at a higher rate than the expected growth for passenger transport (European Commission, 2016a).

Consequently, it was assumed that the growth rate for the HSR between Lisbon and Madrid will be equal to the forecasted growth rate of the Iberian GDP for the next 45 years. Those growth rates were elaborated using the Real GDP long-term forecast made by OECD and the both values are visible in Appendix 24 (OECD database, 2019).

Using those growth rates is a more conservative approach than employing the 2% growth for the high speed service considered, after the ramp-up, as in RAVE (2006) or that applying the growth rate forecasted of 2% for the Portuguese GDP according to AVEP (2011). This assumption is only feasible, since according to European Commission (2014a) the different modes of transport will have similar increases.

When assessing this plan, it is essential to make a prediction of the demand level and, in this specifically project, it is necessary to estimate the passenger demand in passenger-km, since posterior it will be necessary to determine the revenues that are charge in terms of passenger-km.

AVEP (2011) estimated the occupancy rate per each route in the new HSR for the first year operating in the High Speed track and the number of seats occupied per route in each station, the information regarding the number of seats occupied are compiled in table 12.

	Lisbon-Évora	Évora-Caia	Caia-Mérida	Mérida-Cáceres	Cáceres-Plasencia	Plasencia-Navalmoral	Navalmoral-Talavera	Talavera-Madrid
Madrid-Lisbon (without stops)	222	222	222	222	222	222	222	222
Madrid-Lisbon (stops in Plasencia, Mérida, Badajoz and Évora)	274	301	200	216	216	236	236	236
Madrid-Lisbon (stops in Talavera, Cáceres, Badajoz and Évora)	259	285	184	184	247	247	247	248
Madrid-Badajoz (stops Talavera, Navalmoral, Plasencia, Cáceres and Mérida)	0	0	71	150	213	226	279	278
Madrid-Badajoz (stops Cáceres and Mérida)	0	0	66	135	185	185	185	185
Madrid-Talavera	0	0	0	0	0	0	0	157
Lisbon-Évora	188	0	0	0	0	0	0	0

Table 12 Number of seats occupied per route in 2020
Source: AVEP (2011)

The passenger demand measured in passenger-km for the 1st year in function, was achieved considering 85% of the values of table 12 to adjust to the expected ramp-up effect and then multiplying those values per the number of routes made in the first year, this is, 365 days multiplying by the 2nd column of table 9, and the length of each branch.

In table 13, it is showed the passenger demand outputs for the 1st and the following years of exploration that were computed assuming, as mentioned before, that the transport sector will growth at the forecast rate of growth of the Iberian GDP that are present in Appendix 24. In the 2nd year of operations it was also considered the 95% of the predictable ramp-up.

	5	6	7	8	9
Passenger demand (passenger-km)					
Serie-102	1,882,539,914	2,129,647,028	2,270,388,302	230,0427,538	2,331,587,127
Serie-104	194,493,243	220,022,935	234,563,517	237,666,999	240,886,229
	10	**11**	**12**	**13**	**14**
Passenger demand (passenger-km)					
Serie-102	2,363,614,892	2,396,254,655	2,429,266,137	2,462,447,577	2,495,586,717
Serie-104	244,195,155	247,567,308	250,977,865	254,405,982	257,829,728
	15	**16**	**17**	**18**	**19**
Passenger demand (passenger-km)					
Serie-102	2,528,522,579	2,561,137,351	2,593,369,801	2,625,232,802	2,656,605,838
Serie-104	261,232,473	264,602,044	267,932,116	271,224,019	274,465,301
	20	**21**	**22**	**23**	**24**
Passenger demand (passenger-km)					
Serie-102	2,687,641,556	2,718,585,751	2,749,743,717	2,781,439,791	2,813,980,997
Serie-104	277,671,734	280,868,711	284,087,774	287,362,430	290,724,402
	25	**26**	**27**	**28**	**29**
Passenger demand (passenger-km)					
Serie-102	2,847,686,048	2,882,910,434	2,920,011,705	2,959,313,871	3,001,016,856
Serie-104	294,206,614	297,845,796	301,678,887	305,739,362	310,047,875
	30	**31**	**32**	**33**	**34**
Passenger demand (passenger-km)					
Serie-102	3,045,251,347	3,092,144,785	3,141,852,846	3,194,547,434	3,250,274,311
Serie-104	314,617,930	319,462,691	324,598,243	330,042,346	335,799,728
	35	**36**	**37**	**38**	**39**
Passenger demand (passenger-km)					
Serie-102	3,309,094,386	3,371,082,737	3,436,335,108	3,504,935,882	3,576,836,700
Serie-104	341,876,681	348,280,963	355,022,464	362,109,903	369,538,284
	40	**41**	**42**	**43**	**44**
Passenger demand (passenger-km)					
Serie-102	3,651,908,825	3,730,015,511	3,811,084,815	3,897,402,130	3,987,712,764
Serie-104	377,294,306	385,363,842	393,739,458	402,657,268	411,987,646

Table 13 Passenger demand in passenger-km
Source: Author

According to AVEP (2011), the freight demand will constitute 25% of the international rail transport between the 2 Iberian countries. Therefore, the demand in the first year was assumed to be 85% of the 25% of the exchanges made through rail between Portugal and Spain (in tonne-kilometre), since it was necessary to consider the ramp-up of 85% applicable to the 1st year in functions. The values corresponding to the rail exchanges between the two countries were obtained from Eurostat (2019) and are shown in Appendix 25.

In the 2nd year, it was applied 95% of ramp-up and the forecast growth rate was considered to be equal to the expected growth rate of the GDP (see Appendix 24). For the following years, the ramp-up was abolished and the expected annual growth rate of GDP was employed.

The outputs of those computations are exposed in table 14 and to convert the demand from tonne-kilometre to kilometre, it was divided by the maximum load carried on each trip. In this computation, the maximum load was considered to be 75% of the theoretical maximum load.

	5	6	7	8	9
Freight demand (tkm)	163,770,973	185,267,979	197,511,722	200,124,976	202,835,695
Freight demand (km)	8,240,049	9,321,659	9,937,697	10,069,181	10,205,570
	10	**11**	**12**	**13**	**14**
Freight demand (tkm)	205,621,940	208,461,426	211,333,250	214,219,859	217,102,788
Freight demand (km)	10,345,758	10,488,625	10,633,119	10,778,358	10,923,411
	15	**16**	**17**	**18**	**19**
Freight demand (tkm)	219,968,033	222,805,345	225,609,397	228,381,309	231,110,596
Freight demand (km)	11,067,574	11,210,332	11,351,416	11,490,883	11628,206
	20	**21**	**22**	**23**	**24**
Freight demand (tkm)	233,810,539	236,502,520	239,213,097	241,970,487	244,801,399
Freight demand (km)	11,764,052	11,899,498	12,035,879	12,174,616	12,317,052
	25	**26**	**27**	**28**	**29**
Freight demand (tkm)	247,733,560	250,797,894	254,025,508	257,444,587	261,072,525
Freight demand (km)	12,464,582	12,618,762	12,781,158	12,953,187	13,135,725
	30	**31**	**32**	**33**	**34**
Freight demand (tkm)	264,920,691	269,000,171	273,324,508	277,908,658	282,756,600
Freight demand (km)	13,329,343	13,534,600	13,752,177	13,982,826	14,226,747
	35	**36**	**37**	**38**	**39**
Freight demand (tkm)	287,873,634	293,266,291	298,942,901	304,910,804	311,165,793
Freight demand (km)	14,484,208	14,755,537	15,041,152	15,341,424	15,656,141
	40	**41**	**42**	**43**	**44**
Freight demand (tkm)	317,696,669	324,491,536	331,544,135	339,053,283	346,909,828
Freight demand (km)	15,984,738	16,326,618	16,681,466	17,059,285	17,454,583

Table 14 Freight demand in tkm and km
Source: Author

When considering the freight transport, it is necessary to clarify that the intermodal rail-road terminal will be located in Poceirão, while the Spanish intermodal rail-road terminal is located in the capital province of Castile–La Mancha, Toledo. The 2 intermodal rail-road terminals will be at a distance of 536 km and the cargo service will be function 300 days/year.

If assumed that each locomotive performs 5 journeys per day, it is possible to determine the number of rolling stocks necessary to fulfil the freight demand. In table 15, it is showed how many units of rolling stock is required to accomplish the demand and, similar to the passenger service, it was considered essential to possess extra units. In year 30, 31, 35 and year 41, it will be acquire 13, 1, 1 and 1 units, respectively, to substitute the units bought in the beginning of the project and in the 6th, 10th and 16th year that had already achieve the end of their useful life.

	5	**6**	**7**	**8**	**9**
Rolling stock	11	12	13	13	13
Rolling stock (+5% safety)	12	13	14	14	14
Buy rolling stock (cargo)	----	1	----	----	----
	10	**11**	**12**	**13**	**14**
Rolling stock	13	14	14	14	14
Rolling stock (+5% safety)	14	15	15	15	15
Buy rolling stock (cargo)	1	----	----	----	----
	15	**16**	**17**	**18**	**19**
Rolling stock	14	14	15	15	15
Rolling stock (+5% safety)	15	15	16	16	16
Buy rolling stock (cargo)	----	1	----	----	----
	20	**21**	**22**	**23**	**24**
Rolling stock	15	15	15	16	16
Rolling stock (+5% safety)	16	16	16	17	17
Buy rolling stock (cargo)	----	----	1	----	----
	25	**26**	**27**	**28**	**29**
Rolling stock	16	16	16	17	17
Rolling stock (+5% safety)	17	17	17	18	18
Buy rolling stock (cargo)	----	----	1	----	----
	30	**31**	**32**	**33**	**34**
Rolling stock	17	17	18	18	18
Rolling stock (+5% safety)	18	18	19	19	19
Buy rolling stock (cargo)	13	2	----	----	3
	35	**36**	**37**	**38**	**39**
Rolling stock	19	19	19	20	20
Rolling stock (+5% safety)	20	20	20	21	21
Buy rolling stock (cargo)	----	----	----	----	----
	40	**41**	**42**	**43**	**44**
Rolling stock	20	21	21	22	22
Rolling stock (+5% safety)	21	23	23	24	24
Buy rolling stock (cargo)	2	----	1	----	----

Table 15 Rolling stock required for cargo
Source: Author

11.2 Passenger and cargo fares

In the past, passenger rail fares were determined through the sum of a fixed component and a variable component according to the distance travelled. Nevertheless, the fares for HST have adopt alternatives, trying to create different spectrums of prices and discounts to benefit potential clients and offer complementary services to influence positively the demand level (RAVE, 2006; European Commission, 2009a). For example, in Spain, there a big range of prices, inclusive a special discount for regular passenger on the Spanish High-Speed network, as you can observe in Appendix 26 (RAVE, 2006).

This approach aims to create a satisfying fare system for the masses, while delivering a high quality service to the society and maximisation the revenues for the operating company (European Commission, 2018b).

According to RAVE (2006), the passenger fare for the HSR between Lisbon and Madrid will be proportional to the length covered. For the shuttle service, this is Lisbon-Évora and Madrid-Talavera, it was expected to charge 0.083€/passenger-km, while for the remaining services it would be charge 0.139€/passenger-km (AVEP, 2011). These fares are different because they use distinct types of rolling stock and, therefore, have divergent costs associated to the execution of their daily activities.

Since the mentioned prices are referent to 2011, it was required to calculate its present value, being employed the data from table 7 regarding historical inflation rate, to achieve the results displayed in table 16.

Passenger price/km		
	2011	**2019**
Serie-102 Talgo-Bombardier	0.139 €	0.151 €
Serie-104 CAF-Alstom	0.083 €	0.090 €

Table 16 Passenger price/km
Source: Author
Data source: AVEP, 2011

After achieving the present value for the passenger fare, it was computed the ticket price for the scope of journeys made in this High Speed Line by multiplying the fares and the distances between each station, present in table 1 and 2. The ticket prices achieved were round up to multiples of 5 cents, a common practice in the Portuguese rail fares and the results of those computations are exhibited in table 17.

		Ticket price
Serie-102	Madrid-Lisbon (without stops)	108.90 €
	Madrid-Lisbon (with stops)	101.45 €
	Madrid-Talavera	21.50 €
	Madrid-Navalmoral	31.20 €
	Madrid-Plasencia	40.00 €
	Madrid-Cáceres	49.95 €
	Madrid- Mérida	60.70 €
	Madrid-Badajoz	70.10 €
	Madrid-Évora	83.25 €
	Talavera-Navalmoral	10.90 €
	Talavera-Plasencia	18.50 €
	Talavera-Cáceres	28.50 €
	Talavera-Mérida	39.20 €
	Talavera-Badajoz	48.60 €
	Talavera-Évora	61.80 €
	Talavera-Lisbon	79.95 €
	Navalmoral-Plasencia	10.90 €
	Navalmoral-Cáceres	18.80 €
	Navalmoral-Mérida	29.55 €
	Navalmoral-Badajoz	38.90 €
	Plasencia-Cáceres	10.90 €
	Plasencia-Mérida	20.75 €
	Plasencia-Badajoz	30.15 €
	Plasencia-Évora	43.30€
	Plasencia-Lisbon	61.45€
	Cáceres-Mérida	10.75 €
	Cáceres-Badajoz	20.15 €
	Cáceres-Évora	33.30 €
	Cáceres-Lisbon	51.50 €
	Mérida-Badajoz	10.90 €
	Mérida-Évora	22.55 €
	Mérida-Lisbon	40.75 €
	Badajoz-Évora	13.20 €
	Badajoz-Lisbon	31.35 €
	Évora-Lisbon	18.20 €
Serie-104	Madrid-Talavera	12.85 €
	Lisbon-Évora	10.85 €

Table 17 Ticket price
Source: Author

As in RAVE (2006), the shorter journeys, as Navalmoral-Plasencia, Plasencia-Cáceres and Mérida-Badajoz, have a minimum fare of 10.90€, this is the present value of 10€ applied in RAVE (2006). This minimum fare had in consideration the fares of other transport modes and it is a way to avoid an excessive demand that would be difficult to satisfy.

For the direct service between Lisbon and Madrid, it was considering a higher value of 100€ that currently would be 108.90€, since it has more value for consumers, because the train does not have to make stops and save almost 1 hour in the journey (RAVE, 2006).

Similar to the passenger fare, the freight fare will only have a variable component, that is proportional to the transport of one tonne of cargo, and it was collected from RAVE (2004) that estimated a freight price/ton-km of 0.04€. Using the inflation rate growth between 2004 and 2019, displayed in table 9, the present value of this fare was determined to be 0.0515€, as it is showed in table 18.

	2004	**2019**
Freight fare/ton-km	0.0400 €	0.0515 €

Table 18 Freight fare/ton-km
Source: Author
Data source: RAVE (2006)

11.3 Residual value

When assessing the viability and the requirements of this project, RAVE took in account the residual value of the investment as the non-depreciated value of assets (RAVE, 2009a).

To accomplish coherence between the new linkage between both Iberian capitals and the already operating rail services in Iberian Peninsula, the residual value will be computed as the value of assets liquid from cumulative depreciations that follow a linear depreciation methodology, that is the system used in IP and ADIF (IP, 2018b and Ministerio de Hacienda, 2019).

ADIF depreciates its buildings and constructions in 50 years, which means that, each year the infrastructures will be depreciated at a 2% rate, while the rolling stock was considered to have a useful life of 25 years and therefore will be depreciated at a 4% rate/year, as according to Tribunal de Contas (2014). After 40 years of operating, the rolling stock purchase in the first year of operation, that includes passenger and cargo rolling stock, and in the 6th, 10th and 16th year, will be totally depreciated as it shown in table 19.

<table>
<tr><th colspan="4">Residual Value</th></tr>
<tr><th colspan="2"></th><th>Rate of depreciation</th><th>Residual value (in M€)</th></tr>
<tr><td colspan="2">Buildings and constructions</td><td>2%</td><td>995.537</td></tr>
<tr><td colspan="2">Rolling stock (1st purchase)</td><td>4%</td><td>0</td></tr>
<tr><td rowspan="10">Cargo</td><td>Rolling stock (bought in year 6)</td><td>4%</td><td>0</td></tr>
<tr><td>Rolling stock (bought in year 10)</td><td>4%</td><td>0</td></tr>
<tr><td>Rolling stock (bought in year 16)</td><td>4%</td><td>0</td></tr>
<tr><td>Rolling stock (bought in year 22)</td><td>4%</td><td>0.30976</td></tr>
<tr><td>Rolling stock (bought in year 27)</td><td>4%</td><td>1.19701</td></tr>
<tr><td>Rolling stock (bought in year 30)</td><td>4%</td><td>23.5909</td></tr>
<tr><td>Rolling stock (bought in year 31)</td><td>4%</td><td>4.07215</td></tr>
<tr><td>Rolling stock (bought in year 34)</td><td>4%</td><td>8.24995</td></tr>
<tr><td>Rolling stock (bought in year 40)</td><td>4%</td><td>8.84836</td></tr>
<tr><td>Rolling stock (bought in year 42)</td><td>4%</td><td>5.06321</td></tr>
<tr><td>Passenger</td><td>Rolling stock (bought in year 30)</td><td>4%</td><td>407.638</td></tr>
<tr><td colspan="3">Total</td><td>1,454.51</td></tr>
</table>

Table 19 Residual Value
Source: Author
Data source: Ministerio de Hacienda (2019)

11.4 Fixed costs

Every business has costs that are fixed, this is, costs that do not change regardless the level of activity. It is the example of infrastructure maintenance, that must have, a fixed examination period interval to execute preventive maintenance to assure security in the infrastructures and in the equipment employed during the service offer.

UIC (2015) affirms that preserving 1km of HSR in Europe costs an average of 90,000€ each year. Nevertheless, the expected cost to maintain 1 km of HSR in the section under analysis is more expensive, with an expected cost of 121,038€/km, as it is showed in table 20 (AVEP, 2011).

In order to safeguard an efficient logistic regarding the rolling stock, it is necessary to plan and control the rolling stock and the cargo in freight transport. To do so, companies incur in costs to implement automatic systems and to maintain the quality and efficiency of cables. According to AVEP (2011), these will undertake annually 4,716€/km.

Other essential cost to deliver a good service is ensure security to employers and to consumers, such as surveillance systems or subcontracting security staff, that as an estimated cost of 5,764€/km (AVEP, 2011).

All stations have to be conserved and have costs associated with its care and preservation, such as cleaning staff, energy costs and repair costs. These mentioned expenses differ consonant with the station's size. AVEP (2011) settle that the stations in Badajoz, Caia and Évora have medium dimensions and the terminal stations have big magnitudes, while Mérida, Cáceres, Plasencia, Navalmoral and Talavera possess small installations.

Currently, the terminal stations hold several railroads to provide diverse services, consequently, the costs of both stations should not be considered in totality for this project, only a share of this costs should be imputed in the assessment. ADIF and RAVE considered that the correct value to impute in the present project should be 200,000€/year for the Madrid's station and 410,000€/year associated to the Lisbon's station (AVEP, 2011).

The station in Évora distinguish from the other medium size stations examined in this project, since it requires 321,000€/year, instead of 1,000,000€/year (AVEP, 2011). For the small dimension stations, the same source estimated a cost of 300,000€/year/station, that reflects an obligation of 1,500,000€/year, as it is indicated in table 20.

Fixed costs with infrastructures maintenance		
Track and respective installations	(€/km)	121,038
Traffic management	(€/km)	4,716
Security and civil protection	(€/km)	5,764
Stations:		
Madrid	(€/year)	200,000
Lisbon	(€/year)	410,000
Évora	(€/year)	321,000
Medium stations (Badajoz and Caia)	(€/year)	2,000,000
Small stations (Mérida, Cáceres, Plasencia, Navalmoral and Talavera)	(€/year)	1,500,000

Table 20 Fixed costs with infrastructures
Source: Author
Data source: AVEP (2011)

Beyond the fixed costs associated to infrastructures maintenance and security, there is also fixed costs regarding the operation of passenger transport. Independently, of the demand level, the company stablish, in the beginning of each year of operation, a schedule with the number of services that it is, then, obliged to perform.

Recurring to the table 9 that expose the number of expeditions per day to execute for each service and to the data available in the table 1 and 2, that indicates the length between each station in this HSR, it was possible to determine the fixed costs with passenger transport that are related with the minutes of trains' operation or the km performed by the rolling stock.

The values are comprised in table 21, where it is possible to observe that the costs of circulation and the cost of operating time are different for the different rolling stock used. The S104 only executes small distances, shuttle journeys, consequently it presents higher costs that the S102.

Fixed costs with passenger transport						
	S104	**S102**	**Year 5- 10**	**Year 10-15**	**Year 15-30**	**Year 30-45**
Costs of operating time (€/train-minute)	4.288	3.789	16,244,248	18,948,664	19,193,849	24,466,759
Costs of circulation (€/train-km)	6.6239	3.8251	58,254,556.7	67,141,960	68,025,384	86,515,110
General costs (€/train-km)	0.6869	0.6869	9,574,665.78	11,113,993	11,205,604	14,335,225
Other costs (€/train-km)	0.2061	0.2061	2,872,817.90	3,334,683	3,362,171	4,301,194
Infrastructure tolls (€/train-km)	0.8142	0.8142	11,349,573.45	13,174,254	13,282,848	16,992,623

Table 21 Fixed costs with passenger transport
Source: Author
Data source: Atlantic Corridor (2016); RAVE (2004)

The costs of operating time were collected from RAVE (2004) and considers the expenses with the staff on board and the driving time. The cost of circulation was obtained from the same source and reflects the cost with energy, maintenance and manoeuvre.

According to RAVE (2005), this maintenance implemented in a High-Speed service has 5 phases: a more ordinary maintenance regarding the cleaning and the comfort of the rolling stock that it is executed after each journey; a maintenance before and during exploration (the drivers verify before and during every trip if there is something out of normal); an inspection of essential components that are performed every 3 days or when it is travelled 4,000 km; a more extensive inspection that are execute at every 300,000 km; and, an ever deeper inspection and maintenance when the rolling stock gets older than 13 year.

The general costs and other costs are identical for both rolling stocks, since the first one is related with administrative and monitoring activities, while the second cost includes the marketing campaigns, possible videos or other type of multimedia contents to be exposed in the stations or in the media, and other general costs (RAVE, 2004).

The infrastructure tolls costs considered is a weight average between the Spanish infrastructure tolls of 0.57€/train-km and the Portuguese infrastructure tolls of 1.34€ (Atlantic Corridor, 2016), to achieve the weight average cost, it was used the distances made in Portuguese solo and in Spanish territory, according to table 2.

11.5 Variable costs

Beside the fixed costs, the operation of an HSR line requires to bear variable costs that are related with operations costs that are displayed in table 22.

Variable costs			
Passenger transport		**S104 CAF-Alstom**	**S102 Talgo-Bombardier**
Costs of sales	(% of passenger revenues)	12.9	12.9
Freight transport			
Costs of operation	(€/km-locomotive)	7.7	
Maintenance	(€/km-locomotive)	1.5	

Table 22 Variable costs
Source: Author
Data Source: Atlantic Corridor (2016); AVEP (2011); RAVE (2004)

In an HSR passenger transport, there is costs associated to the process of sales, namely with personnel, surveillance and commission to agents in attempts to increase the volume of sales. These costs were considered to be 12.9% of revenues achieved from passenger transport, regardless the rolling stock employed (RAVE, 2004).

For each km made by a cargo transport, the group exploring the business incurs in 7.7€ that includes operation costs, infrastructure fees and terminal services. Additionally, the maintenance of this type of transport is, in average, 1.5€/ km-locomotive (Atlantic Corridor, 2016; AVEP, 2011). In the table 23, it is express the forecast variable costs regarding the freight transport for every year of operation, according to the cost mentioned and the demand level for freight transport previously mentioned in the subchapter demand.

	5	6	7	8	9
Costs of operation	65,892,833	74,586,285	79,550,660	80,628,184	81,735,731
Maintenance	12,215,901	13,827,584	14,747,932	14,947,695	15,153,024
	10	**11**	**12**	**13**	**14**
Costs of operation	82,864,440	84,006,004	85,153,446	86,299,424.1	87,438,373
Maintenance	15,362,276	15,573,911	15,786,635	15,999,088.8	16,210,239
	15	**16**	**17**	**18**	**19**
Costs of operation	88,566,218	89,680,843	90,782,691	91,867,597	92,940,837
Maintenance	16,419,331	16,625,972	16,830,244	17,031,375	17,230,343
	20	**21**	**22**	**23**	**24**
Costs of operation	94,010,913	95,088,380	96,184,456	97,309,758	98,475,306
Maintenance	17,428,725	17,628,477	17,831,679	18,040,300	18,256,381
	25	**26**	**27**	**28**	**29**
Costs of operation	99,693,394	100,976,386	102,335,487	103,777,610	105,307,275
Maintenance	18,482,203	18,720,057	18,972,021	19,239,377	19,522,962
	30	**31**	**32**	**33**	**34**
Costs of operation	106,928,888	108,647,833	110,470,055	112,397,136	114,431,182
Maintenance	19,823,594	20,142,270	20,480,092	20,837,355	21,214,448
	35	**36**	**37**	**38**	**39**
Costs of operation	116,574,790	118,831,270	121,203,541	123,689,930.4	126,285,985.7
Maintenance	21,611,852.5	22,030,182.37	22,469,978.7	22,930,931	23,412,215
	40	**41**	**42**	**43**	**44**
Costs of operation	128,986,978	131,790,421	134,775,344	137,898,359	141,165,336
Maintenance	23,912,953	24,432,685	24,986,061	25,565,038	26,170,704

Table 23 Variable cost of cargo transport
Source: Author

12. Uncertainty

As pointed by Black (1975), the volatility, or uncertainty in the case of firm's investments, is the big unknown at the time to calculate an option's value. In Real Options, it is not possible to determine volatility by observing previous levels of uncertainty as it is done with Financial Options.

An HSR project is exposed to several number of risks, as financial, climate, technologic, regulation, business and operational risk, there are explain in more detail in table 24.

Sort of risk	Risk
Financial risk	Credit risk; interest rate risk; liquidity risk.
Climate risk	Extreme temperature (overheat the tracks until buckling and diminish comfort during travels); snow; hoarfrost; ice; vigorous sunshine or wind; heavy rainfall and thunderstorms; inundations; earthquakes; high variation in humidity; sediment and leaves deposits; landslides; fires; fog; bridge abrasion.
Technologic Risk	Existence of autonomous vehicles; new platforms to share vehicles; electric power to supply all transports; obsolescence of infrastructures. system of online sales and information security.
Regulation Risk	Changes in laws (including taxation rates. for example); changes in ethical principles. regulation and/or European directives
Business/ Operational Risk	Archaeological risk; construction risk; deadline risk for construction; insolvency risk; demand risk; insufficient capacity risk; bad public image; efficient problems; suppression of services or delayed services; deficiency of experience in High-Speed Railroad businesses

Table 24 Underlying risks in the High-Speed Railroad between Lisbon and Madrid
Source: Tribunal de Contas (2014); Tas and Ersen (2012); Infraestruturas de Portugal (2018b); ADIF (2019); UIC (2015); European Commission (2017a); European Commission (2018b)

This project is also subject to a positive side of technological uncertainty, a "good uncertainty", in the sense, that in the next years it can be created new machineries to improve efficiency of railways or to diminish the cost of building this sort of business and make this proposal more attractive (Murto, 2007). This is an important aspect since UIC (2015) expects, in a short period of time. technologic refinements in HSR: more tracks built and, consequently, wider services; an increment in maximum speeds to 320 or even 360km/h; safer and more efficient brake systems; more efficiency in energy consumption; less noise pollution; better telecommunications services; a standardisation of rolling stock with new materials; and enhancement of comfort, security and safety, with new systems of detection of natural catastrophes.

In an attempt to attenuate the lack of CP's experience in the High-Speed Railroad business and the modest experience of RENFE in operating in Portuguese solo, the exploration of this service will be secured by an international player resulting of a joint-venture between CP and RENFE

(Tribunal de Contas, 2014): two institutions that in 2018 saw their credit risk rating improved from a Ba2 to a rating of Ba1 (Stable) according to the Moody's Investors Service, as well the two corporates in charge of rail infrastructures in Iberian Peninsula (Infraestruturas de Portugal, 2019).

The mainly source of uncertainty in a High-Speed Railway is the revenue that it is determined by the ticket's price and the traffic flow in the railway, consequently the main uncertainty in this sort of problems is comes from the uncertainty regarding the future demand level that will have direct impact in the sales revenues (Brandão and Saraiva, 2008; Pimentel et al., 2012).

Consequently, it is crucial to diminish uncertainty, make a good forecast considering the existent transportation infrastructures, the population living or working in high density areas as well as their flows, the merchandise flows and corresponding growth throughout the years.

This parameter is not stable throughout the time, since it is affected by the time left to the end of the project and the stream of cash flows obtained and expected (Black and Scholes, 1973), being extremely difficult to determine it (Damodaran, 2000).

Uncertainty in firms' projects are usually determined in one of the two following ways: the uncertainty can be forecasted based on uncertainty observed in analogous projects; or, managers can conceive different market scenarios, exploring the effect in their project, and set out a probability for the varied plots, achieving a weighted average risk (Damodaran, 2000).

In this evaluation, the HSR considered was based on peers' projects, more specifically, the European railroads' standard deviation in operating income that currently reaches 27.10% (Damodaran Online, 2019b).

13. Opportunity cost

In the past, European projects summited to approval of community funds presented financial studies applying different discount rates according to their perspective of risk and macroeconomics characteristics. European Commission allows that each State member originates its own Financial Discount Rate (FDR), so all national projects can have consistency (European Commission, 2014). However, the differences in the discount rates are hard to support, even within the same country (Florio, 2006).

To compare the numerous projects in a coherence way, the EC suggests the adoption of a unique FDR (Florio, 2006). An existence of a unique rate for all EU is only feasible considering that country member have access to an integrated financial market (Florio, 2006). This rate aims to capture the opportunity cost of capital as the loss of profit consequential from other project with an analogous risk level that provide a higher return (European Commission, 2014b).

One approach to compute a FDR is considering it as a real return on government bonds if it addresses a public investment, as a long-term real interest rate on loans if it is a private project or as a Weighted Average Capital Cost (WACC) if it is a mix investment (European Commission, 2014b). Other way is seeing the FDR as an opportunity cost rate of efficient financial portfolio, this is, an average return of a diversified securities (European Commission, 2014b and Florio et al, 2018).

According to European Commission (2008), for projects comprehended in the period 2007-2013 the standard FDR applied was 5%, nevertheless, this rate decreased, for projects comprehended between 2014 and 2020, for 4% (European Commission, 2014a). Both rates include inflation, thus being real term rates. The more recent rate approximates of an average of all real yield government debt of EU's country members with long duration since 80's decade (European Commission, 2009c).

The HSR between the two Iberian capitals is, as mentioned before, a project under community funds and support from the EU, therefore this project will apply the benchmark FDR of 4% as the opportunity cost. This decision solves the difficulty of achieving a FDR involving two nations and allows to make future comparisons with projects under the same conditions, this is, candidates to CEF grants.

14. Static NPV

To determine the static NPV it is necessary to anticipate every single Cash Flow. In table 25, it is represented the forecasted Cash Flows for the construction period, while in table 26, it is detailed the expected Cash Flows for the exploration period of 40 years.

	Construction period			
Year	**1**	**2**	**3**	**4**
Infrastructure Investment	885.36	1779.01	2012.00	822.12
Rolling stock investment				520.81
Cash Flow	**-885.36**	**-1779.01**	**-2012.00**	**-1342.93**
Discounted Cash Flow	**-823.59**	**-1539.43**	**-1619.58**	**-1005.59**

Table 25 Cash Flows during construction period
Source: Author

Year	5	6	7	8	9
Rolling stock investment	0	2.82	0	0	0
Operational Costs	301.13	319.26	332.68	340.87	349.30
Passenger Revenue	334.02	385.42	419.10	433.14	447.79
Freight Revenue	9.31	10.74	11.68	12.07	12.48
Residual value	0	0	0	0	0
Operational Cash Flow	42.19	74.07	98.10	104.34	110.96
Depreciation	120.39	122.89	122.89	122.89	122.89
EBIT	-78.20	-48.82	-24.79	-18.55	-11.93
Interests pay	201.51	196.47	191.43	186.39	181.36
EBT	-279.70	-245.29	-216.22	-204.94	-193.28
Income after taxes	0	0	0	0	0
Cash Flow	-159.32	-122.40	-93.33	-82.05	-70.39
Discounted Cash Flow	-110.97	-79.31	-56.26	-46.00	-36.72
	10	11	12	13	14
Rolling stock investment	3.05	0	0	0	0
Operational Costs	376.78	386.08	395.63	405.41	415.42
Passenger Revenue	463.02	478.80	495.11	511.91	529.17
Freight Revenue	12.90	13.34	13.79	14.26	14.74
Residual value	0	0	0	0	0
Operational Cash Flow	96.08	106.06	113.27	120.76	128.50
Depreciation	125.40	125.40	125.40	125.40	125.40
EBIT	-29.31	-19.34	-12.12	-4.63	3.10
Interests pay	176.32	171.28	166.24	161.20	156.17
EBT	-205.63	-190.62	-178.36	-165.84	-153.07
Income after taxes	0	0	0	0	0
Cash Flow	-80.23	-65.22	-52.97	-40.44	-27.67
Discounted Cash Flow	-38.93	-29.44	-22.24	-15.80	-10.05
	15	16	17	18	19
Rolling stock investment	0	3.44	0	0	0
Operational Costs	427.48	437.98	448.70	459.65	470.83
Passenger Revenue	546.88	565.01	583.56	602.55	621.94
Freight Revenue	15.24	15.74	16.26	16.79	17.33
Residual value	0	0	0	0	0
Operational Cash Flow	134.64	139.34	151.12	159.68	168.44
Depreciation	125.40	127.90	127.90	127.90	127.90
EBIT	9.24	11.44	23.22	31.78	40.54
Interests pay	151.13	146.09	141.05	136.02	130.98
EBT	-141.89	-134.65	-117.83	-104.23	-90.44
Income after taxes	0	0	0	0	0
Cash Flow	-16.49	-6.75	10.07	23.67	37.46
Discounted Cash Flow	-5.57	-2.12	2.94	6.44	9.48

	20	**21**	**22**	**23**	**24**
Rolling stock investment	0	0	3.87	0	0
Operational Costs	482.26	493.94	505.92	518.21	530.85
Passenger Revenue	641.79	662.17	683.15	704.85	727.36
Freight Revenue	17.88	18.45	19.03	19.64	20.26
Residual value	0	0	0	0	0
Operational Cash Flow	177.42	186.67	192.39	206.27	216.77
Depreciation	127.90	127.90	130.40	130.40	130.40
EBIT	49.52	58.77	61.99	75.87	86.36
Interests pay	125.94	120.90	115.87	110.83	105.79
EBT	-76.42	-62.13	-53.88	-34.96	-19.43
Income after taxes	0	0	0	0	0
Cash Flow	51.48	65.77	76.53	95.44	110.98
Discounted Cash Flow	12.12	14.40	15.59	18.09	19.56
	25	**26**	**27**	**28**	**29**
Rolling stock investment	0	0	4.28	0	0
Operational Costs	543.87	557.32	571.22	585.62	600.55
Passenger Revenue	750.79	775.28	800.96	827.97	856.44
Freight Revenue	20.92	21.60	22.31	23.07	23.86
Residual value	0	0	0	0	0
Operational Cash Flow	227.83	239.56	247.78	265.42	279.74
Depreciation	130.40	130.40	132.91	132.91	132.91
EBIT	97.43	109.15	114.87	132.51	146.83
Interests pay	100.75	95.72	90.68	85.64	80.60
EBT	-3.33	13.44	24.19	46.87	66.23
Income after taxes	0	9.81	17.66	34.22	48.35
Cash Flow	127.08	143.84	157.10	179.78	199.14
Discounted Cash Flow	20.84	21.94	22.29	23.73	24.45
	30	**31**	**32**	**33**	**34**
Rolling stock investment	58.98	9.25	0	0	14.73
Operational Costs	673.18	690.42	708.30	726.87	746.16
Passenger Revenue	886.44	918.09	951.51	986.82	1,024.11
Freight Revenue	24.70	25.58	26.51	27.49	28.53
Residual value	0	0	0	0	0
Operational Cash Flow	178.98	244.00	269.72	287.44	291.75
Depreciation	167.14	164.64	164.64	164.64	172.15
EBIT	11.84	79.36	105.08	122.80	119.60
Interests pay	75.56	73.48	68.29	63.11	57.92
EBT	-63.73	5.89	36.79	59.69	61.68
Income after taxes	0	4.30	26.86	43.58	45.02
Cash Flow	103.41	170.52	201.43	224.33	233.83
Discounted Cash Flow	11.81	18.12	19.91	20.63	20

	35	36	37	38	39
Rolling stock investment	0	0	0	0	0
Operational Costs	766.20	787.03	808.68	831.19	854.58
Passenger Revenue	1,063.50	1,105.09	1,149.01	1,195.39	1,244.31
Freight Revenue	29.63	30.79	32.01	33.30	34.67
Residual value	0	0	0	0	0
Operational Cash Flow	326.92	348.85	372.34	397.50	424.39
Depreciation	169.65	169.65	169.65	169.65	169.65
EBIT	157.28	179.20	202.70	227.86	254.75
Interests pay	52.74	47.55	42.37	37.18	32.00
EBT	104.54	131.65	160.33	190.68	222.75
Income after taxes	76.31	96.10	117.04	139.19	162.61
Cash Flow	274.18	301.29	329.98	360.32	392.40
Discounted Cash Flow	21.81	22.30	22.72	23.08	23.38
	40	**41**	**42**	**43**	**44**
Rolling stock investment	11.06	0	5.75	0	0
Operational Costs	878.88	904.11	930.30	957.70	986.25
Passenger Revenue	1,295.83	1,350.02	1,406.95	1,467.59	1,531.63
Freight Revenue	36.10	37.61	39.20	40.89	42.67
Residual value	0	0	0	0	1,454.51
Operational Cash Flow	441.99	483.51	510.09	550.77	2042.55
Depreciation	174.65	172.15	174.65	174.65	174.65
EBIT	267.33	311.36	335.43	376.11	1,867.90
Interests pay	26.81	21.63	16.44	11.26	6.07
EBT	240.52	289.74	318.99	364.86	1,861.83
Income after taxes	175.58	211.51	232.87	266.35	1,359.14
Cash Flow	415.18	461.89	493.65	539.51	2,036.48
Discounted Cash Flow	23.01	23.81	23.67	24.07	84.51

Table 26 Cash Flows in exploration period
Source: Author

The infrastructure investment, the rolling stock investment and the residual value of the project were already described in the previous chapter.

To reach the revenue value it was multiplied the fare per passenger-km to the passenger demand level, also in passenger-km, and the fare for freight per tonne-kilometre to the freight demand.

The operational cost was obtained by adding the fixed costs to the variable costs that are subject to the passenger revenues and the km made by the cargo rolling stock.

With those parameters, it was computed the operational Cash Flow, by subtracting the operational costs and the investments values to the revenues and the residual value.

The depreciation rate considered was the same exposed in table 19, this is, 4% for the rolling stock and 2% for the infrastructures.

The project involves large amounts to initiate the project and although the project has an international aspect, it will have the private sector involved through the PPP. Consequently, it is expected a loan requisition to help finance the private share, that was, in this project, estimated to be 67% of the total investment. This percentage is the same percentage of private participation in the branch to be constructed between Poceirão and Caia (DGTF, 2011).

It was considered that this initial loan has a life time of 40 years plus 4 year of grace period and, subsequently, will only start to amortise the loan payments when operating the HSR line. Considering that the interest rate for the loan is a fixed one 5%, that is the average rate of cost of debt for the European rail transport, according to Damodaran Online (2019a), it was possible to determine the interests to be paid in each year.

In the year 30, it will be made another substantial investment, this time just in rolling stock, and the group will have the necessity to make other loan. This time, the duration of the loan it was considered to be 20 years and would have the same fixed interest rate as the first loan, 5%.

With the operational Cash Flows, the depreciation and the interests determined, it was discovered the income after taxes, using a 27% rate for taxes, as it is subjected the Portuguese firms.

Although the depreciations being seen as a cost for accounting and to the taxable income, this cost does not result in an exit of funds. Subsequently, the Cash Flow was obtained by adding the depreciation value to the income after taxes. Afterwards, those values were discounted to the present year, 2019, and the sum of all those discounted values results in a negative NPV of 4,846.91 M€, as it is showed in table 27.

PV of project`s cash flows during operation period (in M€)	141.29
PV of investment (in M€)	- 4,988.20
Static NPV (in M€)	- 4,846.91

Table 27 Present Value of investment and NPV (in M€)
Source: Author

15. Black-Scholes and Merton Model

With a timeframe, the investment value, the project uncertainty, the risk-free interest rate, the rate of return shortfall and the different constituents of the present value of expected Cash Flows determined, it was exploited the Black-Scholes and Merton Model to discover if the flexibility value would make this project attractive for investors or not. This methodology uses the following equations from Black and Scholes (1973):

$$\text{Call Option price} = N(d_1)S_t - N(d_2)Ke^{-r(T-t)}$$

Where, $d_1 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S_t}{k}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)\right]$ and $d_2 = d_1 - \sigma\sqrt{T-t}$

In table 28, it is concise the inputs that were determine throughout this thesis and the computation of each component of the Black-Scholes and Merton model equation.

Inputs of the BSM model		
PV of project`s expected cash flows	V_t	141.2857
Investment cost	X	4,988.1954
Riskless interest rate	r	0.1147%
Time to expiration	T	27
Project value uncertainty	σ	27.1%
Rate of return shortfall (dividend yield)	q	4.00%
Cumulative normal distribution computations		
Parameter d_1	d_1	-2.571883
Parameter d_2	d_2	-3.980040
Cumulative normal distribution for d_1	$N(d_1)$	0.005057
Cumulative normal distribution for d_2	$N(d_2)$	0.000034
European option prices using the BSM model		
Call option price	c_t	0.0760
Project value (Call option + Static NPV)		-4,846.8336

Table 28 Black-Scholes and Merton model inputs and result
Source: Author

When considering this methodology, the value of flexibility associated with this project is 0.076M€, however, the value of flexibility is too small to compensate the enormous negative NPV, consequently, the project value with flexibility is still negative by 4,846.83M€.

Nevertheless, this methodology is not appropriate for this type of project since it assumes that the traffic and, consequently the revenues, follow a Geometric Brownian motion (Garvin and Cheah, 2004) and it does not allow the investor to exercise his option before the expiration date, this is, before 2046.

16. Binomial Model

In an attempt to evaluate the project with flexibility, but rejecting the assumption that traffic follows a Geometric Brownian motion, it was executed the binomial model. And in order to eliminate the limitation of only exercise the option at its expiration date, it was performed a decision tree that reflects an American call option.

Using the same inputs as in the Black-Scholes and Merton Model, it was made the decision tree exposed in figure 11, but due to limitations of the program used to construct the decision tree, this one had to possess 10 steps instead of 27, for this reason, the value of the project considering flexibility was analyse every 2 years and 8 months instead of annually.

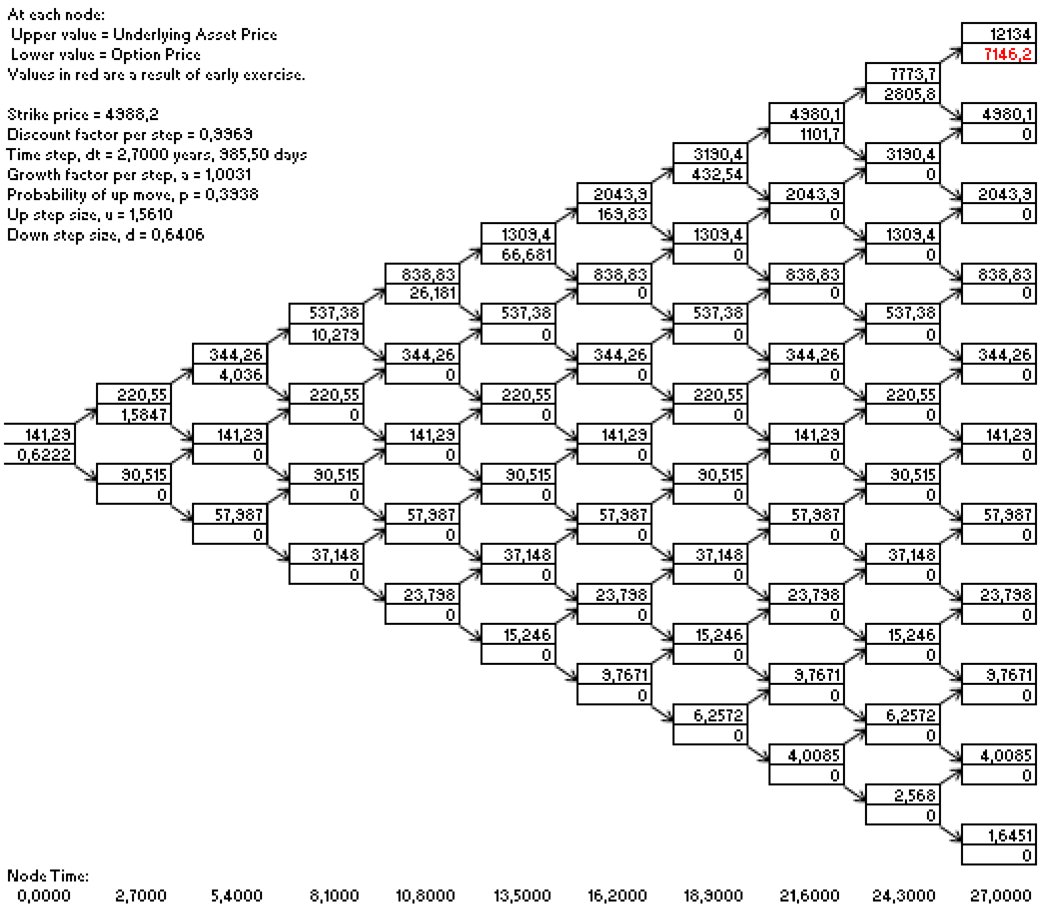

Figure 11 Decision tree of HSR between Lisbon and Madrid (values in M€)
Source: Author

Each node has represented the Present value of expected Cash Flows and the option price. Since the investor should only invest when the option price is higher than the investment cost of 4,988.2M€.

The value in red is the positive value that the investor will obtain if it exercises in that exact moment. In figure 11, it is observable that the changes in the business environmental can generate a profitable project in 27 years from now.

17.Socioeconomics' factors

Beyond the financial aspect, the High-Speed Railroad under evaluation would have repercussions on both societies and their quality of life. Nowadays, those consequences are not allocated to companies, therefore, in one way or in other, it will be the society that pays for those effects or benefit directly from them. According to UIC (2018), there are 5 socioeconomic impacts that should be examined and compared with competitive transports: these are accidents, noise and air pollution, climate change and effects in the supply network.

As it can be seen in figure 12, the rail transport has, on average, smaller costs for society than bus, planes or private vehicles, it costs half of bus costs and near a third of car costs or even plane costs. There is only one factor where railway costs more than any other competitive transport, the up and down stream process since it is acknowledged that railroads demand specific structures to agile multimodal flows.

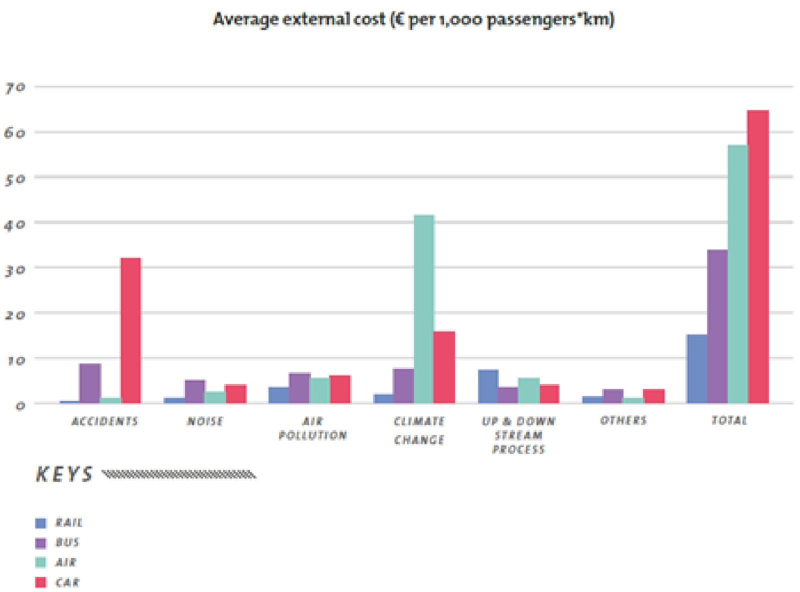

Figure 12 Average external costs (€/ 1000 passengers-km)
Source: UIC (2018)

AVEP (2011) studied the socioeconomic effects on this peculiar case and the average cost of those impacts were summarized in table 29, where it is possible to analyse that between Lisbon and Madrid, an HSR would perform socioeconomic better than a private vehicle. Comparing the railway with air transport, the air gets advantage in terms of noise and air pollution, urban effects and in accidents. In terms of safety and its respective costs, the railway is as secure as the plane being safer than opting by any road transportation.

	Average Cost (€/1000 passengers-km)				
	Road			Railway	Plane
	Automobile	Bus	Motorcycle		
Noise pollution	7.1	1.8	22.0	5.4	2.5
Air pollution	17.5	28.5	5.3	9.4	3.3
Climate Change					
Upper scenario	24.3	11.5	16.1	8.6	63.8
Bottom scenario	3.4	1.7	2.3	1.2	9.1
Nature and sightsee	3.9	1.0	2.9	0.9	1.1
Urban effects	2.2	0.5	1.6	1.8	0.0
Total accidents	23.2	3.3	260.0	1.1	0.5
Deaths	16.0	3.0	229.5	1.0	0.4
Injured	7.2	0.4	30.6	0.1	0.1

Table 29 Environmental impacts and accidents costs (€ 2011)
Source: AVEP (2011)

One of the first impacts of constructing an HSR, and maybe the most visible one, is the creation of new jobs from early implementation. During the construction period, the construction benefits directly and the most from the project, but, afterwards, when it is possible to function, numerous sectors would profit, it would incentive tourism, increase the demand and prices in the real estate market and local businesses would emerge (RAVE, 2006).

Better accessibilities for the general crowd and a faster service will give bigger range of possibilities for companies decide where to locate their business, since it would be created a new route with potential clients and the staff would also have more convenient access to reach their workplace (RAVE, 2006). Nevertheless. reshape the already existing station in Lisbon, Gare do Oriente, can handicap even more the road bottleneck and boost pollution in that area (Santos, 2008).

With changes in the modal split for transports, it is expected to decrease the energetic consumption associated with transports (see Appendix 28), an environmental improvement due to the reduction of pollutants emitted by HSR (see Appendix 29) and a diminish in accidents and their associated costs (see Appendix 30) (RAVE, 2009c).

Additionally, creating a faster service to connect both cities, will save time spent in travelling. In table 30, it is exposed the forecasts for 2030 from RAVE (2006), where it is foreseen a saving of 2,900,726 hours in trips between Lisbon and Madrid considering the different shifts of modal transports that was value in 37,490,227 euros.

Mode	Total time in journeys (h)			Value of time saved (€)
	Without HSR	With HSR	Saved	
HSR	----	7,935,845	-7,935,845	-93,307,184
Plane	2,597,968	808,337	1,789,631	21,600,841
Bus	5,790,174	4,965,554	824,620	9,953,159
Car	34,924,027	28,215,685	6,708,342	80,969,693
Conventional train	1,662,630	148,652	1,513,978	18,273,718
Total	44,974,800	42,074,073	2,900,726	37,490,227

Table 30 Total time in journeys, saved time and value of save time in 2030: Lisbon-Madrid line
Source: RAVE (2006)

According with the same source, time is valued differently weighting the reason of the trip, if it is a business or a leisure trip, and weighting if the journey is done exclusively in one country or if it is international. Table 31 shows that one labour hour has more value that one hour of relaxation and international journeys are pricier that domestic dislocations. There is also a difference between the Portuguese valorisation of time with the Spanish one, Spanish inhabitants appraise their hour of leisure in more 3.71€ than Portuguese's residents. Also, in Spain one hour of labour is worth more expensive that the Portuguese, 25.91€ and 18.68€, respectively.

Type of trip	Work	Leisure	Other
International	43.93	13.16	13.40
Indoor Portugal	18.68	10.14	
Indoor Spain	25.91	13.85	

Table 31 Time value (€/hour)
Source: RAVE (2006)

Additionally, implementing this project would have consequences in the time spent in journeys made in conventional line, especially in the Setúbal peninsula that would see the time spent reduce to almost half, as it is showed in figure 13 (RAVE, 2008).

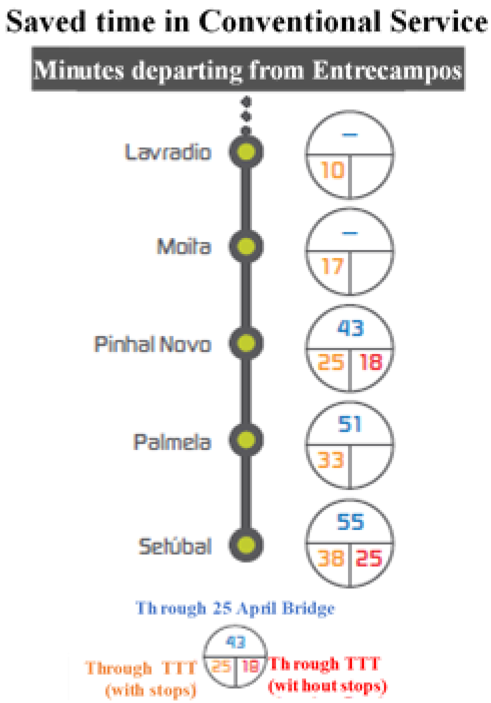

Figure 13 Saved time in Conventional Service
Source: RAVE (2008)

Although this saved time, the superstructure TTT is criticised by the enormous impact that would create in the urban network, namely, on the road system in Lavradio (Santos, 2008), especially after Barreiro underwent in urban requalification that finished in 2018, Santos (2008) also states that this structure has a negative visual impact in the sightsee of Tagus River because of its heavy-duty construction.

This is one of the reasons presented by ADFER (2019) when arguing that locating the TTT between Chelas-Barreiro is a mistake. It is also pointed that this linkage is not the cheapest option compared to the Montijo-Beato union; that constitutes an obstacle to connect the future HSR between Lisbon and Algarve and the NAL to be constructed in CTA, since it increases the railway length between Lisbon and NAL in 40%; it is the option that affects more negatively the Lisbon harbour; and, it block the railway connections to the suburbs (Montijo, Alcochete and Santa Apolónia).

It is also important to emphasize that Tagus Estuary is a Ramsar site[9] and has unique features for many crustaceans, birds, fishes, shellfishes and flora's species, therefore crossing Tagus will

[9] Ramsar site is a wetland with international significance in terms of ecologic, that is subject to intervention and has international support to preserve the habitat and use it sustainably.

have an enormous repercussion in those species due to high risk of polluting sediments and subterranean waters ADFER (2019).

18. Drawbacks

The biggest characteristic of an HSR, as the name suggests, is the speed, and it is the base for many assumptions made in the previous studies. However, this feature should not be analysed in isolation, because it might not be the most important one (Campos and de Rus, 2009). The project is subject to other factors, specially the quality level, not only in the beginning of exploration, but during all concession. Therefore, decreasing costs without having in consideration the well-been of costumers, can result in a lower quality service that would be avoided by consumers and would diminish demand and revenue (European Commission, 2018b).

For Chou et al (2011), quality is the most important indicator to quantify success, but aspects like stations' characteristics, as visual attractiveness and utility, and customer perception towards the corporate, should not be underrated due to their solid impacts in profitability and effectiveness (see Appendix 31).

Passenger perception of quality is also affected by other features, as punctuality, public transport network and/or parking zones, online and physical ticket offices, free hotspot Wi-Fi and suited buildings for reduced mobility (European Commission, 2016b).

Maintenance of infrastructures and rolling stock is a crucial part when operating the business to preserve the attractiveness of the service for the consumers (Vickerman, 1995). The absence or inadequacy in this operation can cause a strong fall in demand,

Since there were made numerous and high investments to create a solid plan and to study the viability of it as well its impacts in society and in the environment and afterwards the development was cancelled, this generate polemic in the Portuguese population that does not comprehend the term sunk costs. According to RAVE (2009c), between 2002 and 2008, it was expended 17,080 thousand euros just for studies concerning the HSR between Lisbon and Madrid.

The fact that in Portugal there will be needed to implement a PPP to originate the HSR, can cause struggles during negotiations, since the two parties have different interests with the project. The government wants to have good repercussions in political terms, create benefits for its society and obtain economic and financial positive outcomes, while private investors only have in consideration the obtainment of maximum return (Chiara et al, 2007). The contract between both sides has to be rigours and motivate private investors in satisfying the general population needs as the government would, if not, the project may be unviable for the government.

In this report is was not scrutinised what would be the synergy's impact that this project would have in IP and in ADIF's activities. Nevertheless, according to IP (2016), the HSR between the two Iberian capitals, would result in a cut of 0.17M€ per year in the Operational Expenditure of IP and 1.8M€ annually for CP.

It was highlighted in the RAVE (2006), that the transport sector is exposed to seasonality, being possible to observe a peak in transport demand during August and a decrease in the demand after the Summer "boom", as it is possible to observe in Appendix 33, this will impact the demand in the HSR and with this report it is unclear if this would create a liquidity restraint.

Other factor that was not addressed in this valuation is the effect that growing levels of insecurity towards air travels associated a terrorist acts, for example, can cause in the demand of HSR networks (Couto et al, 2012). However, the opposite can also occur and should be analysed, this is, how a higher level of mistrust in using a railway system can impact its demand level?

As emphasize throughout this study, uncertainty can have a positive side. In the future, new innovations can revolutionize the transport industry and transport services and diminish CAPEX in both sectors, what could improve the viability of this project and its attractiveness (Murto, 2007). A possible extension of this project could be to examine the impact of innovations shocks in the optimal time to invest.

19. Output's analysis

As expected, the 3 methodologies used gave different outputs.

According to the literature review, after reaching a negative value for the (static) NPV using a Discounted Cash Flows methodology, the investor should immediately reject the possibility to invest, and, since the (static) NPV obtain for this project was - 4,846.91 M€, the investor from an inflexible position should forget this plan.

However, Real Options is an important methodology to consider the "true value" considering that a business is always subjected to different factors that are outside of managers control and, also, subject to competition. The uncertainty affiliated to an HSR business is tremendous and can face large changes. Managers have the power to adapt and even take advantage of those changes and earn more than the initial forecast. These is the main motivation to perform the Black-Scholes and Merton model and a decision tree.

The flexibility value was estimated in 76,000€, using the Black-Scholes and Merton model, but this increment is not enough to make the value of the project positive. The expanded NPV, in this case, is -4,846.83M€ which means that investing, in this project, would destroy value and should not be implemented.

Although the Black-Scholes and Merton model accounts for flexibility, it has strong assumptions and restricts the way of assessing flexibility. The decision tree was elaborated to allow an analysis considering the opportunity to early exercise.

In the bottom of each node, it is the value of option if the investor decides to exercise his option in that exact moment. Consequently, the investor will only earn some profit when that value is superior to the value of investment, this is, higher than 4,988.2M€. After, verifying each node value, only 1 value is higher than the cost of investing that occur in the 27th year. Therefore, the investor should reanalyse the project near the 27th year and understand if the changes in the political, social, demographic, financial and economic environment benefited the project, since according to the decision tree, only in a rare scenario would this project be profitable.

20.Conclusion

Portugal and Spain are 2 of the intervenient of "High-speed railway axis of southwest Europe", one of the priority projects for the transport sector in EU. In this study, it has only approach one branch of the priority project, the connection between Madrid and Lisbon through a High Speed Railroad.

This path will attenuate major problems within the Iberian rail network, namely, the gauge problem that creates a bottleneck between the Iberian Peninsula and the rest of European countries. With this problem diminish, the exchanges between Portugal, Spain and the rest of Europe would help to boost both economies.

In spite of a mass number of companies applying Discount Cash Flow methodology, these methodology exhibits a big constraint: its output is a static value that does not account flexibility. In order to consider flexibility in the project value, a different methodology should be use. In this thesis, it was selected the Real Options methodology to address the problem.

To apply both methodologies it was necessary to forecast the Cash Flows throughout time.

After predicting the Cash Flows, the static NPV obtain was - 4,846.91 M€, according to the Discount Cash Flow methodology, and the investor should reject the project when consider this value.

When employed the Real Options, the value of the project increased as expected. Using the Black-Scholes and Merton model the NPV increases in 0.076M€, but it still remains negative and the project, according to this result, should not be implemented.

However, the Black-Scholes and Merton model does not allow the investor to exercise his right to exercise the option before the expiration date, that will occur in 27 years. Therefore, the decision tree was executed to represent the American option of this project, when analysing this methodology, it is observable that only in 27 years from now it is possible to obtain a profitable project, however, it is only in an extremely positive changes scenario, consequently, the investor reanalyse the project near 2046, this is 27 years from now, and adjust the plan to the fluctuations in society to see if those changes were favourable to profitability.

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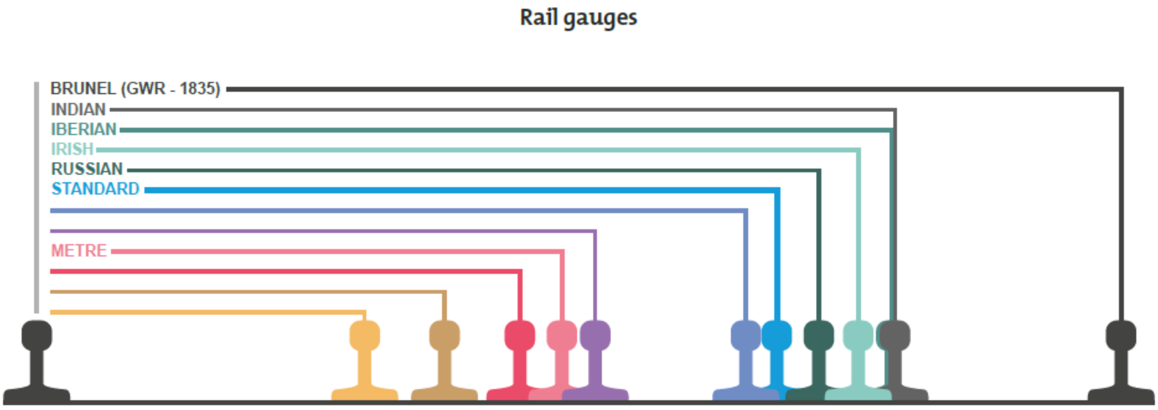
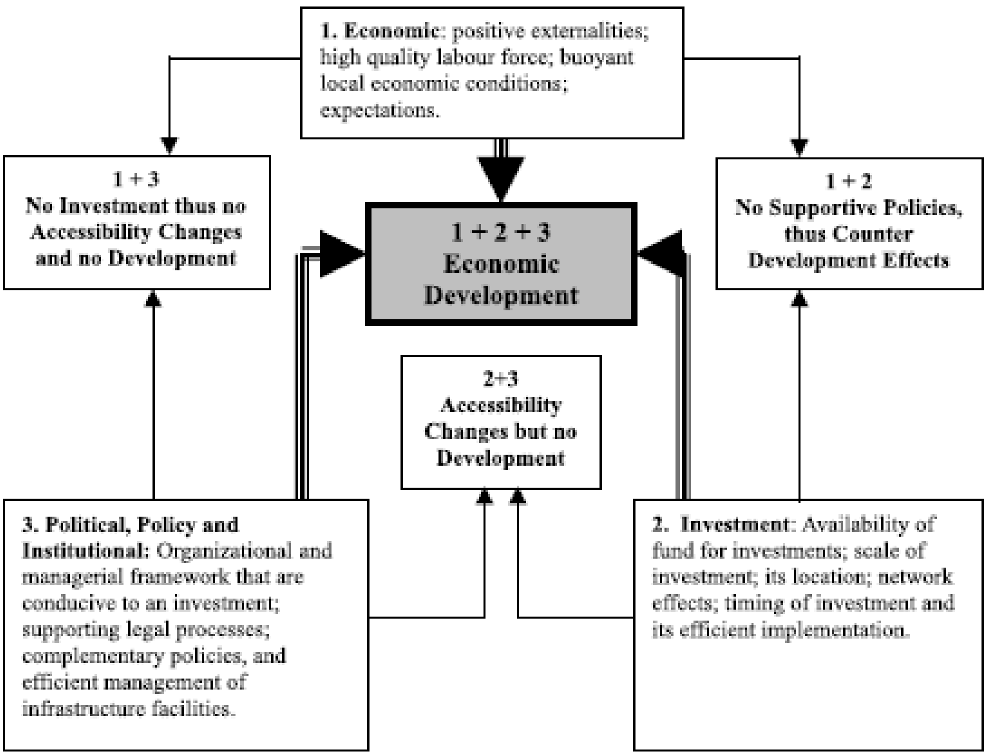
22. Appendix



Appendix 1 Existent Rail gauges



Appendix 2 The requirements for achieving economic development
Source: Figure 1 of Banister and Berechman (2001)

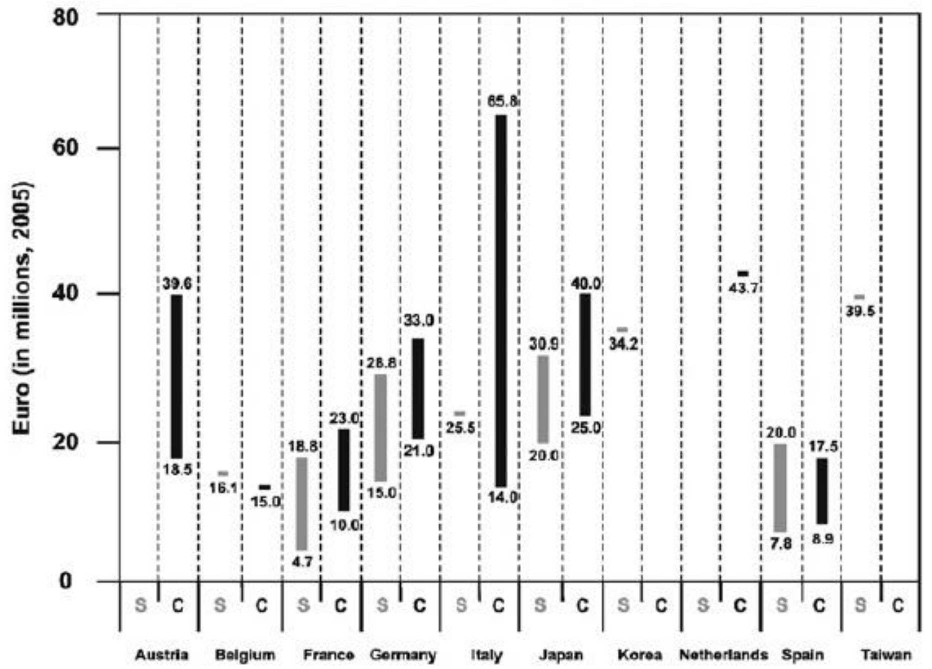


Fig. 3. Average cost per kilometer of new HSR infrastructure. *Notes*: S = Lines in Service; C = Lines under Construction (2006), *Source*: HSR Database. Elaborated from UIC (2005b). Data exclude *Planning and land costs.*

Appendix 3 Average cost per kilometer of new HSR infrastructure
Source: Figure 3 of Campos and de Rus (2009)

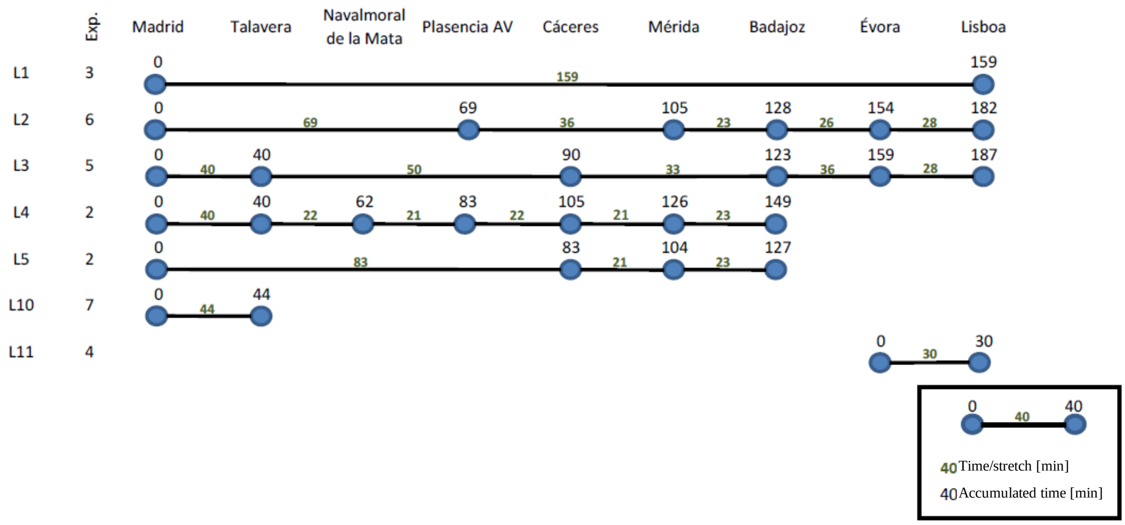
Appendix 4 Spanish geomorphology
Source: *Instituto Geográfico Nacional*
http://centrodedescargas.cnig.es/CentroDescargas/buscadorCatalogo.do?codFamilia=25VEC

	Long course Serie-102/112 Talgo-Bombardier
Maximum commercial Speed	330km/h
Maximum acceleration in curves	1,2m/s2
Lateral acceleration in curves	1,5m/s2
Traction units	2
Passengers carriage (maximum)	12
Traction	Electric
Electric supply	25kv, 50Hz
Install power	8 000kw
Bogies	Bo-Bo
Motor axles	8
Maximum weight per axis	17t
Pneumatic brake	3 disks per axis
Electric brake	Recuperation (4200kw) and rheostatic (3200kw)
Length	20m
Maximum width	2,96m
Height	4m
Direction of travel	Bidirectional ("push-pull")
Number of seats	318 (S-102) / 365 (S-112)
Manufacture	Talgo-Bombardier

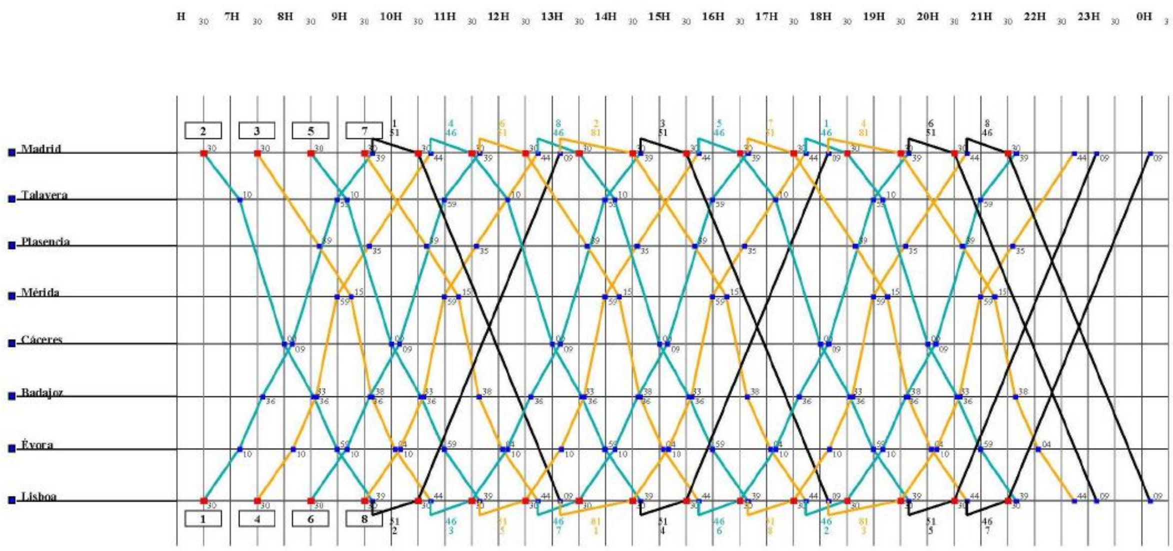
Appendix 5 Technical specifications of Serie-102/112 Talgo-Bombardier
Source: AVEP (2011)

	Shuttle Serie-104 CAF-Alstom
Length of ending carriage	27,350mm
Length of middle carriage	25,780mm
Distance between end of bogie	19,000mm
Connecting doors	800mm
Doors per side	2 (bar-cafeteria 1)
Maximum width	2,880mm
Waistline external width	2,920mm
Maximum height	4,100mm
Floor height on the rail	1,250mm
Train weight	256t
Maximum cargo per axis	17t
Full power in wheel	4,000kW
Nominal power	3,750kW
Power voltage	25kV 50Ht ca
Gauge	1,435mm
Motors	three-phase asynchronous (8)
Commercial Speed	250km/h
Maximum Speed	270km/h
Acceleration from 0 to 100km/h	0,72m/sg2
Average residual acceleration to maximum speed	9,5m/sg2 236
Average deceleration at 120km/h	0,4m/s2
Average deceleration at 250km/h	0,5m/s2
Seats	237
Manufacturer	CAF and Alstom

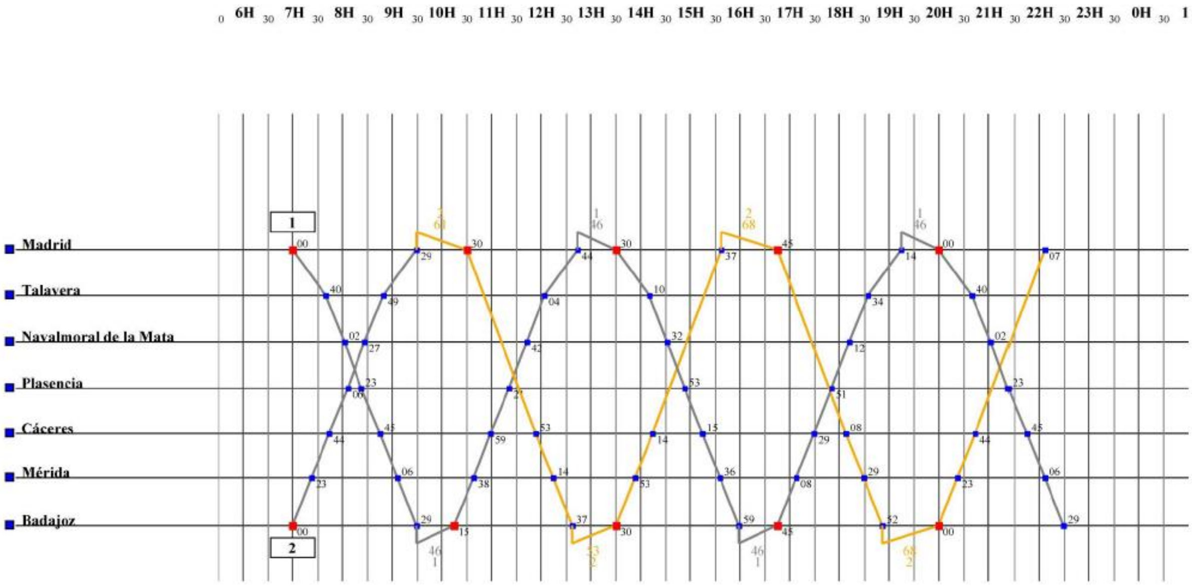
Appendix 6 Technical specifications of Serie-104 CAF-Alstom
Source: AVEP (2011)



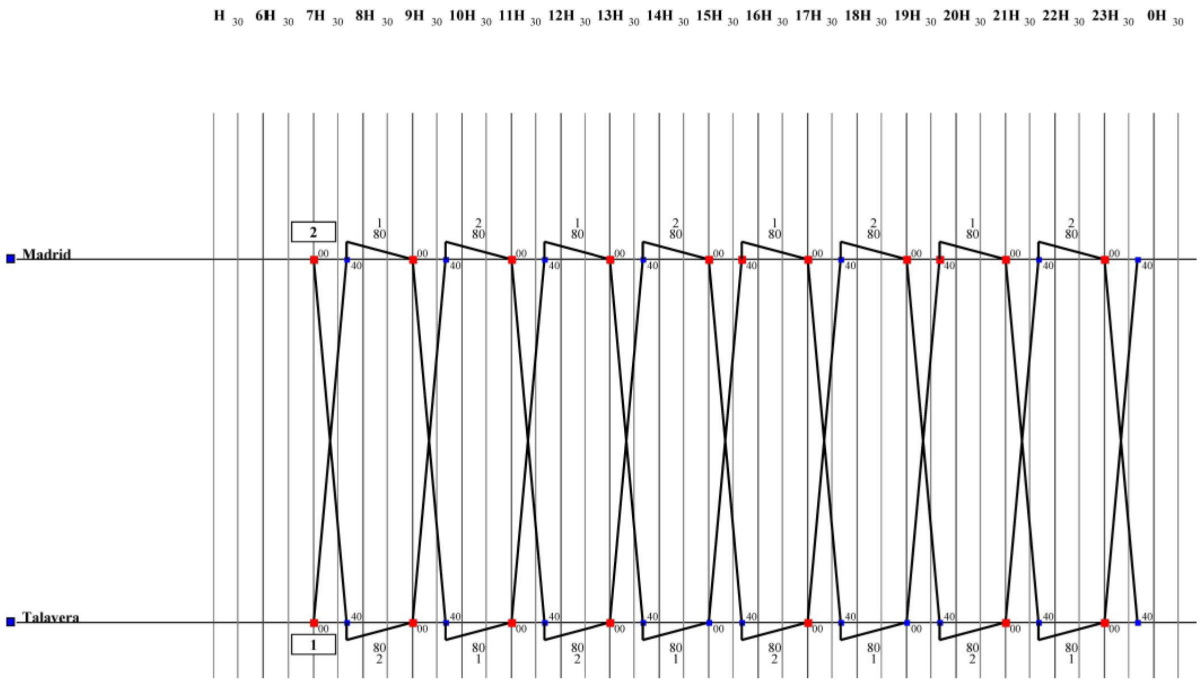
Appendix 7 Service scheme in 2020
Source: Figure 10-3 of AVEP (2011)



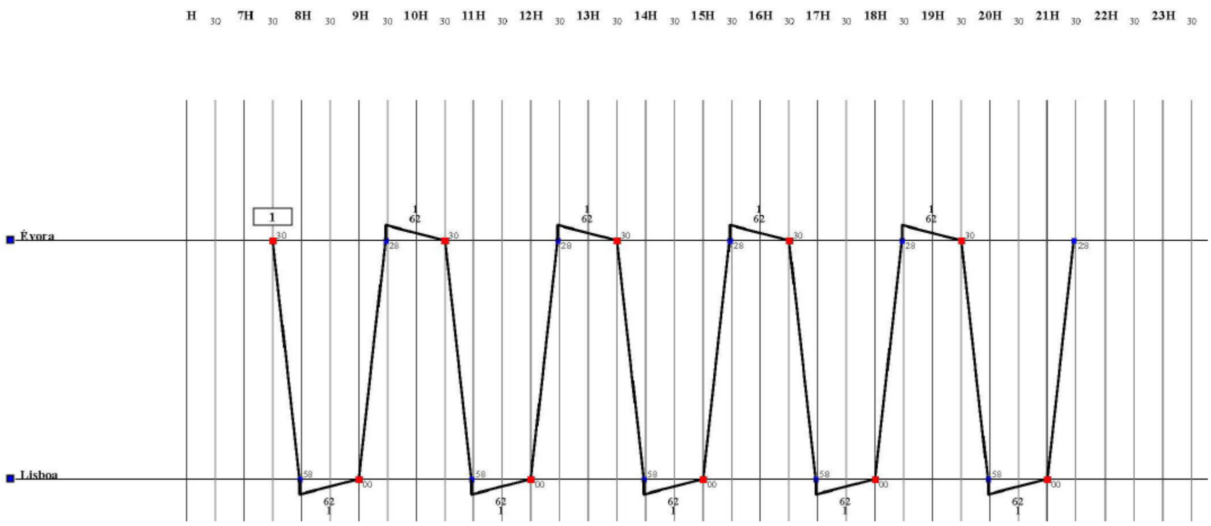
Appendix 8 Service schedule between Madrid and Lisbon (with and without stops) in 2020
Source: Figure 12-17 of AVEP (2011)



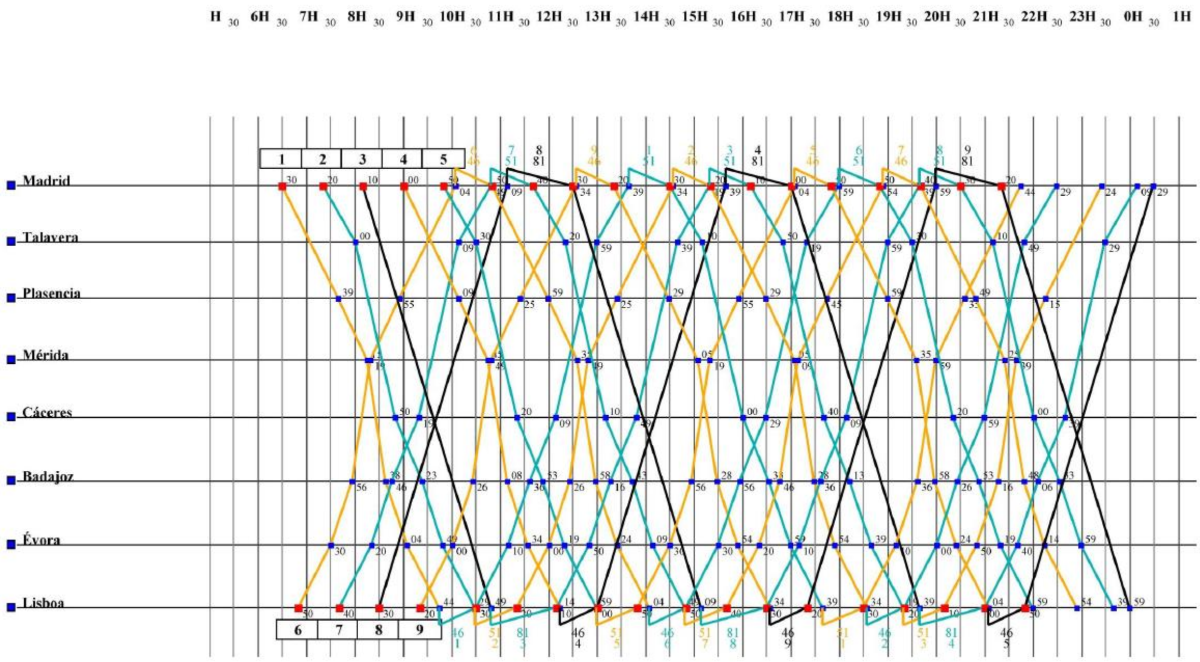
Appendix 9 Service Schedule between Madrid and Badajoz in 2020
Source: Figure 12-18 of AVEP (2011)



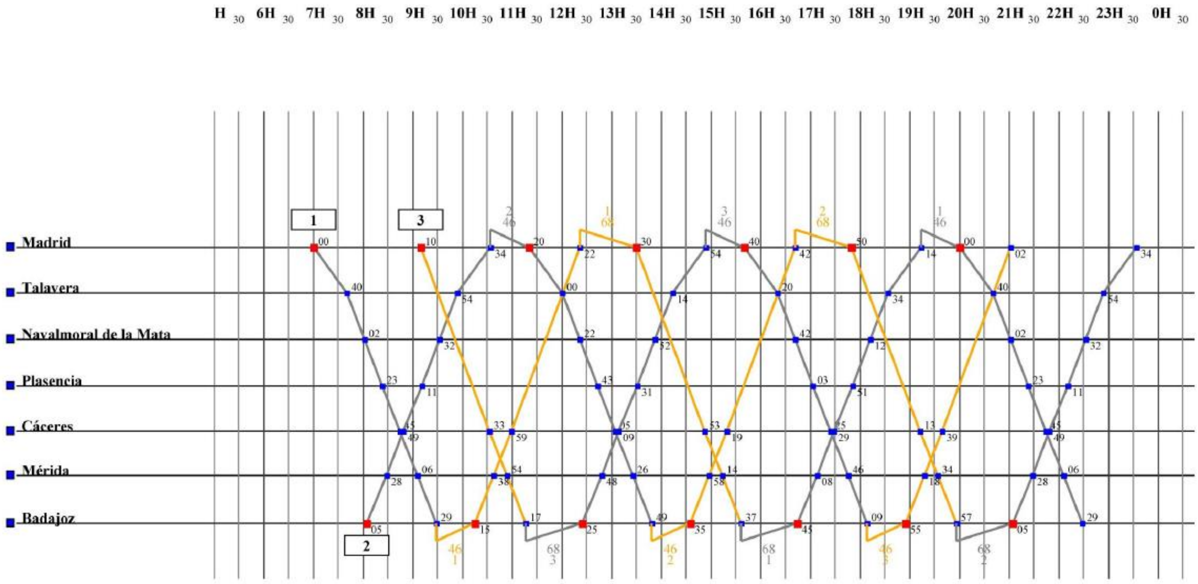
Appendix 10 Service Schedule between Madrid and Talavera in 2020
Source: Figure 12-19 of AVEP (2011)



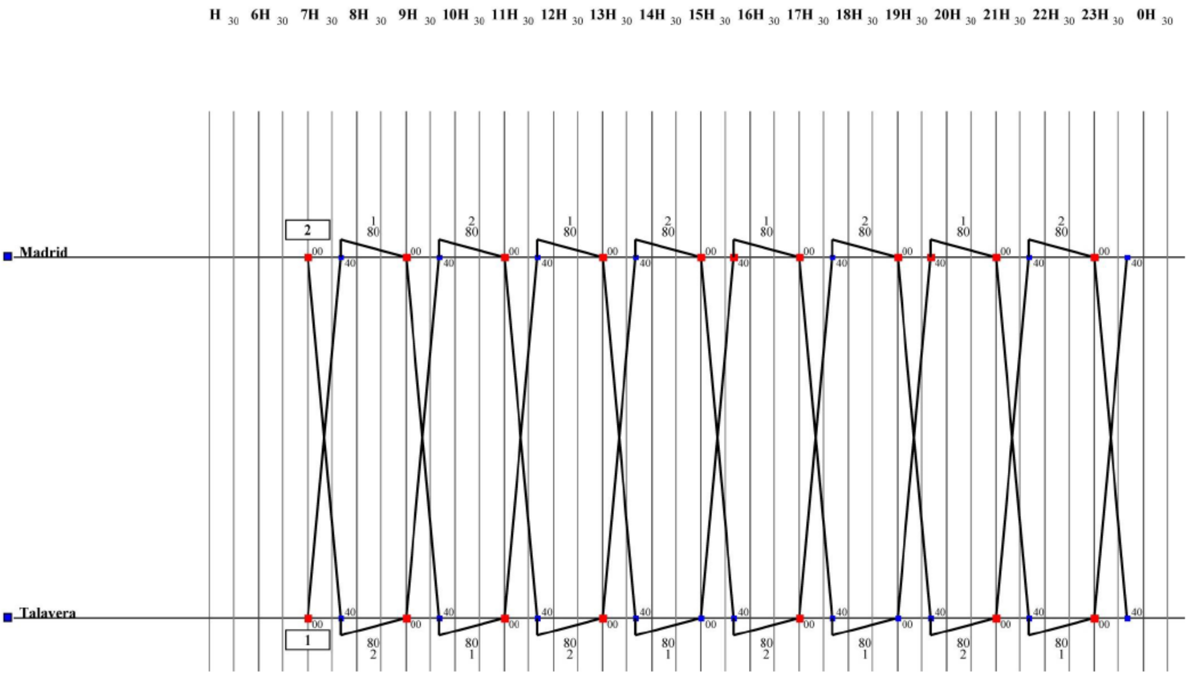
Appendix 11 Service Schedule between Lisbon and Évora in 2020
Source: Figure 12-20 of AVEP (2011)



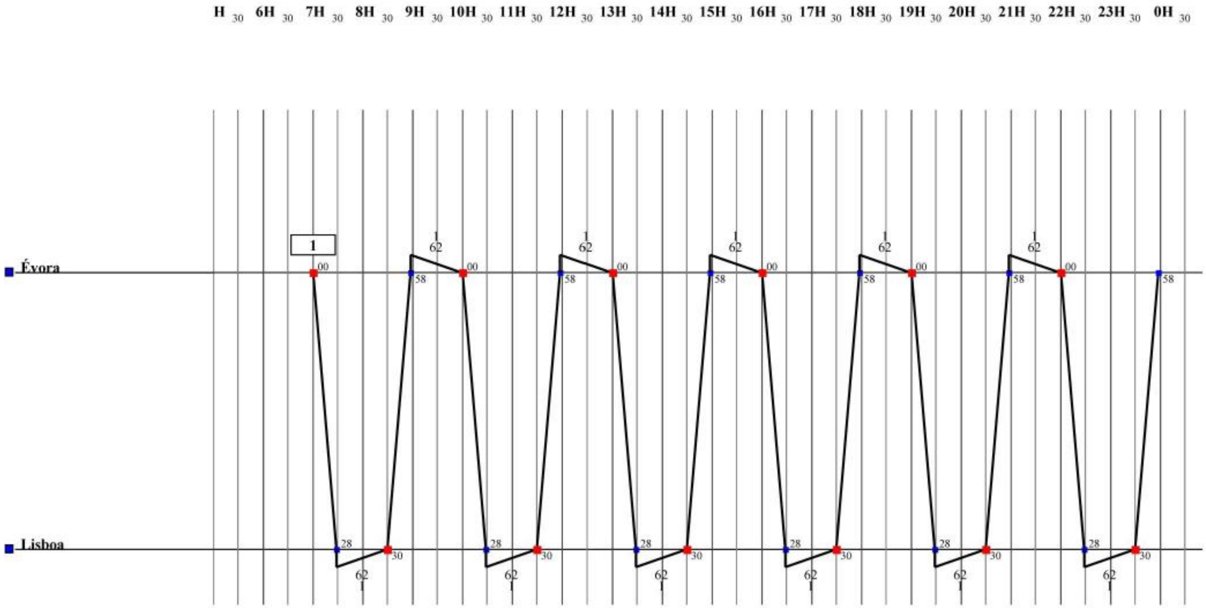
Appendix 12 Service schedule between Madrid and Lisbon (with and without stops) in 2025
Source: Figure 12-28 of AVEP (2011)



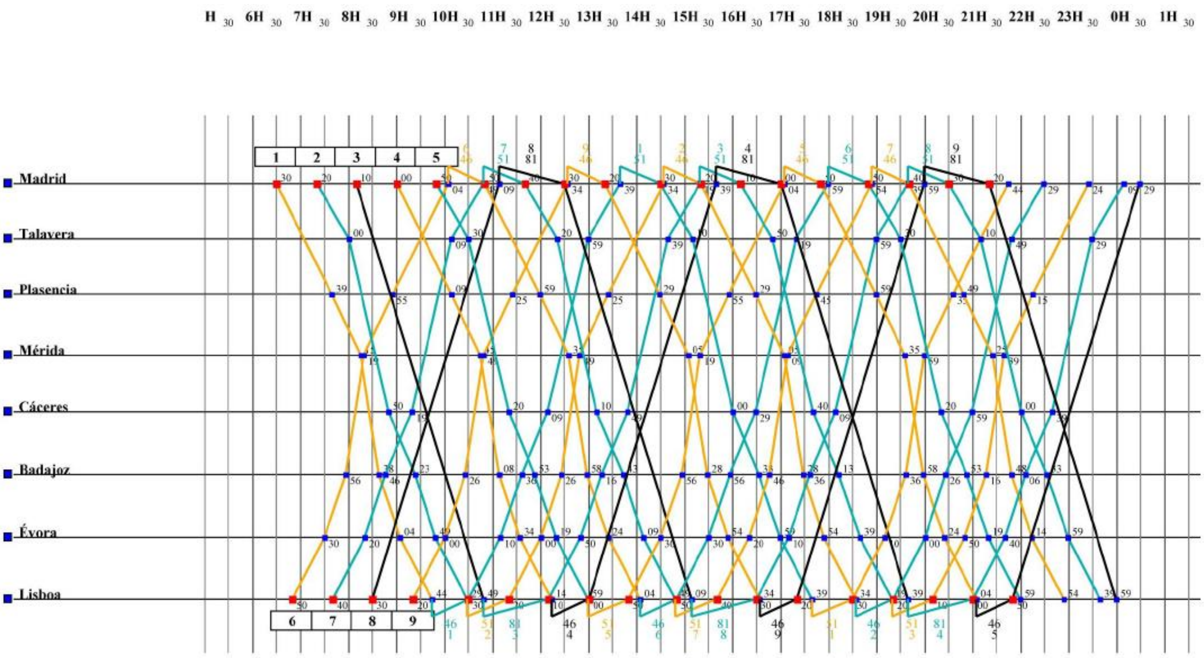
Appendix 13 Service schedule between Madrid and Badajoz in 2025
Source: Figure 12-29 of AVEP (2011)



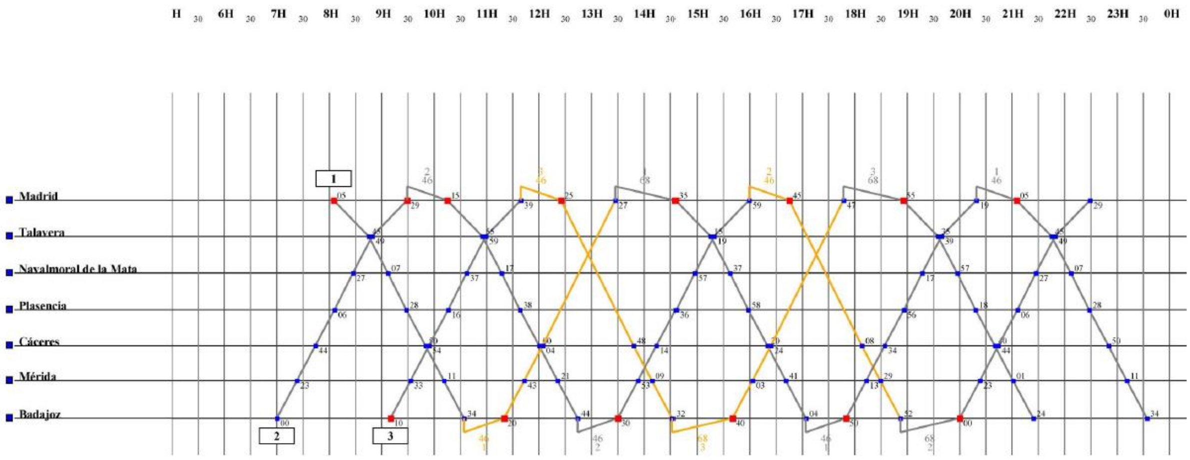
Appendix 14 Service schedule between Madrid and Talavera in 2025
Source: Figure 12-30 of AVEP (2011)



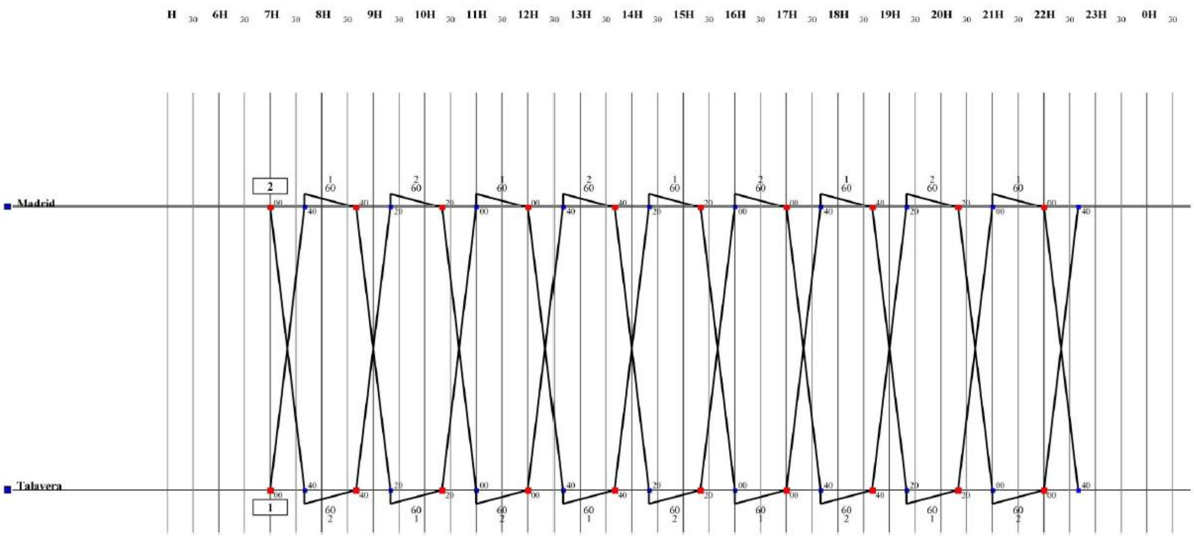
Appendix 15 Service schedule between Lisbon and Évora in 2025
Source: Figure 12-31 of AVEP (2011)



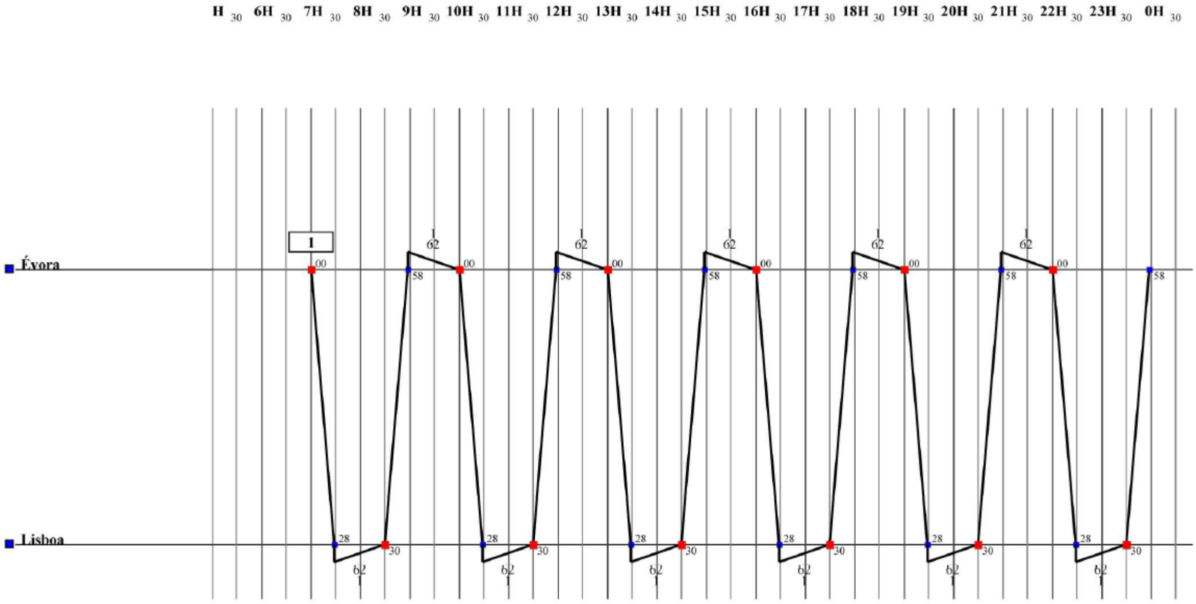
Appendix 16 Service schedule between Lisbon and Madrid (with and without stops) in 2030
Source: Figure 12-39 of AVEP (2011)



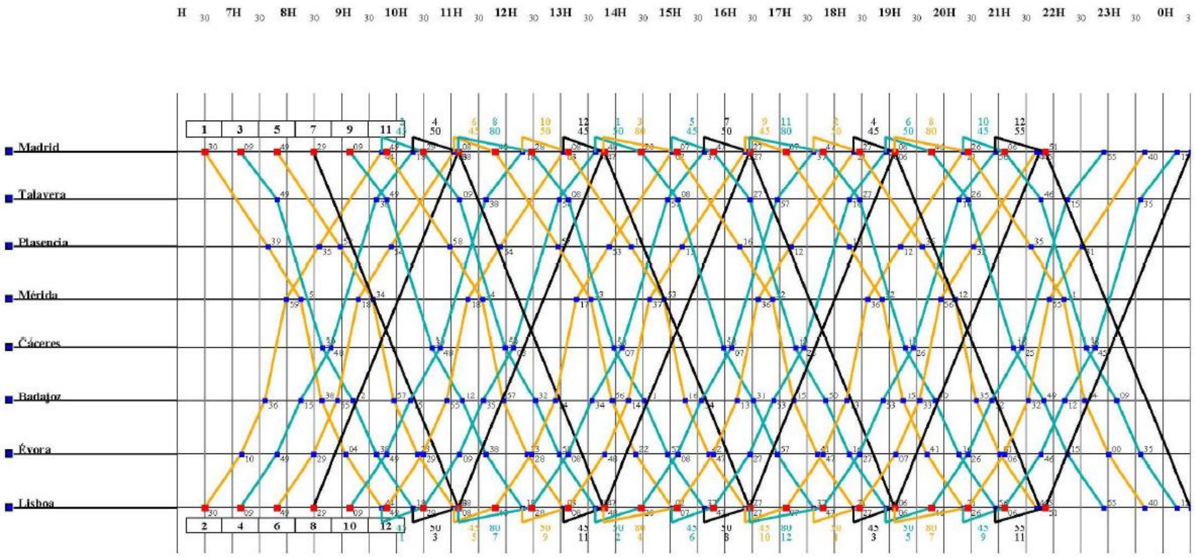
Appendix 17 Service schedule between Madrid and Badajoz in 2030
Source: Figure 12-40 of AVEP (2011)



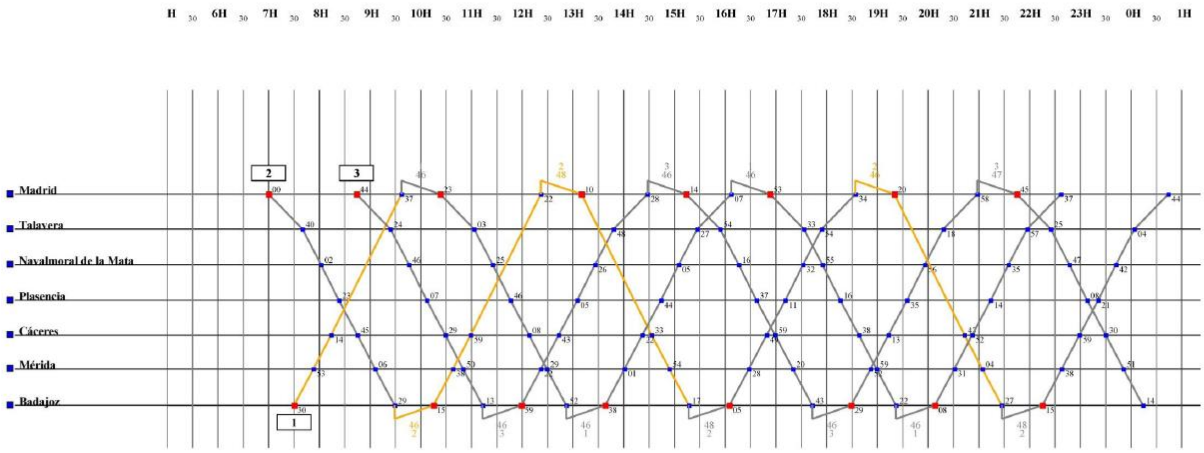
Appendix 18 Service schedule between Madrid and Talavera in 2030
Source: Figure 12-41 of AVEP (2011)



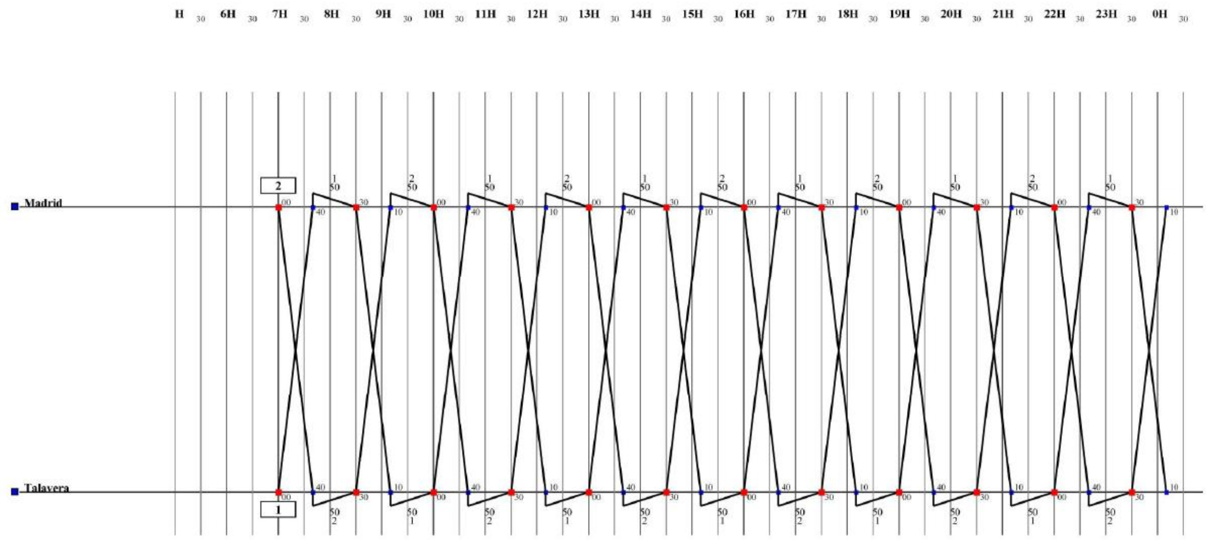
Appendix 19 Service schedule between Lisbon and Évora in 2030
Source: Figure 12-41 of AVEP (2011)



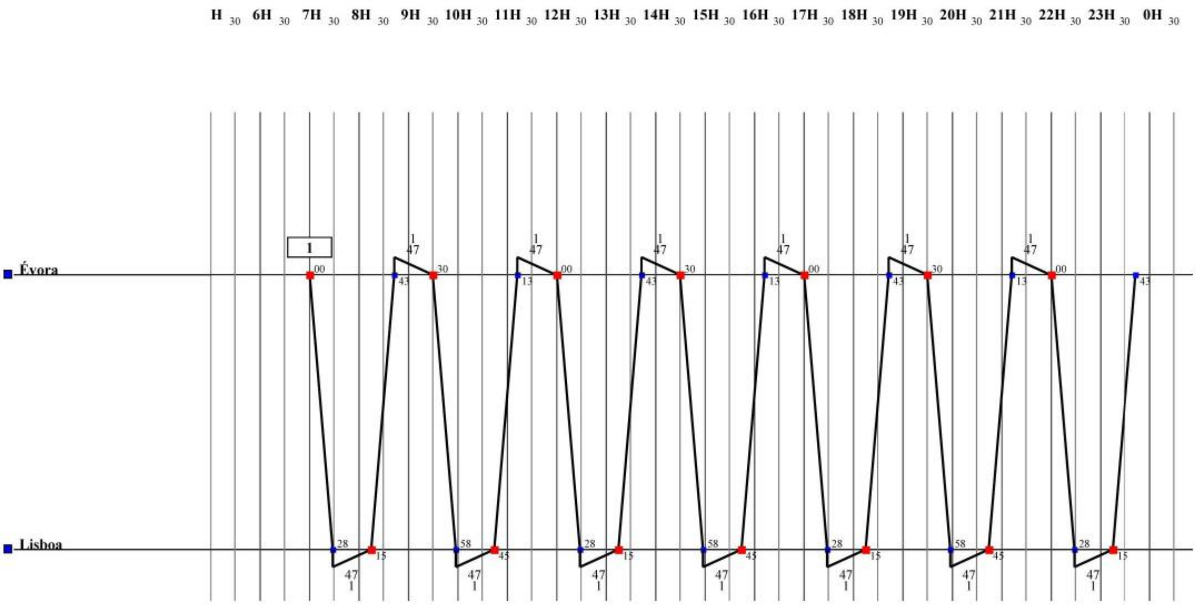
Appendix 20 Service schedule between Madrid and Lisbon (with and without stop) in 2045
Source: Figure 12-50 of AVEP (2011)



Appendix 21 Service schedule between Madrid and Badajoz in 2045
Source: Figure 12-51 of AVEP (2011)



Appendix 22 Service schedule between Madrid and Talavera in 2045
Source: Figure 12-52 of AVEP (2011)



Appendix 23 Service schedule between Lisbon and Évora in 2045
Source: Figure 12-53 of AVEP (2011)

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
PT	273,223.22	278,172.9	280,305.9	284,659.2	291,752.9	292,334.3	283,628.2
ES	1,319,389.15	136,1169	1,411,847	1,470,780	1,526,213	1,543,270	1,488,119
PT+ES	1,592,612.36	1,639,342	1,692,153	1,755,439	1,817,966	1,835,604	1,771,747
%PT+ES		2.93%	3.22%	3.74%	3.56%	0.97%	-3.48%
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
PT	289,013.5	283,733.6	272,304.1	269,226.6	271,631.3	276,580.6	281,059.6
ES	1,488,328	1,473,463	1,430,324	1,405,927	1,425,328	1,474,249	1,522,523
PT+ES	1,777,341	1,757,197	1,702,628	1,675,153	1696960	1,750,830	1,803,583
%PT+ES	0.32%	-1.13%	-3.11%	-1.61%	1.30%	3.17%	3.01%
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
PT	288,566.8	294,778.4	301,275.1	307,469	313,015	317,958.8	322,590.2
ES	1,568,988	1,613,018	1.651,137	1,671,748	1,688,704	1,705,933	1724619
PT+ES	1,857,554	1,907,796	1,952,412	1,979,217	2,001,719	2,023,892	2047209
%PT+ES	2.99%	2.70%	2.34%	1.37%	1.14%	1.11%	1.15%
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
PT	327,167	331,797.9	336,490.7	341,242.1	346,052	350,916.6	355,822.8
ES	1,744,982	1,766,838	1,789,912	1,813,963	1,838,758	1,864,064	1,889,672
PT+ES	2,072,149	2,098,636	2,126,403	2,155,205	2,184,810	2,214,981	2,245,495
%PT+ES	1.22%	1.28%	1.32%	1.35%	1.37%	1.38%	1.38%
	2031	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
PT	360,757.1	365,674.3	370,569.6	375,447.1	380,311.2	385,167.8	390,017.5
ES	1,915,409	1,941,124	1,966,673	1,991,943	2,016,873	2,041,469	2,065,619
PT+ES	2,276,166	2,306,798	2,337,243	2,367,390	2,397,184	2,426,637	2,455,637
%PT+ES	1.37%	1.35%	1.32%	1.29%	1.26%	1.23%	1.20%
	2038	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**
PT	394,867.4	399,737.7	404,650.6	409,628.9	414,690.4	419,850.7	425,129.4
ES	2,089,457	2,113,190	2,137,078	2,161,398	2,186,416	2,212,411	2,239,692
PT+ES	2,484,324	2,512,928	2,541,729	2,571,027	2,601,106	2,632,262	2,664,821
%PT+ES	1.17%	1.15%	1.15%	1.15%	1.17%	1.20%	1.24%
	2045	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**
PT	430,539	436,088	441,783.2	447,634.4	453,657.4	459,868.1	466,287.4
ES	2,268,577	2,299,357	2,332,210	2,367,247	2,404,570	2,444,307	2,486,596
PT+ES	2,699,116	2,735,445	2,773,993	2,814,881	2,858,227	2,904,175	2,952,883
%PT+ES	1.29%	1.35%	1.41%	1.47%	1.54%	1.61%	1.68%
	2052	**2053**	**2054**	**2055**	**2056**	**2057**	**2058**
PT	472,899.6	479,731	486,806	494,137.1	501,726.3	509,570.9	517,662.9
ES	2,531,495	2,579,034	2,629,258	2,682,243	2,738,065	2,796,682	2,857,983
PT+ES	3,004,395	3,058,765	3,116,064	3,176,380	3,239,791	3,306,253	3,375,646
%PT+ES	1.74%	1.81%	1.87%	1.94%	2.00%	2.05%	2.10%
	2059	**2060**	**2061**	**2062**	**2063**	**2064**	
PT	525,993.9	534,555.4					
ES	2,921,850	2,988,225					
PT+ES	3,447,844	3,522,780					
%PT+ES	2.14%	2.17%	2.26%	2.32%	2.37%	2.42%	

Appendix 24 Real GDP long-term forecast (Million US dollars)
Source: Author
Data source: OECD (2019)

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Rail freight transport from Portugal (tkm, Millions)								
To Spain	458	260	233	238	132	39	175	295
Rail freight transport from Spain (tkm, Millions)								
To Denmark	1	2	1	2	1	:	1	1
To Germany	202	180	191	191	181	160	151	148
To France	297	238	258	:	:	82	35	66
To Portugal	201	142	143	134	76	53	65	79
To Sweden	1	1	2	3	5	12	15	
To United Kingdom	:	35	50	46	32	22	6	63
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
Rail freight transport from Portugal (tkm, Millions)								
To Spain	271	304	379	445	423	346	330	
Rail freight transport from Spain (tkm, Millions)								
To Denmark	1	1	2	3	5	6	6	
To Germany	187	162	173	192	182	193		
To France	112	192	151	187	105	99	121	
To Portugal	286	351	399	395	404	419	405	
To Sweden	8	6	6	8	9	11	7	
To United Kingdom	47	26	31	30	15	20	22	

Appendix 25 International rail freight transport of Portugal and Spain (in millions tkm)
Source: Eurostat (2019)

Table A.22: Spain: ticket types

As listed	Meaning	Conditions
Ida y vuelta	Return	Available for AVE, long-distance, Avant and medium distance conventional services
Niños	Children	40% discount for children under 14 who occupy a seat 100% discount for children under 4 who do not occupy a seat 100% discount for up to two children, who do not occupy seats, under six (on Cercanías services) or four (on Rodalies services in Barcelona)
Compra Múltiple	Multiple purchase	20% discount on three journeys completing a circuit back to the starting point
Billete Promo		For AVE and long-distance trains, dynamically priced with discounts of up to 70%
Billete Promo+		For AVE and long-distance trains, dynamically priced with discounts of up to 65%
Billete Flexible		The same price as the General/Base tariff, but with better conditions regarding changes and cancellations
Tarifa 4 Mesa		For AVE and long-distance trains, up to four people seated around a table, at 60% of the cost of four seats, only available on suitable trains and cannot be combined with other offers
Combinado Tren+Autobús	Combined train and bus	Combines a rail ticket with a ticket on one of five interurban bus operators to provide connections beyond the rail network
Turista Plus		For some AVE and long-distance trains, a 20% discount on Turista class, which can be combined with any tariff
BonoAVE		For all AVE and some long-distance trains, a non-transferrable ("nominative") ticket giving a 35% discount on the General/Base fare for ten round trips between named stations
BonoAVE Flexible		For all AVE and some long-distance trains, a non-transferrable ("nominative") ticket for ten round trips anywhere on the trains covered, for €725 (Turista) and €1,200 (Preferente), for travel to be completed within four months
BonoAVE Colaborativo		For all AVE and some long-distance trains, a non-transferable ticket for four named people for eight round trips between named stations
Abono Plus (Avant)		For 30 or 50 journeys, to be completed within a 30-day period within six months of purchase
Abonos Mensuales	Monthly tickets	Non-transferrable ticket for travel between two name stations, with up to two journeys per day on Rodalies services in Barcelona or unlimited travel elsewhere, some variation between regions
Tarjeta Plus 10		On Avant trains, a non-transferrable ticket for ten single journeys to be completed in eight days within two months of purchase
Tarjeta Plus 10 Estudiantes		On Avant trains, a non-transferrable ticket for ten single journeys to be completed in ten days within two months of purchase, for holders of a student card
Tarjeta Dorada	Over-60, disabled and disabled companion card	For AVE and long-distance trains, a €6 annual card for passengers aged over 60 or disabled passengers over 18 entitling them to a 25% discount Friday to Sunday and a 40% discount Monday to Thursday: those over 65% disabled can also take a companion

Appendix 26 Discount fares in Spanish railways
Source: European Commission (2016)

As listed	Meaning	Conditions
Tarjeta +Renfe Joven 50		Non-transferrable €50 card for those aged 14-25 (inclusive) with discounts on AVE and long-distance (50% if booked over 30 days ahead, 40% if booked over 15 days ahead, or 30%), 25% on suburban (Cercanías or Rodalies), medium distance and Avant
Carné Joven	Youth carnet	For AVE, long-distance and medium-distance trains, for those aged 14-25 (inclusive), issued by a local administration, giving a 20% discount on any train and class: for Avant trains, equivalent discounts are also offered to holders of various youth cards issued in other countries
Familia Numerosa	Large family	For families with documents issued by the competent authority, on any fare, a discount of 20% for members of the Familia Numerosa and 50% for members of the Familia Numerosa Especial
Grupos - Descuentos	Group discounts	For AVE and long-distance trains, for groups from 10 to 25, 20% off the General fare and 30% off return tickets For medium-distance conventional trains, for groups of 10 or more, 20% off the General fare and 40% for children under 14 (or 40% for adults and 50% for children from schools, associations and cultural organisations) and free for children under 4 For Avant trains, for groups from 10 to 25, and by application for groups over 25, 15% off the General fare For charter trains, as agreed in the charter contract For Cercanías and FEVE (narrow gauge lines), discounts on the General fare of 30%, 40% for return tickets and 50% for children under 12, with additional discounts in specific local marketing campaigns Different rules apply in the Cercanías of Madrid, Murcia/Alicante and Valencia None of the group discounts can be combined with any other discount
Congresos y Eventos	Conferences and events	Discounts on all trains for a minimum of 75 people assisting an event, applied for 30 days in advance, valid from two days before to two days after the event
Renfe Spain Pass		Valid only for non-residents of Spain, and requires a passport, for 4, 6, 8, 10 or 12 journeys in Turista or Club class completed in a month within six months of purchase

Source: Renfe website, interpreted by Steer Davies Gleave, conditions have been translated and summarised.

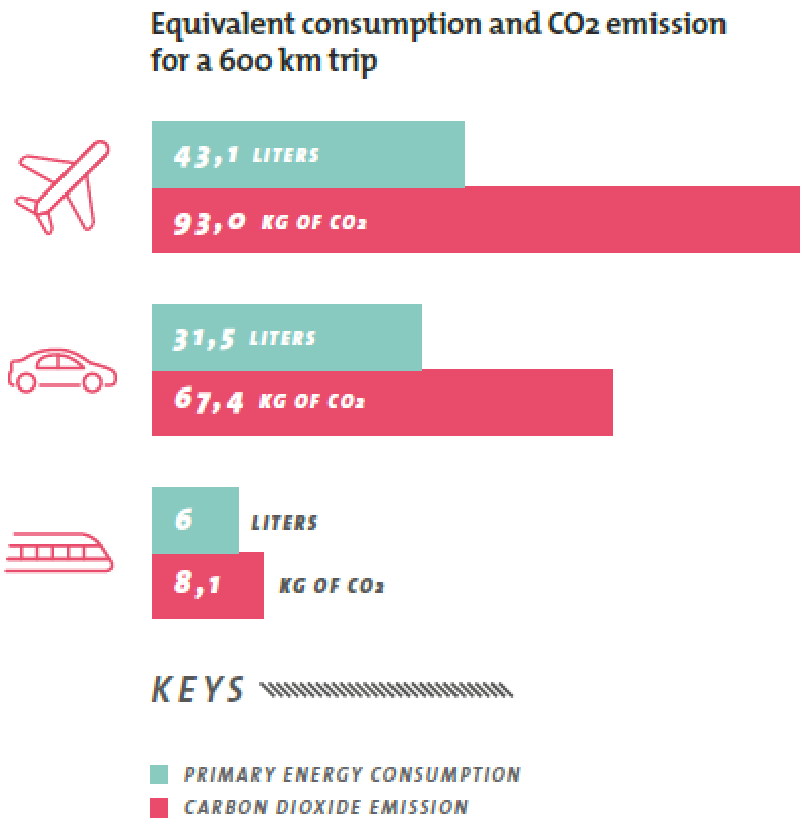
Appendix 27 Discount fares in Spanish railways (continuation)
Source: European Commission (2016)

	Km/year			Fuel saved/year	
	Without HSR	**With HSR**	**Δ**	**Gasoline**	**Diesel**
Lisbon-Madrid	721,870,343	613,358,578	108,511,765	2,844,558	3,826,900

Appendix 28 Private vehicle fuel consumption in 2030
Source: RAVE (2006)

Pollutant	Road (Tons)		HSR (tons)	Road + HSR (Ton)		Δ	
	Without HSR	With HSR		Without HSR	With HSR	Absolute	%
CO	709	615	0	709	615	-95	-13,4
VOC	70	60	0	70	60	-10	-14,8
NO_x	631	539	27	631	567	-64	-10,2
SO_2	0	0	38	0	38	+38	
Particles	53	46	3	53	49	-4	-8,4
CO_2	144,043	123,225	35,130	144,043	158,355	+14,312	+9,9
Cost (€millions)	47,0	40,0	6,1	47,0	46,0	-1,0	-2,1

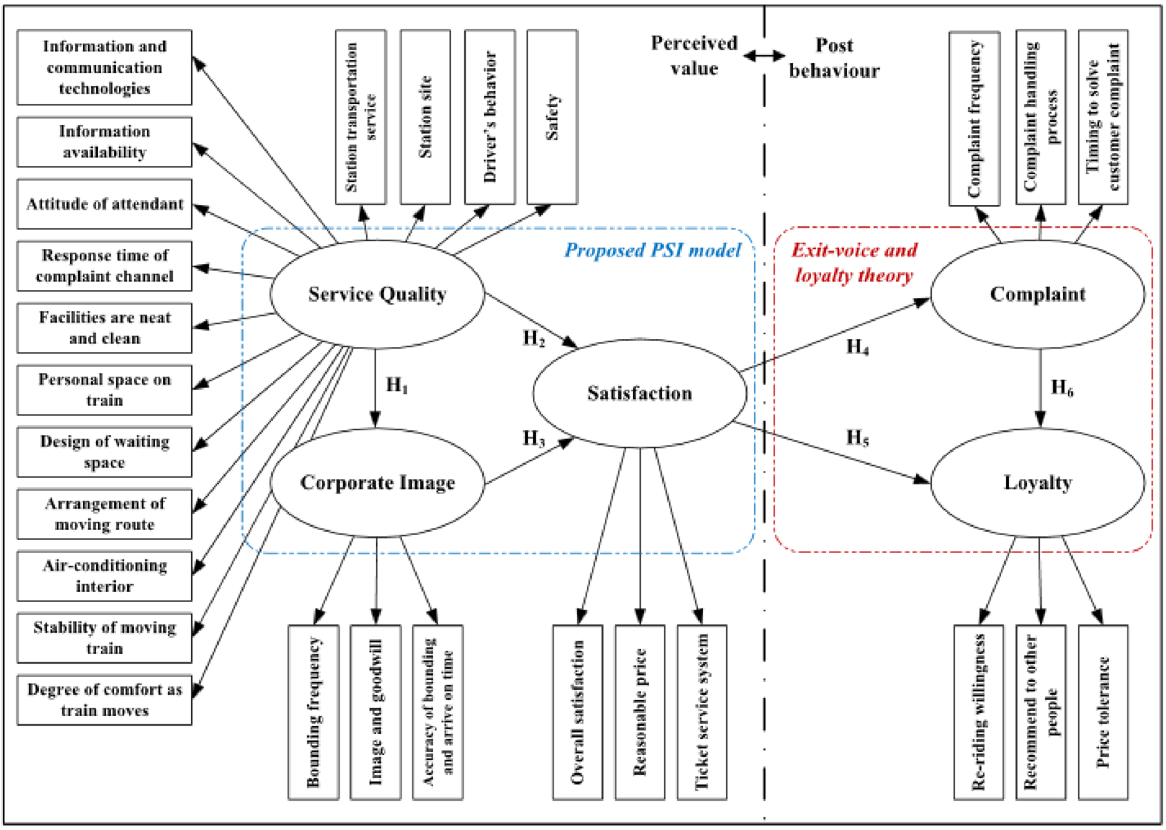
Appendix 29 Air pollution in 2030: Lisbon-Madrid line
Source: RAVE (2006)



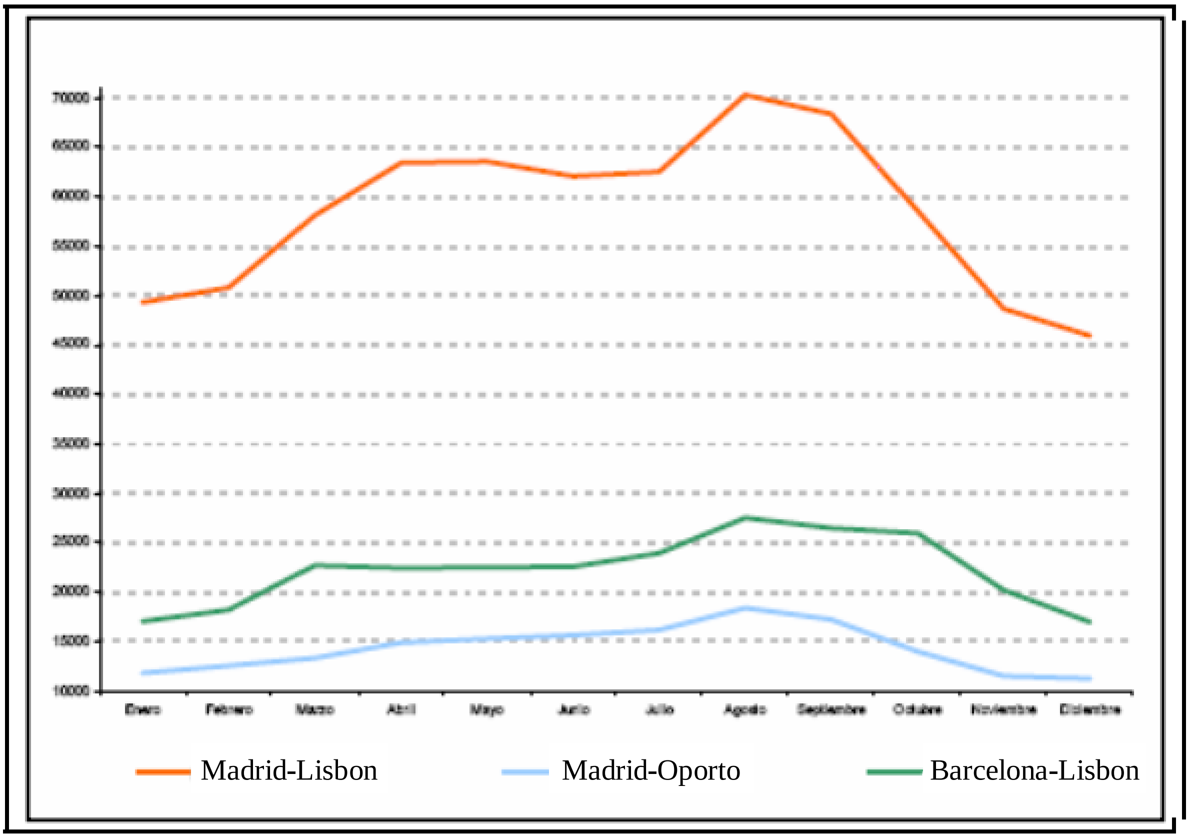
Appendix 30 Equivalent consumption and CO_2 emission for a 600km trip
Source: UIC (2018)

		Without HSR	With HSR	Avoid victims	%
2030	Deaths	6	5	1	16,7
	Severe injures	36	30	6	16,7
	Slightly injures	158	135	23	14,6
	Total victims	200	170	30	15,0
	Accidents costs (€ millions)	9,17	7,67	1,51	16,4

Appendix 31 Road accidents: Lisbon-Madrid line in 2030
Source: RAVE (2006)



Appendix 32 Perceived value (PSI), post-behavior model, and research hypotheses
Source: Chou et al, 2011



Appendix 33 Seasonality of passenger traffic Lisbon/Oporto-Madrid and Lisbon-Barcelona
Source: Figure 2.30 of RAVE (2006)