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# Critical Success Factors Identified in High-Speed Railway Infrastructure: Public-Private Partnerships in Portugal and the Netherlands

## Fatores Críticos de Sucesso Identificados em Infraestruturas Ferroviárias de Alta Velocidade: Parceiras Público-Privadas em Portugal e nos Países Baixos

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### Abstract

The purpose of this research is to develop a list of recommendations and good practices that allow governments, private investors, and railway stakeholders to make better and more efficient decisions with respect to the implementation of new high-speed rail lines contracted by public-private partnerships. The research method in this work is based on exploratory and collective case studies and the identification of critical success factors. Consequently, this work analyses the high-speed line connecting Amsterdam with the Belgian border and the Lisbon-Poceirão-Caia section. This study has enabled us to draw up a list of recommendations and good practices. Cross-border cooperation for international sections, singles contracts for substructure and superstructure and an independent contract for signalling and communication systems.

*Keywords:* critical success factor (CSF); public-private partnership (PPP); high-speed railway; high-speed line (HSL); high-speed train (HST).

*JEL codes:* G38; H54; H76; R40; R42.

### Resumo

O objeto desta investigação é desenvolver uma lista de recomendações e boas práticas que permita a governos, investidores privados e partes interessadas ferroviárias que tomem melhores decisões e mais eficientes na implementação de novas linhas ferroviárias de alta velocidade contratadas através de parceiras público-privadas. A metodologia de investigação baseia-se em estudos de caso exploratórios e coletivos e na identificação de fatores críticos de sucesso. Assim, esta investigação analisou a linha de alta velocidade que liga Amesterdão à fronteira com a Bélgica e o troço Lisboa-Poceirão-Caia. Este artigo permitiu desenvolver a seguinte lista de recomendações e boas práticas. Cooperação transfronteiriça para os troços internacionais, um único contrato para a subestrutura e para a superestrutura, um contrato independente para os sistemas de sinalização e comunicações.

*Palavras-chave:* fator crítico de sucesso (FCS); parceria público-privada (PPP); ferrovia de alta velocidade; linha de alta velocidade (LAV); trem de alta velocidade (TAV).

*Códigos JEL:* G38; H54; H76; R40; R42.

## 1. INTRODUCTION

Exclusively public railway managers and operators, an absence of cost-reducing competition, and a lack of private investment are the historical factors that have prevented railway transport being as efficient as it might (European Parliament, 2016). The European Union initiated railway transport liberalisation in 2006 with international freight transport, in 2007 with domestic freight transport, continuing in 2010 with international passenger transport, and finally including domestic passenger services on the 14th December, 2020 (Diario Oficial de la Unión Europea, 2004b, 2007, 2016). These measures are the initial steps towards an efficient railway system in Europe.

The most efficient railway transport management and development can be obtained through public–private partnership (PPP) contracts. PPPs entail reduced public financing, mobilise private investment, and grant access to private-sector advantages including skilled project management and innovation. Public services such as road transport have implemented this partnership successfully, but it is not a common model in high-speed railway transport. A limited number of high-speed railway lines have been constructed using PPP contracts. Even so, in many of these cases, the result has not been optimal. The following situations illustrate this (European PPP Expertise Centre 2020; World Bank, 2017, 2020).

Since 2007, a high-speed railway line has connected the Channel Tunnel with London. Formerly known as the Channel Tunnel Rail Link, this line is currently called High Speed 1. The PPP contract had to be restructured during the construction period due to two obstacles: difficulties in obtaining private financing and the British Government's opposition to augmenting the direct grants. High Speed 1's income was generated by the track access payments of Eurostar, the international railway enterprise that operates the passenger rail services between France and the United Kingdom through the Channel Tunnel. The concession contract included the purchase of the British public participation in Eurostar. Nevertheless, the Eurostar services were merely a third of what was forecast, and the concessionaire had to sell its participation in Eurostar (Butcher, 2011; National Audit Office, 2001, 2005, 2012, 2015).

Since 2010, a cross-border high-speed line has connected the towns of Figueras (Spain) and Perpignan (France) through the Pyrenees. The PPP contract was awarded to the company TP Ferro. The Figueras-Perpignan line should receive traffic from the Spanish Barcelona-Figueras high-speed line. However, when the cross-border line was ready to begin operation, the Barcelona-Figueras line was still under construction and the Figueras-Perpignan line had no rail traffic. The concession period was extended to solve this issue, but ultimately, the PPP contract was terminated early. Currently, the Spanish and French national railway managers are operating this Spanish-French international section (Boletín Oficial del Estado, 2004, 2016; Eiffage 2013; Ministerio de Fomento, 2009, 2011; Sanz Gandásegui, 2005; Secretario de Estado de Relaciones con las Cortes, 2015).

These experiences reveal the need for an in-depth study of why high-speed railway PPP contracts fail, so that such failures can be avoided. In both cases cited, the failures proceeded from the decisions of public authorities and private investors. Hence, this article examines two high-speed railway lines, one Dutch and one Portuguese, both of which were designed through PPP contracts. These high-speed rail lines allowed both Portugal and the Netherlands to not only connect their capital with that of the neighbouring country, but also the European high-speed rail network. Notably, the Portuguese government used the Dutch experience as a reference, implementing improvements to create its own PPP model (Tribunal do Contas, 2014). The first case study focuses on the Dutch line, the HSL-Zuid high-speed line. This 100 km line was completed in 2007 and connects Amsterdam with the Belgian border. Due to rolling stock and signalling problems, the Dutch HSL-Zuid high-speed line suffered a significant delay in its ability to begin commercial services (Geluk, 2007; Omega Centre, 2011; Railway Gazette International, 2015). The second case study focuses on the Portuguese high-speed railway section between Lisbon-Poceirão-Caia that connects with the Spanish border. The Lisbon-Poceirão-Caia section was part of the Portuguese RAVE high-speed railway network, which was designed through six PPP contracts, in 2004. However, only the contract for the Poceirão and Caia section was awarded. Because of the 2008-2010 international financial crisis, which affected Portugal deeply, the PPP contract for the Poceirão-Caia section was rescinded during the design phase and the project for the entire network was discarded (Diário da República, 2011; Direcção-Geral do Tesouro e Finanças, 2010; Rede Ferroviária de Alta Velocidade, 2007; Tribunal de Contas, 2014).

In the general context of PPPs for high-speed railways, several economic aspects have already been studied. Firstly, Bonnafous (1987) concluded that the first European high-speed railway line, which connected Paris and Lyon, generated direct economic benefits in terms of tourism and industry. An extended article on railway PPPs was published by Dehornoy (2012), who deduced that the most successful concessions were those focusing on integrated traffic (for airport links) and traffic availability (for high-speed infrastructure). Moreover, Crozet (2016) concluded that PPPs permit the construction and opening of new high-speed lines in a timely fashion; however, public bailouts are needed to solve financial problems. The relationship between investment and the social benefits of high-speed rail transport experiences in Europe (and worldwide) has been investigated by several researchers (De Rus, 2009; De Rus and Nash, 2009; Campos, de Rus and Barrón, 2009). They concluded that it was better than alternative modes of transport in terms of time savings, reliability, comfort, safety, and reduced pollution.

Koppenjan and Leijten (2005, 2007) and Priemus (2011a, 2011b) analysed the Dutch sector in detail, in particular the HSL-Zuid high-speed line, to assess the participation of private investors in railway infrastructure. They established that the Dutch government was not able to implement innovative contracts successfully due to its limited knowledge of PPPs. The Lisbon-Poceirão-Caia section and the remainder of the Portuguese RAVE high-speed railway network has been developed according to the interests of the nation, politicians, private investors, and construction companies. De Azevedo Isidoro, Marat-Mendes, and Regina Tângari (2018) realised that the network's layout has not changed significantly from 1845 to 2015 and that developments were made successfully during social and economic transformations. Despite its limited budget, Portugal has been leading the European Union in terms of new transport infrastructure being developed through PPPs. However, Macário, Ribeiro, and Duarte Costa (2015) identified several pitfalls related to PPP regulation. Through a huge study on Portuguese road and railway PPPs, Pereira (2016) explains that most projects overestimate the demand forecast. In contrast, while exploring the advantages of PPPs, Rolland Sobral and Neves Cruz (2011) noted the success of private financing in Portugal, including adherence to a budget and deadlines, and the know-how of private investors.

The Portuguese public-private high-speed rail model has been analysed by many authors. Besanko and Tenreiro Gonçalves (2013) concluded that the state-owned company RAVE should have described how the social and economic benefits would be higher than the infrastructure costs. Pedro, De Abreu e Silva and Brookes (2015) described the influence of the external stakeholders. Oliveira Cruz, Kokkaew, and Cunha Marques (2017) issued recommendations for reducing risks (e.g., the initial construction of just one line to test the PPP model, splitting the infrastructure and operational management, or re-tendering the contract within 5 to 10 years). With respect to the financial implementation and management of the Portuguese high-speed railway network, De Abreu e Silva, Silva, and Sussman (2011) also determined that PPPs must be adapted to each project, and it is necessary to consider the interface generated from the split between substructure and superstructure works.

The failures that became apparent during the implementation (as previously described) could be repeated, even if the conclusions of the studies reviewed were applied to new high-speed rail lines constructed through PPP contracts. The aim of this research is therefore to develop a list of recommendations and good practices that can serve as a tool for governments, private investors, and railway stakeholders ,to help them make the best decisions possible prior to the construction of a new line. For that reason, this study analyses the Portuguese adaptation of the HSL-Zuid Dutch high-speed line PPP model, as they took the Dutch experience as a reference for the Lisbon-Poceirão-Caia section that was part of the Portuguese RAVE high-speed railway network.

## 2. RESEARCH METHOD

Case study theory was applied to this research in accordance with Stake (1995) and Yin (2009), the most relevant authors in this area. Stake (1995) defines a case study as a "study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (p. 7) and Yin (2009) describes it as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evidenced" (p. 9). These authors each identified groups of three case study types. According to the reason for selecting a case study, Stake (2003) identified intrinsic, instrumental, and collective case studies, and according to the purpose of the research, Yin (2009) identified explanatory, descriptive, and exploratory case studies. This research falls into the collective and exploratory categories due to the novelty of the HSL-Zuid line and the Lisbon-Poceirão-Caia section being analysed together. The two case studies are analysed and compared to identify the critical success factors (CSFs) in high-speed railway infrastructure with PPP contracts. Rockart (1982) defined CSFs as "the few key areas of activity in which favourable results are necessary for a particular manager to reach his or her goals" (p. 4).

This method was proven in research into PPP transport infrastructures (Koppenjan, 2005; Liyanage and Roumboutsos, 2016; Liyanage and Villalba-Romero, 2015; Liyanage, Njuangang, and Villalba-Romero, 2016; Ribeiro, Couchinho, Macário, and Liyanange, 2016; Voordijk, Liyanage, and Temel-jotov Salaj, 2016). Indeed, one of the most important authors in this area is Rosário Macário (Macário et al., 2015), who is herself from Portugal.

The steps applied to this research article comprise five sequential actions: (a) the collection of a wide range of data on the HSL-Zuid Dutch high-speed line and Lisbon-Poceirão-Caia section (part of the Portuguese RAVE high-speed railway network), from the railway infrastructure concessionaire, railway infrastructure managers, railway undertakings, public authorities, and railway-specific publications; (b) the classification of the data into six areas: project, infrastructure, transport service, contract, corporate structure, and investment; (c) comparison of the case studies; (d) identification and analysis of the CSFs; and (e) development of a list of recommendations and good practices for governments, private investors, and railway stakeholders.

## 3. DESCRIPTION OF THE CASE STUDIES

### 3.1. Case 1: Hogesnelheidslijn Zuid Line

In 1997, the first study on the construction of a high-speed line between Amsterdam, Rotterdam, and Belgium was carried out. In 1986, France, Belgium, the Netherlands, and Germany had agreed to develop a railway line that connected Paris, Brussels, and Amsterdam. In 1996, the Netherlands decided that the Dutch route connecting Amsterdam to the Belgian border was the shortest and quickest option. This route crossed a protected natural area called the Groene Hart ("green heart") located in an urban area in the western Netherlands (Cantarelli et al., 2010; Koppenjan and Leijten, 2005; Omega Centre, 2011).

The 100-km line that links Amsterdam, Schiphol (Amsterdam airport), Rotterdam, Breda, and the Belgian border, and which connects the Belgian high-speed railway network, was named the Dutch HSL-Zuid high-speed line (Omega Centre, 2011). This modern infrastructure offered better journey times for the passengers on the railway services. The time differences between high-speed and conventional railway journeys are provided in Table 1:

**Table 1. Journey times for routes on the HSL-Zuid Dutch high-speed line**

| Connection | High-speed railway journey time | Conventional railway journey time | Time saved |
|---|---|---|---|
| Amsterdam – Rotterdam | 35 minutes | 58 minutes | 23 minutes |
| Amsterdam – Breda | 1 hour and 2 minutes | 1 hour and 42 minutes | 40 minutes |
| Amsterdam – Antwerp | 1 hour and 7 minutes | 2 hours and 5 minutes | 58 minutes |
| Amsterdam – Brussels | 1 hour and 45 minutes | 2 hours and 51 minutes | 1 hour and 6 minutes |
| Amsterdam – Paris | 3 hours and 11 minutes | 4 hours and 13 minutes | 1 hour and 2 minutes |
| The Hague – Brussels | 1 hour and 44 minutes | 2 hours and 8 minutes | 24 minutes |

*Note:* Data from Railway Gazette International (2005).

The line was ready to come into operation in 2007. However, due to a delay in the delivery of the new high-speed railway rolling stock, commercial transport services actually began in 2009, with locomotives and coaches travelling at a maximum speed of 160 km/h between Amsterdam and Rotterdam. In March 2012, the new high-speed trains began running domestic services between Amsterdam and Breda. In December of the same year, an international service to Brussels was added. One month later, the new high-speed trains were removed from operation due to a high failure rate in the electronic systems. In December 2014, the Dutch government ended the transport service concession early. The following month, Nederlandse Spoorwegen (NS) was awarded an exclusive concession to operate the Dutch passenger railway network, including the HSL-Zuid Dutch high-speed line, for a period of 10 years (Geluk, 2007; Gerrits et al., 2015; Nederlandse Spoorwegen, 2015; Omega Centre, 2011; Railway Gazette International, 2010, 2015).

The technical features of the Dutch HSL-Zuid high-speed line include a Union Internationale de Chemins de Fer (UIC) gauge (1,435 mm), double track, 25,000 V electrification, an ERTMS level 2 signalling system with a maximum speed of 300 km/h, an ERTMS level 1 signalling system with a maximum speed of 160 km/h, and a GSM-R telecommunications system for voice and data (Van Gerrevink, 2008; Wegner, 2008; Omega Centre, 2011; Van Ammers, 2008; Ernst & Young, 2009).

### 3.2. Case 2: Lisbon-Poceirão-Caia section

The Lisbon-Poceirão-Caia connection was the Portuguese section of the Lisbon-Madrid high-speed railway line and also part of the Portuguese high-speed railway network. For this reason, it is necessary to introduce the network as a whole, even though the case study focuses on just the Lisbon-Poceirão-Caia section. In 1988, Portugal launched the construction of a high-speed rail network in coordination with Spain; they agreed to design the lines with UIC-gauge (1,435 mm). The company Rede Ferroviária de Alta Velocidade, known by its acronym RAVE, was established in 2000. This company comprised the Portuguese State (60%) and Rede Ferrovíaria Nacional (REFER) (40%), the Portuguese national railway infrastructure manager, whose aim was to analyse and prepare for the RAVE Portuguese high-speed railway network to be implemented. In 2001, Portugal and Spain set up a European economic interest group christened Spain-Portugal high-speed (in Portuguese: Alta Velocidade Espanha-Portugal; and in Spanish: Alta Velocidad España-Portugal). Both nations were responsible for the cross-border sections. This group was made up of RAVE and the Administrador de Infraestructuras Ferroviarias (ADIF), the Spanish national railway infrastructure management organisation (Diário da República, 1988; Rede Ferroviária de Alta Velocidade, 2004; Tribunal de Contas, 2014).

In a binational summit between Portugal and Spain, in 2003, the following cross-border sections were defined: Porto-Vigo, Lisbon-Madrid, Aveiro-Salamanca, and Faro-Huelva. In 2004, Portugal unveiled its high-speed railway network, which comprised the agreed-upon sections with Spain in addition to a domestic section between Lisbon and Porto. The European Union included the Lisbon-Porto, Lisbon-Madrid, and Aveiro-Salamanca sections in the high-speed railway axis of its southwestern Europe priority project; and the Porto-Vigo section in the Iberian Peninsula priority project. The Lisbon-Madrid section was classified as one of the five highest-priority axes for the European Union (Diário da República, 2004; Diario Oficial de la Unión Europea, 2004a; Rede Ferroviária de Alta Velocidade, 2004; Tribunal de Contas, 2014).

Following various Portuguese-Spanish summits up to 2009, the Portuguese high-speed rail network was designed with the features described in Table 2:

**Table 2. Portuguese high-speed rail network**

| Axis | Journey time | Traffic | Length | Maximum speed | Stations |
|---|---|---|---|---|---|
| Lisbon-Madrid | 2 hours and 45 minutes | Passengers and freight | 206 km | 350 km/h | Lisbon, Évora and Elvas/Badajoz. |
| Lisbon-Porto | 1 hour and 15 minutes | Passengers | 314 km | 300 km/h | Lisbon, Ota, Leiria, Coímbra, Aveiro and Porto. |
| Porto-Vigo | 60 minutes | Passengers and freight | 100 km | 250 km/h | Porto, Sá Carneiro Airport, Braga and Valença/Tuy. |
| Aveiro-Salamanca | 2 hours and 45 minutes | Passengers and freight | 70 km | 250 km/h | Aveiro, Viseu and Guarda. |
| Évora-Faro-Huelva | Lisbon-Faro 1 hour and 30 minutes | Passengers | 200 km | 300 km/h | Évora and Faro. |
| | Faro-Huelva 30 minutes | | | | |

*Note:* Data from Rede Ferroviária de Alta Velocidade (2006, 2008, 2009).

There is a high level of cross-border mobility between Portugal and Spain due to cultural, linguistic, economic, and cultural relations. However, there is also an important deficit in public transport links. Due to its geographical location, the new high-speed railway axis benefits both Portugal and Spain, particularly the Spanish regions of Galicia, Castilla y León, Extremadura, and Andalucía, (Gutiérrez Gallego, Naranjo Gómez, Jaraíz-Cabanillas, Ruiz Labrador, and Su Jeong, 2015; Chen, Correia and de Abreu e Silva, 2015; Carvalho, Partidario and Sheate, 2017, Varela Cornado, 2018).

The Portuguese government decided to open the tendering only for the axes considered to be a priority for Portugal. These axes were Lisbon-Madrid, Lisbon-Porto, and the first phase of the Porto-Vigo section, which was designed with polyvalent sleepers in 1,668 mm Iberian gauge. These sections are summarised in Table 3.

**Table 3. Portuguese high-speed rail network priority axes**

| Axis | Journey time | Traffic | Length | Maximum speed | Stations |
|---|---|---|---|---|---|
| Lisbon-Madrid | 2 hours and 45 minutes | Passengers and freight | 206 km | 350 km/h | Lisboa, Évora and Elvas/Badajoz. |
| Lisbon-Porto | 1 hour and 15 minutes | Passengers | 314 km | 300 km/h | Lisbon, Ota, Leiria, Coímbra, Aveiro and Porto. |
| Porto-Vigo 1st Phase Braga-Valença | 60 minutes | Passengers and freight | 55 km | 250 km/h | Braga and Valença/Tuy. |

*Note:* Data from Rede Ferroviária de Alta Velocidade (2006, 2007, 2008, 2009).

The Portuguese government justified the construction of these three priority high-speed rail axes in Portugal mainly due to the socioeconomic benefits involved in connecting with the Spanish and European passenger and freight railway networks (Diário da República, 2010).

In 2010, due to the international financial crisis that hit Portugal in 2008 and was felt even more strongly in 2009, an economic stability and growth programme was established. This programme included delaying the tendering for the Lisbon-Porto and Porto-Vigo axes (Ministério das Finanças e da Administração Pública, 2010). In 2011, the Portuguese government published a strategic transport plan for the period 2011-2015 in which the Lisbon-Madrid high-speed railway line project was scrapped (Diário da República, 2011). That year, RAVE was extinguished and integrated into REFER, which assumed the role of RAVE in the Spain-Portugal high-speed European economic interest group (Tribunal de Contas, 2014).

## 4. ANALYSIS AND DISCUSSION OF THE CASE STUDIES

### 4.1. CSFs in the case studies

This research analyses the evolution of the PPP model implemented for the Dutch HSL-Zuid high-speed line, which Portugal took as a reference for the Lisbon-Poceirão-Caia section that was part of its RAVE high-speed network (Tribunal do Contas, 2014). This section compares the two case studies and then identifies and analyses the CSFs that Portugal harnessed for its new PPP structure based on the Dutch approach.

#### *4.1.1. Cross-border cooperation for international sections*

The Netherlands and Belgium had problems signing an agreement on the cross-border route for political and environmental reasons. Because of this dispute, a technical team was set up by Dutch and Belgium railway enterprises to define the route. In 1996, the route was chosen, and the Netherlands compensated Belgium with a sum of 400 million euros (Omega Centre, 2011).

ERTMS Levels 1 and 2 signalling systems were utilised in both countries. Siemens was part of the Infraspeed consortium and installed ERTMS Level 1 in the Dutch HSL-Zuid high-speed line as well as the cross-border Belgian line. ERTMS Level 2 was put in in the Netherlands by Alcatel, and in Belgium by Alstom. The specifications of the ERTMS system requirements left a certain degree of freedom for interpretation, resulting in the ERTMS Level 2 systems installed by Alcatel and Alstom being incompatible (Baggen et al., 2008).

In 2007, after ERTMS Version 2.2.2 was implemented in the infrastructure of the two countries, it was observed that trains could not operate without stopping at the border. It was therefore necessary to update the infrastructure and the on-board equipment once again, to ERTMS Version 2.3.0 (Geluk, 2007). Indeed, that same year, the infrastructure was updated to Version 2.3.0 on both the HSL-Zuid and Belgian lines, but a new technical problem arose in both countries (Railway Gazette International, 2007). To solve this problem, it was necessary to publish ERTMS Version 2.3.0 Corridor, a specific system requirement specification for this cross-border link (Tweede Kamer, 2008).

Negotiations between the Dutch and Belgian governments revealed different interests. The main reason for the Netherlands to construct the Dutch HSL-Zuid high-speed line was to connect with the high-speed railway network that could only be reached via Belgium. However, Belgium already had a connection to the European high-speed railway network through France (Springvloet, 2013). This explains the difficulties in defining the cross-border section and the economic benefit Belgium received from the Netherlands. An important technical problem was encountered as a consequence of the ERTMS Level 2 signalling system being installed by different companies in each country. The ERTMS system requirement specifications are published in a way that allows them to be implemented by different companies. However, technical failures are common, and there is often a need to integrate sections using ERTMS installed by different companies. For the Portuguese RAVE high-speed railway network, the cross-border cooperation between Portugal and Spain was completely different.

The main reason for Portugal to construct the Lisbon-Poceirão-Caia section and its high-speed railway network was to connect to the European network. The motivation was similar to that of the Netherlands, but in this case, it was necessary to cross Spain to do so. From the initial idea to the construction of the RAVE network in 1988, Portugal and Spain cooperated in designing the cross-section routes, stabilising the UIC gauge, creating a European economic interest group, and agreeing on travel times. Portugal and Spain also determined that cross-border sections were the responsibility of both countries (Diário da República, 1988; Tribunal de Contas, 2014). These decisions were made in the binational summits.

#### *4.1.2. Single contract for substructure and superstructure*

The Dutch HSL-Zuid high-speed line infrastructure was built with separate contracts being awarded for the superstructure and substructure. The substructure was divided into seven sections, as described in Table 4, each having its own associated contract.

**Table 4. Substructure contracts for HSL-Zuid**

| Contract | Consortium | Participant enterprises |
|---|---|---|
| HSL-A4 Noordelijk Holland | Hollandse Meren | Ballast Nedam, Van Hattum and Vermeer. |
| Zuid-Holland Midden | HSL-Consortium Zuid-Holland Midden | NBM-Amstelland, HBG and Heijmans. |
| Zuid-Holland Zuid | HSL-Drechtse Steden | Ballast Nedam, Van Hattum & Blankevoort and Strukton. |
| HSL-A16 Brabant Noord | HSL-Brabant | Ballast Nedam, Volker Stevin, Strukton, Boskalis and Vermeer. |
| HSL-A16 Brabant Zuid | HSL-Consortium Brabant Zuid | HBG, NBM, Heijmans, Holzmann, HAM and Van Oord. |
| Groene Hart Tunnel | - | Bouygues/Koop Tjuchem. |
| Connections with existing rail infrastructure | Infrarail | - |

*Note:* Data from Omega Centre (2011) and Priemus (2011a).

In July 2000, seven traditional design and construction contracts were signed, five of them for substructure works, another for the tunnel under the "green heart", and the last for the connection with the existing railway network (Priemus, 2011a). These contracts involved a five-year construction period and were intended to terminate in 2005 (Springvloet, 2013).

For the tunnel under the "green heart", the process was fluid: foreign companies contributed innovative solutions that allowed cost reductions (Koppenjan & Leijten, 2005). For the five substructure contracts, the bids totalled 2.54 billion euros, some 43% higher than the budget of 1.78 billion euros

(Koppenjan & Leijten, 2005). The Dutch government tried to negotiate with the bidders, but this was stopped when a court of arbitration declared it illegal (Koppenjan & Leijten, 2005). The prices were later reduced, but the Dutch government had to accept changes in the scope of the project. Some risks were initially transferred to the private investors, such as the elimination of the penalty for delays in delivery (Koppenjan & Leijten, 2005). Subsequently, a parliamentary investigation found that construction companies had collaborated to share the work and increase the prices during the tendering process (Priemus, 2011a).

The entire 90 km-superstructure was contracted out through a single PPP covering the design, construction, financing, and maintenance, with a period of five years for the construction and 25 years for the maintenance (Van Ammers, 2008). The PPP superstructure contract was awarded to Infraspeed, which included the following companies: Fluor Daniel BV, NBM-Amstelland, Siemens Nederland BV, Siemens AG, Deutsche Bank, and ING (Priemus, 2011a, 2011b). Infraspeed presented an offer based on an engineering project that was later modified due to the substructure works having been contracted out previously; this resulted in incorrect calculations and design issues (Von der Heidt, Gillett, Charles, and Ryan, 2009). This PPP contract also included the implementation of the ERTMS signalling and GSM-R communications systems.

Several lessons can be learned from the Dutch strategy. For the substructure, five civil works contracts were awarded, each of them with an average length of 16 km. These small sections led to higher bids relative to the budget since every section involves fixed costs. The Dutch government therefore had to pay these fixed costs five times for the substructure contracts: if it had not split the line up into these sections, the costs would have been reduced. The five substructure contracts were tendered at the same time, which had several effects. Bidders could choose to bid only for the most profitable sections and some sections could be declared void. Reduced economic competition arose as bidders had a higher probability of being awarded a contract, and prices were not adjusted on the tenders that received no interest. Moreover, the Dutch construction companies fixed the process through an illegal agreement to increase the prices above the budget. This might seem exceptional, but it is more common than expected. For the superstructure, a PPP contract for the whole line was awarded. The division between substructure and superstructure works generated a technical risk in the interface between the systems. The lesson here is that the substructure and superstructure should be made by the same engineering team or company, because a change in one of these has repercussions in the other.

Other aspects of the Dutch strategy can be qualified as positive initiatives: the construction of the tunnel under the "green heart"; and the connection with the existing railway network, both contracts awarded independently. The first task can be classified as singular because, as a unique piece of engineering, it needed a specific design and construction, and demanded innovative solutions. The second task, which included the interface between the new high-speed railway line and the existing railway network, included important technical risks due to the different systems involved and the need to modify these. For public administration purposes, it is very useful to separate this kind of project from the rest of the line to better control the planning, avoid technical risks, and reduce delays.

The Portuguese government applied these recommendations to the Lisbon-Poceirão-Caia section as well as to the rest of the high-speed railway network. The infrastructure works were divided into the six PPP contracts presented in Table 5.

**Table 5. PPP contract scope for the Portuguese high-speed rail network**

| Axis | Section | PPP Contract | Scope |
|---|---|---|---|
| Lisbon-Madrid | Poceirão-Caia | PPP1 | Substructure and superstructure.<br>Évora station.<br>Conventional freight railway line between Évora and Caia. |
| | Lisbon-Poceirão | PPP2 | Substructure and superstructure.<br>Tejo new bridge, Terceira Travessia do Tejo (TTT). |
| Lisbon-Porto | Lisbon-Pombal | PPP3 | Substructure and superstructure.<br>Leiria station. |
| | Pombal-Porto | PPP4 | Substructure and superstructure.<br>Aveiro station. |
| Porto-Vigo | Braga-Valença | PPP5 | Substructure and superstructure. |
| All axes | All sections | PPP6 | Signalling and communications systems. |

*Note:* Data from Rede Ferroviária de Alta Velocidade (2007) and Tribunal de Contas (2014).

The substructure and superstructure works for each section were included in the same PPP contracts. The scope of the PPP1, PPP2, PPP3, PPP4, and PPP5 contracts was the following: design, construction, financing and maintenance for 40 years; during operation, the payments were based on availability, traffic, and maintenance (Rede Ferroviária de Alta Velocidade, 2007; Tribunal de Contas, 2014). The PPP6 contract included the signalling and communications systems for the entire high-speed railway network. For the Lisbon-Madrid axis, Portugal was responsible for the connection between Lisbon, Poceirão, and Caia, which was divided into 2 contracts. The first (contract PPP1) included the high-speed section between Poceirão and Caia. Contract PPP1 also included the construction and operation of Évora station and a conventional freight railway line between Évora and Caia (Direcção-Geral do Tesouro e Finanças, 2008; Tribunal de Contas, 2014). Contract PPP2 included the high-speed section between Lisbon and Poceirão and a new bridge in Lisbon, named Terceira Travessia do Tejo. Contract PPP1 was signed in 2010 with ELOS–Ligações de Alta Velocidade (Direcção-Geral do Tesouro e Finanças, 2010; Tribunal do Contas, 2014). This consortium was made up of Brisa Auto-Estradas de Portugal S.A.; Soares da Costa Concessões SGPS, S.A.; Soares da Costa S.A.; Iridium Concesiones de Infraestructuras S.A.; Dragados S.A.; Lena Concessões e Serviços, SGPS, S.A.; Lena Engenharia e Construções, S.A.; Bento Pedroso Construções S.A.; Odebrecht, Investimentos em Concessões Ferroviárias, SGPS, S.A.; Círculo Corrente, Unipessoal, Lda.; Edifer – Construções Pires Coelho & Fernandes, S.A.; Edifer – Desenvolvimento de Negócios, S.A.; Zagope – Construções e Engenharia, S.A.; Zagope SGPS, Lda.; Banco Millenium BCP Investimento, S.A.; and Caixa Geral de Depósitos, S.A. (Direcção-Geral do Tesouro e Finanças, 2008; Tribunal de Contas, 2014). Contract PPP2, which connected Lisbon and Poceirão in the second Portuguese section of the Lisbon-Madrid axis, was launched in 2009 (Direcção-Geral do Tesouro e Finanças, 2009; Tribunal de Contas, 2014). The consortia ELOS–Ligações de Alta Velocidade, ALTAVIA ALENTEJO–Infraestruturas de Alta Velocidade, and TAVE TEJO presented bids (Tribunal de Contas, 2014). In 2010, due to the financial crisis, the Portuguese government discarded this construction (Direcção-Geral do Tesouro e Finanças, 2010; Tribunal de Contas, 2014).

#### *4.1.3. An independent contract for signalling and communications systems*

The following were installed in the Dutch HSL-Zuid high-speed line signalling system: ERTMS Level 1 (maximum speed 160 km/h), ERTMS Level 2 (maximum speed 300 km/H), and the voice and data GSM-R communication system (Van Gerrevink, 2008; Wegner, 2008; Omega Centre, 2011). The installation of these systems was included within the scope of the superstructure PPP contract.

To the ERTMS issues listed in section 4.1.1, it is necessary to add that this signalling system is one of the most technical and obsolescence-prone of the systems integrated into the superstructure. The ERTMS system must be frequently updated with new software versions and hardware components, implying a high level of investment and affecting operations during the implementation process.

Portugal decided to equip its infrastructure with ERTMS Level 2 and GSM-R. These systems were implemented through an independent PPP contract, PPP6. The scope of this contract was the Lisbon-Poceirão-Caia section in addition to the rest of the high-speed railway network. The contractor awarded the tender was responsible for the design, supply, installation, finance, and maintenance for 20 years, with a public payment based on availability (Rede Ferroviária de Alta Velocidade, 2004, 2007; Tribunal de Contas, 2014).

An independent contract for signalling and communications systems has certain advantages. Due to the reduced number of ERTMS suppliers, if these were integrated into consortiums together with the rest of the infrastructure system companies, the number of possible bidders would decrease, the high technological risk during operation would be minimised, and a unique contract would increase the competitivity in the sector.

### 4.2. Discussion of the CSFs

This article looks at the HSL-Zuid high-speed rail line in the Netherlands and the Lisbon-Poceirão-Caia high-speed rail section in Portugal as case studies. They are comparable as they have several common characteristics. The HSL-Zuid line connects Amsterdam with the Belgian border, reaching Brussels on high-speed rails and may also connect it with the rest of the European high-speed rail network. The Lisbon-Poceirão-Caia high-speed rail section links Lisbon with the Spanish border, connected by high-speed rail to Madrid, from where it can also continue to the European high-speed rail network. For this reason, the purpose of both infrastructures was twofold. Firstly, to connect the capital of one country with that of its neighbour by high-speed rail and, secondly, to enable access to the rest of the European high-speed network. Moreover, a characteristic aspect of these two countries is that they both have a long maritime coastline, so that access to the high-speed rail network means having to interconnect with one of their neighbouring countries, in the case of Portugal there was only one possibility, Spain, in order to cross the Pyrenees through the Figueras-Perpignan international section. As far as the Netherlands is concerned, there were two options for this link, Germany and Belgium, but choosing to cross through Belgium also meant connecting to the capital of the European Union, having access to France, and thus, being able to continue through the Channel Tunnel to the United Kingdom. The first aspect to be discussed is, therefore, cross-border cooperation between neighbouring countries for the construction of international border crossings (Omega Centre, 2011; Tribunal de Contas, 2014).

In the two case studies analysed, the cross-border cooperation between the governments of Portugal and Spain, and the Netherlands and Belgium, was completely different. For the Portuguese Lisbon-Poceirão-Caia section, which was part of the Lisbon-Madrid axis, cooperation between the two countries is ongoing through the various Portuguese-Spanish summit meetings and involved the creation of a European economic interest group, in which both countries were responsible for the cross-border connection of the Lisbon-Madrid axis (Diário da República, 1988; Tribunal de Contas, 2014). Spain has experience in this type of cross-border cooperation, since the international high-speed rail section between Figueras and Perpignan that links the high-speed rail networks of Spain and France was built through a public-private collaboration model involving a joint agreement between the two countries. As with the connection between Portugal and Spain, these two countries principally made their decisions in bilateral summits to define the characteristics of the international section between Figueras and Perpignan. On October 10$^{th}$, 1995, as a result of the Spanish-French summit meeting held in Madrid, Spain and France signed the so-called Madrid Agreement, the purpose of which was to establish the grounds for the construction and operation of a high-speed connection between Spain and France through Figueras and Perpignan. Subsequently, in the same way as Portugal and Spain, a European economic interest group was also set up between Spain and France to control and enable the development of the project (Official State Gazette, 1998; López Pita, s.f.; Ministère de l'écologie, du développement durable, des transports et du logement, 2011). Another infrastructure that should be highlighted in terms of cross-border railway cooperation is the Channel Tunnel between France and the United Kingdom. This infrastructure was also developed through public-private collaboration, in a joint project between France and the United Kingdom enacted by the Treaty of Canterbury on February 12th, 1986 (Secretary of State for Foreign and Commonwealth, 1986). All these cross-border agreements and cooperation accords between different countries contrast with the case of the HSL-Zuid line where the Netherlands had to pay compensation to Belgium to agree and finalise the route for the cross-border connection (Omega Centre, 2011).

Currently in Europe, cross-border cooperation is an undeniable reality since it contributes to cohesion, sustainable social development, and facilitates increased economic activity in cross-border territories. Transport infrastructures play a fundamental role in cross-border cooperation and common planning policies are increasing in Europe. To provide cross-border projects with continuity and durability, it is necessary to create an alliance between cross-border territories, which must be institutionalised through an agreement. For this alliance to be robust, it is necessary to ensure the participation of interest groups, guarantee a coherent objective for all participants, and ensure that the results of the cooperation involve similar benefits on both sides of the border (Galko and Volodin, 2016; Castanho, Vulevic, Fernández, Fernández-Pozo, Gómez and Loures, 2017; Kurowska-Pysz, Castanho and Loures, 2018).

The next factor to discuss is the need to carry out the substructure and superstructure work through the same contract. For the HSL-Zuid line, the substructure and superstructure activities were contracted out separately. The substructure contract was awarded first, initiating the engineering design work. After that, the superstructure contract was awarded. The scope of the bids that were submitted for the superstructure were based on an initial substructure project that had already been modified by the winner of the substructure tender. This implied the need to rework the tenders due to erroneous calculations and designs, with the subsequent delay and cost overrun (Von der Heidt, Gillett, Charles, and Ryan, 2009).

For the Lisbon-Poceirão-Caia section, both the substructure and superstructure were included within the same contract (Alta Velocidade, 2007; Tribunal de Contas, 2014). This is also the case of the other high-speed lines contracted through public-private partnerships in Europe, namely, the High Speed 1 line, connecting the Channel Tunnel with London, in the United Kingdom, the French Bretagne-Pays de la Loire line, which links the towns of Le Mans and Rennes, the Sud-Europe Atlantique line, which links the towns of Tours and Bordeaux, the Contournement Nîmes-Montpellier bypass, and the international Figueras-Perpignan section between Spain and France (Official State Gazette, 2016; ERE Eiffage Rail Express and Réseau Ferré de France, 2013; LISEA and SNCF Réseau, 2017; National Audit Office, 2001; OC'VIA and Réseau Ferré de France, 2012).

It is not a coincidence that all these lines, with the exception of the HSL-Zuid line, combined the substructure and superstructure activities into a single contract. This need is justified by the following technical reasons. Firstly, it is necessary to indicate that the substructure supports the superstructure and transmits the loads to the foundation. Secondly, the superstructure is the area above ground level that receives the loads from the trains which are then transferred to the substructure. It is clear, therefore, that there is an interaction between the substructure and superstructure; for this reason, it is necessary for the design to take into account the factors that influence the dimensioning, such as stresses and deformations, in order to obtain a better performance from both the substructure and superstructure as well as vehicle dynamics (Alamaa, 2016; Byun, Hong and Lee, 2015; Giannakos, 2010; Li, Hyslip, Sussmann and Chrismer, 2015; Ministry of Housing and Urban Affairs, 2018; Selig and Waters, 1994).

The last factor to discuss is the separate agreement for signalling and communication systems. Among all the factors, this is the most innovative. Analysing all the European high-speed railway lines constructed through public-private collaboration, Portugal was the only example involving this type of separate agreement for signalling and communication systems, not only for the case study section between Lisbon-Poceirão-Caia, but, indeed, for the entire high-speed network. This decision was an improvement based on the experience of the Dutch HSL-Zuid line, where there were significant delays due to different interpretations of the technical specifications of the ERTMS Version 2.2.2 system. The infrastructure technologists were Siemens in the Netherlands, and Alstom in Belgium. The different interpretations of the two technologists meant that, when a train passed from one country to another, it could not do so continuously, but had to stop, increasing travel times. It was therefore necessary to develop the new technical specifications of ERTMS Version 2.3.0 to close this gap (Alta Velocidade, 2007; Official State Gazette, 2016; ERE Eiffage Rail Express and Réseau Ferré de France, 2013; Geluk, 2007; LISEA and SNCF Réseau, 2017; National Audit Office, 2001; OC'VIA and Réseau Ferré de France , 2012; Tribunal de Contas, 2014; Tweede Kamer, 2008).

Almost every country in the European Union had its own Automatic Train Protection (ATP) system, which were not compatible with one another in most cases. With the increase in international services, it was therefore necessary for the vehicles to possess all the ATP systems of the countries though which they were going to pass. Because of this, in 1989, the European Union launched the development of a single signalling system for the entire network that would facilitate transit between countries. This system was referred to as ERTMS and, in 2000, the first technical specification was published (European Union, 2021). In parallel to the development of the ERTMS system, it was necessary to implement a communication system between the railways and the trains. Thus, it was decided to adapt the existing communication system to the Global System for Mobile Communications (GSM) for railways, which led to the creation of the GSM-R communication system (UIC, 2021b).

Since the first technical specification of the ERTMS system in 2000, 12 new versions of this document have been published (European Union, 2021). The GSM-R communication system will now be replaced by a new development, known as the Future Railway Mobile Communication System (FRMCS) (UIC, 2021a). It is clear that this technology is constantly evolving, representing a significant investment for technologists, infrastructure managers, and railway companies. For this reason, the European Union, aware of the large outlay involved in implementing a single railway signalling system, supported the roll-out of this technology with a subsidy of 3.9 billion euros between 2007 and 2019. (European Commission, 2020). A peculiar fact about this continuous technological evolution is that in Spain, through a public-private collaboration contract, awarded to the technologist Alstom, the ERTMS signalling and GSM-R communication systems have been implemented in the Albacete-Alicante high-speed section, whereas the substructure and superstructure were implemented through a traditional contract (European Commission, 2014).

## 5. CONCLUSION

This research analyses and compares two case studies of high-speed rail lines in Europe contracted out through public-private collaborations. The first is the high-speed line connecting Amsterdam with the Belgian border, part of the Amsterdam-Brussels axis, the so-called HSL-Zuid; the second is the Lisbon-Poceirão-Caia high-speed rail section, included within the Portuguese RAVE high-speed rail network project, and part of the Lisbon-Madrid axis. These projects enable both the Netherlands and Portugal to link to the European high-speed network.

This research has required the application of an exploratory and collective approach and the identification of critical success factors (CSFs). The purpose of this research was to develop a list of recommendations and good practices that can serve as a tool for governments, private investors, and railway stakeholders to help them make the best and most efficient decisions in terms of new high-speed rail line construction.

To that end, we present the following recommendations and good practices. Cross-border cooperation for international sections must be established through an agreement between the countries involved, including stakeholders, to guarantee a common objective and the development of similar benefits for all countries. Single contracts should be awarded for a combination of substructure and superstructure, as the design must be implemented jointly by one group of engineers, since any modifications of the substructure affect the superstructure and vice versa, due to the load transmission relationship between these two elements. An independent contract for signalling and communication systems should also be awarded due to the enormous technological risk involved in implementing the ERTMS signalling and GSM-R communications systems, which are constantly evolving in terms of technical specifications. In addition, greater competitiveness must be allowed in this area due to the reduced number of existing technologists. With this list of recommendations and good practices, it is expected that the implementation efficiency of new high-speed rail infrastructures will improve. In addition, this project could be applied not only to the field of public-private collaborations but also to the railway environment as a whole.

### LIST OF ABBREVIATIONS

ADIF: Administrador de Infraestructuras Ferroviarias
ATP: Automatic Train Protection
ERTMS: European Rail Traffic Management System
FRMCS: Future Railway Mobile Communication System
GSM: Global System for Mobile Communications
GSM-R: Global System for Mobile Communications-Railway
HSL-Zuid: Hogesnelheidslijn Zuid
NS: Nederlandse Sportwagon
PPP: Public–Private Partnership
RAVE: Rede Ferroviária de Alta Velocidade
REFER: Rede Ferrovíaria Nacional
TTT: Terceira Travessia do Tejo
UIC: Union Internationale de Chemins de Fer

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