BRAZIL TAV PROJECT

Halcrow – Sinergia Consortium

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VOLUME 5

TAV CAPITAL COST

Final Report - 2nd Release

SINERGIA
ESTUDOS E PROJETOS LTDA.

Halcrow

Brazil TAV

Halcrow - Sinergia Consortium

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TAV Capital Cost

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Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Initial
1	0	Capex split from operations	01/05/09	MJ/DR
1	1	Review of document	03/05/09	MJ
1	2	Update of unit rates	12/06/09	MJ/DR/RM
2	1	Final Report following Rio de Janeiro meetings	26/06/09	MJ/DR
2	2	Update of CAPEX – Final Report	24/07/09	MJ/DR
2	3	Contingencies removed following Government clarification – Final Report 2nd Release	21/09/09	DR

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Glossary of Acronyms and Abbreviations

	Portuguese	English
AGETRANSP	Agência Reguladora dos Serviços Públicos Concedidos de Transportes Aquaviários, Ferroviários, Metroviários e de Rodovias do Estado do Rio de Janeiro	Regulatory agency of Concessioned Public Transport Services (Water, Rail, Metro, and Roads) of the state of Rio de Janeiro
ANAC	Agência Nacional de Aviação Civil	National Agency of Civil Aviation
ANTT	Agência Nacional de Transportes Terrestres	National Agency of Land (Ground) Transportation
ARTESP	Agência Reguladora de Transporte do Estado de São Paulo	Regulatory Transport Agency of the state of São Paulo
BCR		Benefit-Cost Ratio
BID	Banco Interamericano de Desenvolvimento	
BNDES	Banco Nacional de Desenvolvimento Economico e Social	
CAPEX		Capital Expenditure
CBD		Central Business District
CNT	Confederação Nacional do Transporte	National Confederation of Transport
CPTM	Companhia Paulista de Trens Metropolitanos	São Paulo Metropolitan Train Company
DENATRAN	Departamento Nacional de Trânsito	National Department of Transport
DER-SP	Departamento de Estradas de Rodagem do Estado de São Paulo	Department of Roads of the state of São Paulo
DETRO/RJ	Departamento de Transportes Rodoviários do Estado do Rio de Janeiro	Department of Road Transport in the State of Rio de Janeiro
DfT		UK Department for Transport
DNIT	Departamento Nacional de Infra-Estrutura de Transportes	National Department of Transport Infrastructure
EMBRATUR	Instituto Brasileiro de Turismo	Brazilian Institute of Tourism
FEA		Financial and Economic Appraisal
GDP		Gross Domestic Product
HS/HSR		High Speed Train/High Speed Rail
IBGE	Instituto Brasileiro de Geografia e Estatística	Brazilian Institute of Geography and Statistics
IBOPE	Instituto Brasileiro de Opinião Pública e Estatística	Brazilian Institute of Public Opinion and Statistics
INFRAERO	Empresa Brasileira de Infra-estrutura Aeroportuária	Airport Infrastructure Company of Brazil
IRR		Internal Rate of Return
MCA		Multi Criteria Analysis
NATA		New Approach to Transport Appraisal (UK Government)

	Portuguese	English
NPV		Net Present Value
OPEX		Operating Expenditure
PDDT-Vivo 2000/2020	Plano Diretor de Desenvolvimento dos Transportes 2000/2020	Transport Development Master Plan Study
PDTU-RMRJ	Plano Diretor de Transportes Urbanos da Região Metropolitana do Rio de Janeiro	Urban Transport Master Plan of the Metropolitan Region of Rio de Janeiro
PITU	O Plano Integrado de Transportes Urbanos para 2020	Integrated Urban Transport Plan for the Metropolitan Region of São Paulo
PPP		Public-Private Partnership
PV		Present Value
SEADE	Fundação Sistema Estadual de Análise de Dados de São Paulo	State Agency of Data Analysis of São Paulo
TAV	Trem de Alta Velocidade	High Speed Train
TOR		Terms of Reference
VfM		Value for Money
VOC		Vehicle Operating Costs
VOT		Value of Time
WEBTAG		The Web-based version of the UK DfT's Transport Appraisal Guidance

IMPORTANT NOTICES

THE CONSORTIUM DOES NOT ADVOCATE OR ENDORSE ANY SPECIFIC TYPE OF HIGH SPEED TRAIN OR TECHNOLOGY; WHEREVER POSSIBLE GENERIC HIGH SPEED RAILWAY SPECIFICATIONS AND STANDARDS HAVE BEEN USED TO DEVELOP ALL ASPECTS OF THIS STUDY INCLUDED IN THIS VOLUME. WHERE REFERENCE IS MADE TO A TYPE OF HIGH SPEED TRAIN OR TECHNOLOGY THIS DOES NOT IMPLY A PREFERENCE OR RECOMMENDATION ON THE PART OF THE CONSORTIUM. ALL JOURNEY TIMES ARE APPROXIMATE AND ARE BASED ON SIMULATIONS UNDERTAKEN BY CONSORTIUM. THEY ARE SUBJECT TO CHANGE DEPENDING ON THE FINAL ALIGNMENT ADOPTED.

1 Overview

1.1 Introduction to TAV Project

1.1.1 In 2008, the Inter-American Development Bank (IDB) commissioned Halcrow Group Ltd and Sinergia Estudos e Projetos LTDA (together the "Consortium") to prepare a feasibility study for a 350km/h high speed railway line connecting the cities of Rio de Janeiro, São Paulo and Campinas[1] in Brazil.

1.1.2 The Consortium has undertaken detailed studies as follows:

- Executive Summary
- Volume 1: Demand and Revenue Forecasts;
- Volume 2: Alignment Optimisation;
- Volume 3: Finance and economics including Concessioning;
- Volume 4: Operations and Technology;
- Volume 5: TAV Capital Cost; and
- Volume 6: Real Estate studies.

1.1.3 Figure 1-1 below shows the overall relationship between each volume.

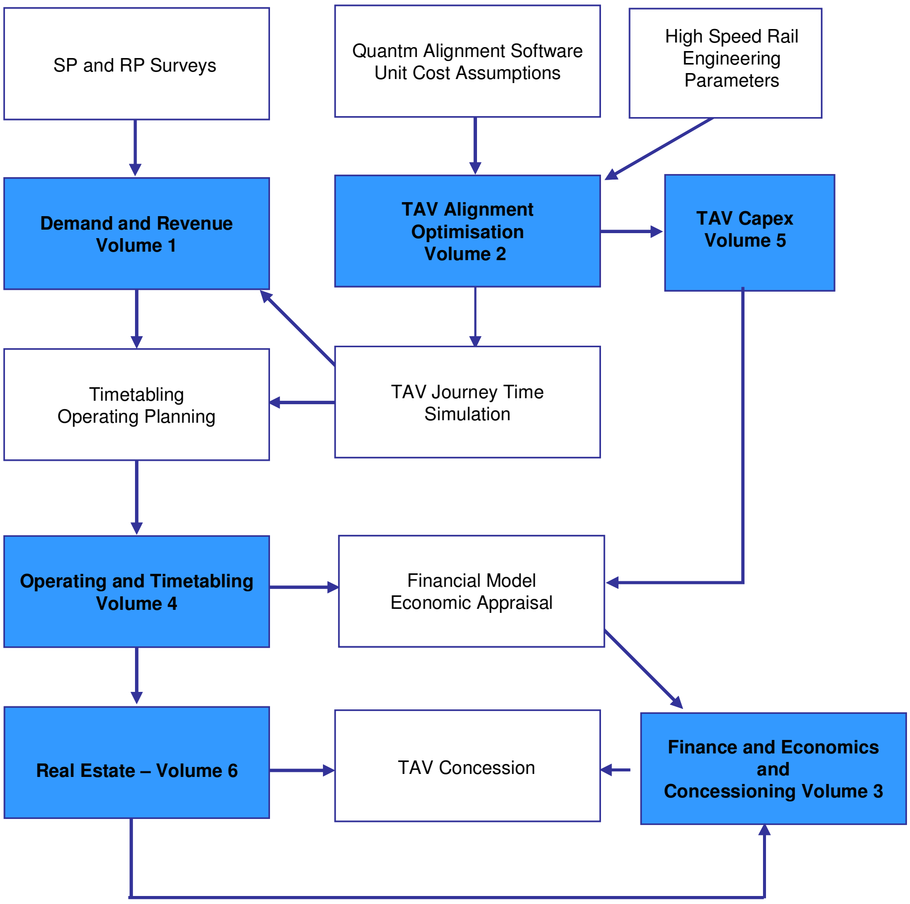


Figure 1-1: TAV Study

[1] Throughout this Executive Summary the project is referred to generically as TAV (*Trem de Alta Velocidade* in Portuguese)

1.1.4 This volume presents the capital costs of building TAV and is organised as follows:

- Chapter 2: TAV Capital Investment Costs; and
- Chapter 3: Results and Conclusions.

1.2 Introduction to High Speed Rail

1.2.1 There is no single accepted definition of what constitutes a high speed railway but generally it refers to trains operating in excess of 200km/h. High speed rail is best suited to city pairs where their distance apart is less than 500km to 600km; beyond this distance, air travel becomes competitive and the relative market share of high speed rail declines.

1.2.2 A number of countries have invested in high speed rail services with Japan and France the leading proponents. Europe has developed an extensive high speed rail network with many thousands of kilometres of track now in operation with commercial speeds varying between 300km/h and 330 km/h, with 300km/h being the most common speed. The recently completed line between Madrid and Barcelona has the potential to run at a higher speed of 350km/h.

1.2.3 The principal characteristics of high speed rail are:

- competitive city centre to city centre journey times compared to air achieved by high speed running;
- very high train capacity with between 450 and 750 seats depending on configuration and length;
- new dedicated fully grade separated alignments operationally independent from existing conventional railway infrastructure, in most cases;
- frequent clock-face services with limited station stops to achieve competitive journey times;
- high levels of passenger comfort including executive and economy classes and catering services;
- high performance and punctuality; and
- conveniently located stations, often with better accessibility compared with airports.

1.3 TAV Engineering Standards

1.3.1 The design for TAV is based on generic high speed rail technology with specific provision for a dedicated, fully segregated alignment to maximise running speed and ensure high operational performance in terms of reliability and punctuality, in accordance with the characteristics set out above.

1.3.2 It is not envisaged in the current feasibility studies that TAV will share any existing track or use joint running with existing Brazilian rail or metro services. The TAV alignment provides for dedicated tracks to the main station in each city with the alignment often located in tunnels in dense urban areas. A schematic layout of TAV is shown in Figure 1-2.

1.3.3 The TAV alignment has been developed based on international high speed line standards, more specifically:

- a maximum design speed of 350 km/h and 1,435 mm gauge with electrified track. **This should not be confused with the maximum operating speed which in this case is set at 300km/h (see section 2.4);**

- a maximum design gradient of 3.5% and 25 ton axle load[2];
- twin and single bore tunnels designed where applicable for 350km/h operation, and a maximum viaduct height of 70 metres for major bridges;
- stations with 'by-pass', or 'through' lines to maintain high speed running and platforms capable of accommodating 400m trains. 'Through' lines avoid the need for trains to slow for safety reasons which would be the case if passing through platforms;
- a signalling system capable of operating at 3 minute headways with in-cab signalling and cab-secure radio;
- TSI Infrastructure Standards (used for operational modelling and CAPEX definition purposes the standard Interoperability of the Trans-European National Standards Organisation, dated 19/03/2008);
- European standards were also used generically for CEN (European Centre for Standardisation), CENELEC (European Committee for Electrotechnical Standardisation, and ETSI (European Telecommunications Standards Institute; and
- UIC (Union Internationale Des Chemins de Fer) leaflets and ABNT (Associação Brasileira de Normas Técnicas) standards.

1.3.4 The precise engineering parameters are set out in the Terms of Reference for this study (Annex 2, Section 2-14).

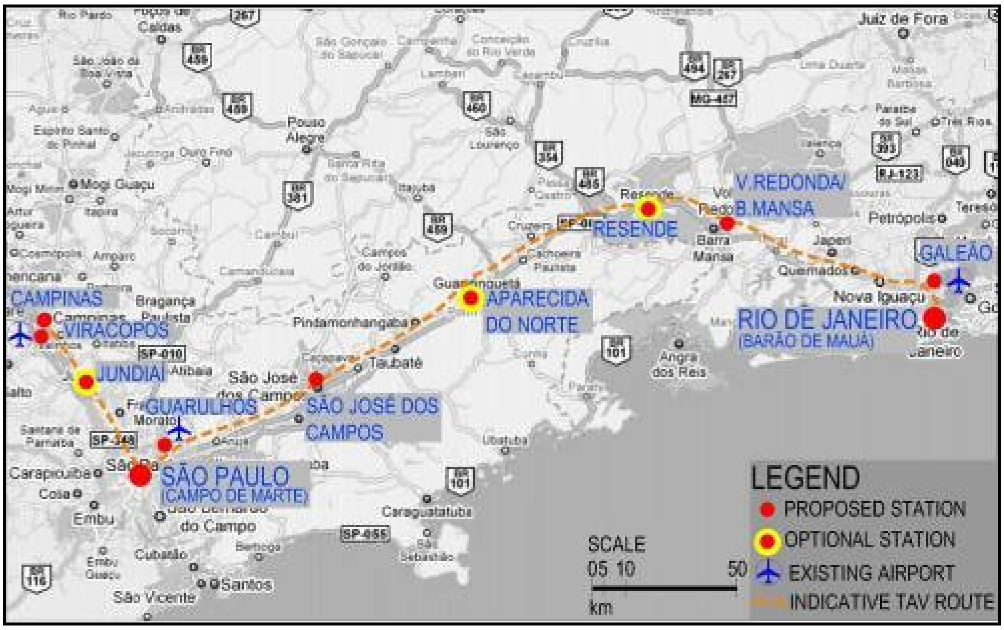
1.4 TAV Alignment and Stations

1.4.1 TAV will run between Campinas, São Paulo and Rio de Janeiro (see Figure 1-2). The TAV alignment developed also fulfils an aspiration to connect the airports of Viracopos, Guarulhos and Galeão with the major urban areas. The total estimated distance between Campinas and Rio de Janeiro is 511 km, while the distance between São Paulo and Rio de Janeiro is approximately 412 km. There are eight proposed/mandated stations in the base case and three further optional stations. Optional stations are shown in yellow in Figure 1-2.

1.4.2 Based on the TAV alignment developed, the non-stop journey time between the two cities is estimated at approximately 1 hour 33 minutes based on 300km/h operation. It is important to stress that TAV journey times will vary depending on the number of stations stops, with Regional long distance services between Rio de Janeiro to Campinas taking up to 2 hours 23 minutes. All journey times are approximate and are dependent on the final alignment, stopping patterns, and train performance including maximum speed, braking and acceleration characteristics. **The journey times shown in this report are therefore indicative and have been developed to assess the overall feasibility of the project**.

[2] Please note that HSR trains commonly have an axle weight of circa 17 tons. Recent Japanese high speed trains have an even lower axle load at 11 tons. However, during construction and maintenance periods freight trains would be used, which have a higher axle load, but lighter axle loads during actual operation will have an impact on track wear and maintenance. The axle load of 25 tons is specified in the Terms of Reference (Annex 2 - Section 2-14).

Figure 1-2: TAV Schematic



1.4.3 TAV will have a mix of new and refurbished stations and a new purpose built alignment. In Rio de Janeiro there are plans to refurbish and rebuild the abandoned station at Barão de Mauá (km 0[3]) which is close to the main bus station at Novo Rio. Provision has also been allowed for a light[4] maintenance facility and stabling sidings at Barão de Mauá. The next station is a new underground station to serve Rio de Janeiro's international airport at Galeão (km 15.2). From Galeão the line climbs through the mountainous region of Sierra das Araras which is the major engineering challenge, requiring numerous sections of tunnels and viaducts.

1.4.4 A further station is planned at Volta Redonda/Barra Mansa (km 118.3), located within the state of Rio de Janeiro. Volta Redonda is an important industrial area with Latin America's largest steel mill. There is also provision for an optional station in the future at Resende[5], to the west of Volta Redonda/Barra Mansa.

1.4.5 Travelling westwards TAV then crosses the state border between São Paulo and Rio de Janeiro states. Provision has been made for a possible spur from the main alignment to serve a new optional station at Aparecida. Aparecida is an important pilgrim site which generates 9.5 million visitors per year (2008).

1.4.6 After Aparecida TAV then reaches the large industrial city of São José dos Campos (km 328.7). São José dos Campos is an important centre for high technology centred on aerospace and engineering, with a population of 1.4 million. This city is the proposed location of the rolling stock maintenance depot, as it has access to the main highway network, has a well developed regional airport, houses the Embraer assembly factory and has available land to accommodate high impact land use.

1.4.7 Westwards from São José dos Campos the next station is at São Paulo's international airport at Guarulhos (km 390.4), which will be built underground.

[3] All distances are from Barão de Mauá at Rio de Janeiro.

[4] The terms 'light' and 'heavy' maintenance are used as follows. 'Light' maintenance refers to cleaning, maintenance checks and watering of trains, while 'heavy' maintenance refers to major maintenance such as removal of bogies, wheel turning, major service checks and so on. Stabling sidings are required at all major terminal stations so that trains can be prepared for service.

[5] The alignment has been straightened to allow for a station at Resende.

1.4.8 Upon reaching São Paulo, a preferred station site has been identified at Campo de Marte (Km 412.2), which is currently a federal airfield in the north of the city. In the Consortium's opinion, the selection of Campo de Marte provides an opportunity to build a major land mark station, but improvements will be needed to deal with the distribution of passengers within São Paulo, as the site is not served by the metro system.

1.4.9 Campo de Marte station will have a number of 'through' platforms to allow trains to run from São José dos Campos to São Paulo and then north westwards towards Campinas, without reversing.

São Paulo to Campinas

1.4.10 From São Paulo, the TAV alignment then turns north westwards towards Campinas. Further analysis was undertaken by the Consortium to examine the potential to reduce the maximum line speed between Campo de Marte and Campinas. Given concerns over the high overall construction costs, reducing the maximum line speed is a potential strategy to reduce the capital cost by allowing TAV to avoid natural obstacles rather than use tunnels or bridges to meet strict geometric criteria for 350km/h running. This is also sensible from a demand perspective because even at relatively modest speeds, TAV will enjoy considerable competitive advantage over existing bus and car modes because of traffic congestion in the corridor between Campinas and São Paulo. However, due to the topography between São Paulo and Campinas, which contains a series of small hills lying across the alignment, a significant speed reduction, potentially below 100km/h, would be required before any real cost savings could be achieved and for this reason no further analysis was undertaken. Reducing the maximum line speed of this section to Campinas would also impact on any future aspirations for TAV to serve stations beyond Campinas in future projects.

1.4.11 On the alignment there is provision for an optional parkway style station at Jundiaí, located between Anhanguera and Bandeirantes highways. The TAV alignment then proceeds northwards to include a further station at Viracopos airport (Km 487.6). Thus the TAV alignment fulfils an aspiration of the Government to connect the airports of Viracopos, Guarulhos and Galeão with the major urban areas. The final station is at Campinas (Km 510.7), the third largest city in the state of São Paulo after São Paulo and Guarulhos. This will also be a refurbished station including stabling sidings.

2 TAV Capital Investment Costs

2.1 Introduction

2.1.1 The TAV project will involve the construction, equipping and operation of a new high speed railway. The objective of this volume is to describe the analytical and empirical process carried out to estimate the capital cost associated with the TAV Project.

2.1.2 This section provides an analysis of the following areas:

- Uncertainties associated with cost estimation;
- Accuracy and assumptions involved in the analysis;
- Source of Quantities;
- Source of Unit Costs; and
- Assumptions adopted to estimate all categories of cost.

2.2 Uncertainties associated with cost estimation

2.2.1 Estimating the capital cost of a project can arguably be the most critical and difficult element of any engineering project, mainly due to the following factors:

- Published data available in the form of technical journals and papers usually present overall costs excessively aggregated, due to the need of the publisher to presere intellectual property rights, thereby securing a commercial benefit;
- Lack of similar projects in the area under analysis, making the compilation of reliable cost information difficult. Although similar schemes are running in parallel in many countries in the region (Argentina, Mexico, United States, etc.), there is at present no high-speed rail line operating in the Continent;
- Although the technology applied to high-speed rail shares many common aspects with conventional railways, which facilitates estimating the costs of the system, some of their elements are significantly different. This is the case of the signalling system, for instance. Opposite to conventional lines, where the signals are displayed by a combination of devices located inside and outside the train cab, communication in high-speed railways is almost entirely integrated in-cab; and
- The lapsed time between the initial cost estimates and the opening of the scheme creates an array of uncertainties that often drive modifications to the final cost of the scheme, such as improvements in technology, changes in the local and international economy, new constraints generated along the proposed alignment, etc. This is the case in particular for very large scale projects, such as TAV, as the construction period is extended over time and the footprint area is also larger, which frequently gives rise to additional contingencies.

2.2.2 Benchmarking similar projects is a suitable exercise to validate engineering schemes, as it allows a crosscheck of the results and ensures the project is within an expected range of costs. Section 3 shows the results obtained when benchmarking TAV against similar systems.

2.3 Accuracy and assumptions involved in the analysis

2.3.1 The TAV project is at the feasibility stage where some key areas have been developed in greater detail than others. For example, more effort has been spent developing a TAV alignment as this is the single largest cost item and carries the greatest project risk. Other costs, such as stations, are smaller as a proportion of total cost and therefore do not warrant detailed analysis at this stage. The principal objective of this analysis is to assess the overall economic viability of the TAV project with a reasonable level of accuracy before proceeding to more detailed studies.

2.3.2 Should the government decide to proceed with this project beyond the scope of this current study, to the design and implementation stages, a more detailed analysis of all engineering disciplines involved will be required. Although this study aims to provide a reasonable estimation of costs for each category of expenditure (alignment, electrification, rolling stock, etc.), further cost refinements can only be obtained once the detailed design of all elements of the project are completed, including construction technology and the estimation of resources.

2.3.3 To obtain reliable unit costs, inputs provided by local Brazilian specialists were applied. However, inevitably in some cases it has been necessary to use international costs converted into Brazilian Reais (R$), as the TAV system is based on international technology and much of the equipment will need to be imported.

2.3.4 All prices are in 2008/09 values and where other estimates have been used, these have been inflated appropriately, under the assumption that an identical inflation rate applies to all costed items, which is a common approach for feasibility studies. Table 2-1 shows the exchange rates used for converting costs into R$.

Table 2-1: Exchange Rates 2009

Currency	Rate
Exchange rate GBP (£) to Brazilian R$	3.46
Exchange rate Euro (€) to Brazilian R$	2.90
Exchange rate US Dollar (US$) to Brazilian R$	2.55

2.4 Source of Quantities

2.4.1 With respect to quantities, three sources of information were used, as follows:

- **Quantm software output** (validated by Halcrow specialists). As Quantm specifically covers the study of the alignment, this tool was only applied to derive quantities related to these costs. This software produces a summary report (see Figure 2-1 below) that includes all the quantities applied to each of the items included in the cost analysis performed by the software. For further detail on Quantm software, please refer to Volume 2;
- **Engineering analysis.** Whenever the Quantm process was not applicable, the source of quantities was obtained from engineering estimations based on data obtained from the alignment and operation studies, as it is better described below; and
- **Other sources.** The socio-environmental analysis for this project was outside the scope of works of the Consortium. However, following the request of the Client, the costs obtained by the Brazilian consultant Prime Engenharia, responsible for this study, were included in the Capital Cost estimation. The Consortium has not performed a validation on these quantities.

2.4.2 Table 2-2 presents a summary of capex data sources for quantities and unit costs.

Figure 2-1: Sample Quantm Summary Report[6]

```
Quantm Alignment Summary Report
Date:                   06/23/09 14:49:04

Project:                Brazil TAV
Project ID:             1642
Scenario:               TAV SP 101_5
Alignment:              Track Centre Lines
```

Item	Quantity		Cost
Cut	38,200,000	m3	1,640,000,000
Tunnel Debris	1,020,000	m3	0
Import Vol	0	m3	0
Borrow	2,190,000	m3	54,300,000
Fill	25,700,000	m3	505,000,000
Export Vol	0	m3	0
Dump	15,700,000	m3	325,000,000
Paving	549,000	m3	62,900,000
Mass Haul	381,000,000	m3 km	781,000,000
Ret. Wall	102,000	m2	94,200,000
Culvert	0	m	0
Bridge	111,588	m	8,570,000,000
Tunnel	13,193	m	2,140,000,000
Area	13,600,000	m2	723,000,000
Linear	219,240	m	0
Fixed Cost			0

2.5 Source of Unit Costs

2.5.1 Various sources were consulted in order to obtain the appropriate rates for each item.

- **Halcrow specialists/Internal record:** The extensive experience of Halcrow in rail projects worldwide provided a solid source of data, in particular for those categories where international rates were considered applicable. For items such as Signaling and Telecommunications, the analysis was also supported by inputs provided by external specialists.
- **Published information:**

  A. Technical journals. A research using international publications was conducted in order to support the estimation of unit rates. However, in many cases, the costs provided in these publications had such a high level of aggregation that makes it difficult to extract reliable results. Without a proper analysis of the collected data, there is a risk of comparing elements that might appear to be similar but which actually have key differences;

  B. Franklin and Andrews Spon's[7] series: Some items were estimated using the Franklin and Andrews Spon's series of Construction Price books, and following a validation exercise, these unit costs were converted into suitable equivalent costs to reflect the Brazilian price market. This validation process was performed against

[6] The quantities and costs shown in this table are illustrative only.

[7] Spon's books are considered a valid source of reference as they are built up from years of specialist experience and understanding of the key drivers and components that affect the cost of railway projects. Their recent experience in high-speed railway projects includes an extensive review of the estimated costs of the Channel Tunnel Rail Link.

known projects with specialist input from Halcrow's Engineers, to ensure they are applicable to High Speed Line construction.

- **Third parties:**

  A. PROMPT Engenharia Ltda. This firm has been hired by the Brazilian Government to review the unit costs associated to this project. Their rates are mainly based on those published in SICRO 2 (Sistema de Custos Rodoviários) of São Paulo, updated to December 2008. Appendix G includes a report produced by PROMPT describing the source of the rates they have estimated.

  B. PRIME Engenharia. As mentioned above, the socio-environmental study of this project was outside the scope of works of the Consortium. The rates included in this category have been provided by the consultant Prime Engenharia. The Consortium has not performed a validation on these rates.

2.5.2 Table 2-2 presents a summary of Capex data sources for quantities and unit costs.

Table 2-2: Source of data for quantities and rates

Category	Source of Quantities	Source of Unit Costs
Earthworks (cut, fill, etc)	Quantm software	Prompt Engenharia
Structures – Bridges & Tunnels	Quantm software	Prompt Engenharia
Permanent way	Length of alignment: from Quantm Quantity of crossings: from Vol 4 - Operations study	Halcrow + Prompt Engenharia
Stations	Surface requirements for each station based on ridership forecast	Local specialists in real estate + Halcrow
Depots	Characteristics of heavy and light depots	Local sources + Halcrow
Signalling & telecommunications	S&T specialists (ISV)	S&T specialists (ISV) validated by Halcrow
Electrification	Halcrow, based on characteristics of the route	Halcrow
Socio-environmental costs	Prime Engenharia	Prime Engenharia
Rolling stock	Timetable generated by VoyagerPlan software	Halcrow – Benchmark of HS trains in several systems world-wide

2.6 Organisation of costs and contingency

2.6.1 The costs are organised in the following categories:

- Civil Engineering Works (Earthworks, Structures)
- Permanent Way;
- Buildings and Equipments;
- System Elements (Signaling, Telecommunication, Electrification);
- Socio-environmental Works;

- Rolling Stock; and
- Complementary services (Testing and certification, Geotechnical studies, Utility diversion, Temporary works during construction, Permanent road access to bridges and tunnels, Design, Project management)

2.6.2 In view of the inherent uncertainties, it is standard practice to include a contingency factor during the feasibility stage. In this capital cost estimation, a specific factor was assigned to each category of costs. Known specific risks include geological conditions, cost data limitations and the accuracy of the Digital Elevation Model and orthophotos applied to the alignment studies. As stated in section 3.2, significant engineering survey work will be required to improve the accuracy of all the costs estimated at this stage.

2.6.3 However, the contingencies were not included in this cost estimate, following the guidelines of the Federal Government, in view of risk sharing through public participation in this project.

2.7 Civil Engineering Works

2.7.1 The Civil Engineering Works costs are split into 2 categories, as shown below:

- Earthworks, which includes: site clearance, planting on banks, fill, cut, borrow, dump and mass haul
- Structures, which includes: tunnelling, bridges and retaining walls

Earthworks costs

Earthworks: Site Clearance

2.7.2 This item refers to the surface that needs to be cleared to enable the start of the works. For this reason, when estimating this area the underground track sections have been excluded.

2.7.3 The unit cost applied for this item is R$ 0.29 per square metre (m^2). This rate has been provided by PROMPT Engenharia.

Earthworks: Planting on banks

2.7.4 This item refers to the planting of vegetation on the sides of the cutting or embankment areas, to protect the bank works from erosion.

2.7.5 The unit cost applied for this item is R$ 1.05 per square metre (m^2). This rate has been provided by PROMPT Engenharia.

Earthworks: Fill

2.7.6 This item refers to the act of building the embankments along the TAV route, from the level of natural/excavated terrain up to the proposed level of the under side of ballast, and is measured as the volume of cubic metres required to complete this task.

2.7.7 This volume is estimated by Quantm, based on the typical cross sections shown in Volume 2 Alignment Studies, Appendix C.

2.7.8 The unit cost applied for this item is R$ 2.71 per cubic metre (m^3). This rate has been provided by PROMPT Engenharia.

2.7.9 The cost of labour and plant required to perform this task is included in this rate. No allowance for material and/or transportation has been included, as they are being covered by other Earthwork items mentioned in this section, namely Borrow and Mass haul.

Earthworks: Cut

2.7.10 This item refers to the act of excavating the natural terrain along the TAV route up to the proposed level of the under side of ballast, in those sections where cutting works are required, and is measured as the volume of cubic metres required to be excavated to complete this task.

2.7.11 This volume is estimated by Quantm, based on the typical cross sections shown in Volume 2 Alignment Studies, Appendix C.

2.7.12 Two different unit costs were applied for this item, depending on the characteristics of the excavated land:

- cut in soil: R$ 8.19 per cubic metre (m^3); and
- cut in rock: R$ 22.61 per cubic metre (m^3).

2.7.13 These rates have been provided by PROMPT Engenharia. In the case of cut in soil, PROMPT has presented a separate rate for cutting in 1st and 2nd Category soils, which has been merged into a single rate assuming the following average composition of the ground:

- 1st Category: 25%
- 2nd Category: 65%
- 3rd Category: 10%

2.7.14 The cost of labour and plant required to perform this task is included in this rate. No allowance for transportation has been included, as this is being covered by other Earthwork items mentioned in this section, namely Mass haul and Dump.

Earthworks: Borrow

2.7.15 This item refers to the volume of soil required to be imported from external sources, for those cases where this volume cannot be extracted from the TAV construction site.

2.7.16 This volume is estimated by Quantm, based on the typical cross sections shown in Volume 2 Alignment Studies, Appendix C.

2.7.17 The unit cost applied for this item is R$ 6.70 per cubic metre (m^3). This rate has been provided by PROMPT Engenharia.

2.7.18 Included in this rate is the cost of material, labour and plant required to extract and haul the required volume of soil to the site where it needs to be deposited.

Earthworks: Dump

2.7.19 This item refers to the volume of soil required to be exported to external sites, for those cases where this volume cannot be utilised to build embankment for this project.

2.7.20 This volume is estimated by Quantm, based on the typical cross sections shown in Volume 2 Alignment Studies, Appendix C.

2.7.21 The unit cost applied for this item is R$ 1.78 per cubic metre (m^3). This rate has been provided by PROMPT Engenharia.

2.7.22 Included in this rate is the cost of labour and plant required to haul the required volume of soil to the external site where it needs to be deposited, plus royalty costs if applicable. No allowance for excavation has been included, as this is being covered by another Earthwork item mentioned in this section, namely Cut.

Earthworks: Mass Haul

2.7.23 This item refers to the volume of soil that is excavated in one site of the route and later applied as Fill in a different section within the proposed alignment. This is a parameter used by Quantm, which also provides the volume associated to it.

2.7.24 This volume is estimated by Quantm, based on the typical cross sections shown in Volume 2 Alignment Studies, Appendix C.

2.7.25 PROMPT has presented a separate rate for mass haul for each category of soil being transported, which has been merged into a single rate assuming the average ground composition mentioned above in 2.7.13:

- 1st Category: 25%
- 2nd Category: 65%
- 3rd Category: 10%

2.7.26 The resulting average rate applied for this item is R$ 0.40 per kilometer of hauled volume ($km.m^3$).

2.7.27 Included in this rate is the cost of labour and plant required to haul the required volume of soil from an excavation site to an embankment one, both located within the TAV route. No allowance for material, excavation or deposit of the hauled volume has been included, as this is being covered by other Earthwork items mentioned in this section, namely Cut and Fill.

Structures costs

2.7.28 This category comprises the following items:

- tunnelling,
- bridges and viaducts and
- retaining walls

Structures: Tunnelling

2.7.29 Two different tunnelling approaches have been applied to the project. In those areas where it is required to tunnel below the water table or sensitive structures (urban areas), a twin bore tunnel has been assumed as this allows reduced cover (reduced depth) and therefore produces a less significant total settlement, compared to a larger diameter single bore with a twin track. In rural areas, where there are less sensitive structures and less (or nil) settlement mitigation is required, a single bore tunnel with twin track is assumed.

2.7.30 It should be noted that different tunnel arrangements may be used in specific circumstances, as follows:

- **Lower speed sections.** In the case of urban areas, reduced tunnel sections can be applied, as lower maximum speeds are expected. For example, for services departing from Barão de Mauá towards Galeão Airport, trains will be accelerating and will not reach their maximum speed for a number of kilometres, and the reverse will obviously apply as TAV trains approach Barão de Maura. Similar considerations are valid in other areas, such as the Campo de Marte – Campinas section. As a result of these slower speeds, the cross sectional area of the tunnels can be reduced in these urban areas, from the design advocated for 350km/h running, thus reducing the cost of tunnelling.
- **Construction methodology.** Although this will ultimately be a decision for the bidders, for the purpose of estimating the appropriate rates for tunnelling, the following general methodology was assumed:
  - (a) Tunnels will be constructed with one of the following technologies: NATM (New Austrian Tunnelling Method) or TBM (Tunnel Boring Machine). A brief description of them, together with their expected performance, is provided in Volume 4, Part II, Appendix A.
  - (b) Based on Halcrow's tunnelling experience, the cut-off point between the use of these technologies is set at a tunnel length of 1.5km (>1.5km TBM, <1.5km NATM)

2.7.31 All of the above assumptions have been considered when analysing the best way to estimate the tunnel cost, in order to get a degree of accuracy commensurate with a feasibility study.

2.7.32 The following items are considered included in the rates below:

- Portals
- Secondary lining (only applicable to NATM)
- Ground treatment and settlement mitigation (in Urban areas only)
- Escape Shafts for single bore, 1 per km (i.e. maximum 500m from either portal or shaft)
- Cross Passages for twin bore, 1 per km (i.e. maximum 500m from a cross passage or portal)
- Escape/Ventilation Shafts 1 per 2 km (i.e every other escape shaft is also a ventilation shaft)

2.7.33 Costs do not to include electrification, signalling, track fitting, etc., as they are considered separately.

2.7.34 Table 2-3 below compiles the set of tunnel rates used to estimate the capital cost of tunnelling. These rates were produced by PROMPT Engenharia based on the above assumptions.

2.7.35 Appendix C in Volume 2 (Alignment Studies) shows typical cross sections for single and twin bore tunnels. The quantities applied for this item, included in the CAPEX table, were taken from the Summary Report produced by Quantm. A detailed list of the tunnels considered in this cost is included in Appendix B, describing its length, location, characteristics (soil/rock – urban/rural) and cost.

Table 2-3: Tunnel rates applied in the Capex analysis

Item	Unit	Rate (R$)
Urban area		
Soft ground - Twin bore – Φ 7.85m - NATM (Rate for two tracks)	m	133,713
Soft ground - Twin bore - Φ 7.85m – TBM (Rate for two tracks)	m	83,530
Rural area		
Soft ground - Single bore - Φ 16m - NATM	m	166,355
Soft ground - Single bore - Φ 16m - TBM	m	124,802
Rock - Single bore - Φ 16m - NATM	m	159,325
Rock - Single bore - Φ 16m - TBM	m	106,251

Structures: Bridges and viaducts

2.7.36 The deck area of bridges and viaducts was estimated by Quantm based on the typical cross section shown in Volume 2 (Alignment Studies) – Appendix C.

2.7.37 Quantm requires the unit cost to be input as a rate per square meter, but the results included in its Summary Report represent the total quantity in linear metres (m). In order to keep the consistency in the Capex Table (Appendix A), and following traditional engineering standards, the quantities for bridges have been transformed back into area of deck.

2.7.38 The unit cost applied is R$ 4,745 per square metre (m^2) of deck and has been provided by PROMPT Engenharia.

2.7.39 The above rate includes the following components:

- earthworks and site clearance;
- concrete works: blinding, piles base, footings, pile caps, suspended slabs, walls, columns and piers, beams and casings;
- concrete ancillaries: formwork, reinforcement (foundations, slabs, walls, columns, beams), designed joints, surface finishes and grouting; and
- Deck concrete, steelworks and bearings

2.7.40 At the end of Phase F (See Volume 2 – Alignment Studies) new Geological Information was made available for the area of the TAV alignment between Lorena and Jacarei. Within this information areas of Peat Bog (Turfas) were specifically identified as areas to be avoided because of the poor ground conditions. However, this information has come too late to find a new alignment within the scope of these studies

2.7.41 For the purpose of calculating the capital cost, the use of embankment was considered along this section. When detailed ground investigation is carried out this will enable a greater understanding of the potential for alternative engineering solutions to be used.

2.7.42 A detailed list of the bridges and viaducts considered in this cost is included in Appendix B, describing its length, location and cost.

Structures: Retaining Walls

2.7.43 The area of retaining walls was estimated by Quantm. The unit cost applied for this item is R$ 881 per square metre (m^2). This rate has been provided by PROMPT Engenharia.

2.7.44 The above rate refers to a 1.8m height reinforced in-situ concrete retaining wall and includes:

- excavation;
- reinforcement;
- formwork;
- expansion joints;
- concrete;
- granular backfill;
- drains; and
- profiled finish to one side.

Structures - Summary of costs

2.7.45 Table 2-4 below summarises the quantities and rates applied to each of the above items and the corresponding cost obtained.

Table 2-4: Summary of Civil Engineering Works costs

No	Item	Unit	Unit Cost (R$)	Quantity	Total Cost (R$ billion)
A	**Earthworks**				
1	Site clearance	m^2	0.29	22,637,692	0.01
2	Planting on banks	m^2	1.05	12,355,462	0.01
3	Fill	m^3	2.71	97,935,373	0.27
4	Cut			90,308,265	1.03
4a	In soil	m^3	8.19	70,194,575	0.57
4b	In rock	m^3	22.61	20,113,690	0.45
5	Borrow	m^3	6.70	37,436,649	0.25
6	Dump	m^3	1.78	36,679,681	0.07
7	Mass haul	m^3.km	0.40	1,445,136,504	0.58
	Subtotal A				**2.21**
B	**Structures**				
1	Tunnelling	m		90,912	10.75
1a	Urban area	m		46,578	*4.04*
	Soft ground - Twin bore – Φ 7.85m - NATM (Rate for two tracks)	m	133,713	2,985	*0.40*
	Soft ground - Twin bore - Φ 7.85m – TBM (Rate for two tracks)	m	83,530	43,593	*3.64*
1b	Rural area	m		44,334	*6.71*
	Soft ground - Single bore - Φ 16m - NATM	m	166,355	16,338	*2.72*
	Soft ground - Single bore - Φ 16m - TBM	m	124,802	2,440	*0.30*
	Rock - Single bore - Φ 16m - NATM	m	159,325	18,384	*2.93*
	Rock - Single bore - Φ 16m - TBM	m	106,251	7,172	*0.76*
2	Bridges and viaducts	m^2	4,745	1,499,878	7.12
3	Retaining Walls	m^2	881	322,954	0.28

No	Item	Unit	Unit Cost (R$)	Quantity	Total Cost (R$ billion)
	Subtotal B				**18.16**
	TOTAL				**20.36**

2.8 Permanent way

2.8.1 This category comprises the following items:

- plain line track;
- switches and crossing;
- drainage and
- fences

Permanent way: Plain Line Track

2.8.2 The length of the route was obtained from the alignment studies and can be estimated in 510.7km.

2.8.3 The unit cost applied for this item is R$ 1.55 million per km of single track. This rate has been provided by PROMPT Engenharia.

2.8.4 The above rate includes:

- rails (CEN60E1);
- sleepers;
- fastenings;
- ballast (top and bottom);
- Terram;
- expansion joints;
- buffer stops;
- track laying (labour and plant); and
- lift and slue.

Permanent way: Switches and Crossings

2.8.5 Based on the Proposed Route Layout (Volume 4 – Figure 2-2), the number of switches and crossings was estimated at 250. To get the total cost of this item, a rate of R$ 1.1 million per unit has been applied, based on Spon's books inputs and Halcrow international experience.

Permanent way: Drainage

2.8.6 The unit cost applied for this item is R$ 631,309 per route km. This rate has been provided by PROMPT Engenharia. Applying this rate to the track proposed at surface level, the total cost for this item equals to R$ 242.4 million.

Permanent way: Fences

2.8.7 The length of fences required to delimit the permanent way was calculated taking into consideration the total length of the route that runs on surface level.

2.8.8 The unit cost applied for this item has been provided by PROMPT Engenharia and equals to R$ 48.9 per metre (m). Applying this rate to the track proposed at surface level, the total cost for this item equals to R$ 37.6 million.

2.8.9 The above rate refers to a 2.10m high fencing formed by concrete posts with steel extensions arms at 3m centers.

Permanent way - Summary of costs

2.8.10 Table 2-5 below summarises the quantities and rates applied to each of the above items and the corresponding cost obtained.

Table 2-5: Summary of Permanent Way costs

No	Item	Unit	Unit Cost (R$)	Quantity	Total Cost (R$ billion)
1	Plain line track (per single-track km)	km	1,556,637	1,022	1.59
2	Switches and Crossings	unit	1,073,600	250	0.27
3	Drainage	km	631,309	384	0.24
4	Fences	m	49	767,935	0.04
	TOTAL				**2.14**

2.9 Buildings and Equipments

2.9.1 This category comprises the following items:

- stations and
- maintenance depots

Buildings and Equipments: Stations

2.9.2 The area required for each station was estimated based on the expected ridership and the number of platforms planned for each of them.

2.9.3 To estimate the cost of this item, the following areas were defined for every station, each of them being assigned a unit rate per square metre, based on Brazilian costs, as shown on Table 2-6.

2.9.4 The total surface and cost estimated for each station is shown in Appendix C.

2.9.5 Table 2-7 summarises the cost per station, including the estimated cost for upgrading them in years 2024 and 2034, to cope with the increase in demand.

Table 2-6: Cost assumptions applied to stations

	Ground Level	Underground	Structured (elevated)
Agulha / Station Building (R$/m^2)	1,100	0	1,500
Platform Shelter (R$/m^2)	350	0	0
Platforms (R$/m^2)	550	4,500	800
Landscaped Area (R$/m^2)	300	0	0
Parking Area (R$/m^2)	160	0	550

Table 2-7: Capital cost estimated for each station

Station	Capital Cost (R$ 000)		
	2014	Upgrade 2024	Upgrade 2034
Barão de Mauã (RJ)	71,364	9,100	9,472
Galeão Airport (RJ)	95,207	195	1,102
Barra Mansa Volta Redonda (RJ)	16,735	1,820	464
São José dos Campos (SP)	44,649	4,410	3,692
Guarulhos Airport (SP)	105,274	420	3,856
Campo de Marte (SP)	234,950	9,592	16,204
Viracopos Airport (SP)	97,717	0	1,498
Campinas (SP)	44,101	13,556	11,313
TOTAL	**709,997**	**39,093**	**47,599**

2.9.6 The following considerations were applied when estimating the cost of the stations:

- Costs are estimated in order to allow for a generic analysis. Closer-to-reality estimates will be enabled by masterplans;
- Costs for Agulhas / Station Buildings include M&E. Specific rail structures and M&E are NOT included in the costs of platforms as they are being considered under System Elements costs;
- Cost estimates are based on 6 main components to which external costs have been added (road access, environmental costs, infrastructure costs, local transport infrastructure, etc). These have been estimated as a percentage of the main costs;
- Landscaped areas have been estimated at 20% of the station and platform buildings' area for year 2014, value decreasing to 15% for the station upgrades planned for years 2024 and 2034; and
- Parking areas have been calculated at the initial rate of 1 space/25m^2 of Gross Leasable Area (GLA) for year 2014 and at 1 space/30m^2 of GLA for the station upgrades planned for years 2024 and 2034. GLA stands for, corresponding to circa 2/3 of the Agulha total area.

Buildings and Equipments: Maintenance Depots

Main and subsidiary depots – Civil works

2.9.7 As shown in the Proposed Route Layout (Volume 4 - Figure 2-2), it is envisaged that a Heavy Maintenance Depot will be constructed at São José dos Campos and three Light Maintenance Depots located at Barão de Mauá, Campo de Marte and Campinas.

2.9.8 A unit rate of R$ 900 per square metre provided by local sources was applied for the civil construction of a depot building. An additional 20% was added to cater for environmental mitigation, giving an estimated cost of R$ 1,080 per square metre.

2.9.9 In order to estimate the surface of the depots, the following estimations were applied:

- The analysis is based on the total fleet expected for year 2034 (82 train sets);
- Each train set requiring some form of servicing/inspection every 7 days; and
- 12 train sets required to be in the maintenance depot everyday, allowing for 2 train sets lasting longer than 24 hours and some additional spare capacity

2.9.10 Considering the above, the depot would require eight line sheds with 450m long roads. On top of this, it would also need some stabling sidings to allow for train movements. Based on these assumptions, the following areas have been estimated:

- Light maintenance depot: 5,625 m^2 (225m x 25m) each; and
- Heavy maintenance depot: 22,500 m^2 (450m x 50m);
- Total area: 39,375 m^2

2.9.11 The cost of civil works to build these depots was therefore estimated in R$ 42.52 million.

2.9.12 The depots would also require additional facilities, such as amenities blocks with offices, workshops, mess facilities, toilets, showers, locker rooms, training rooms, driver accommodation, stores, car parking, security and other ancillary buildings. For this reason, a 60% uplift was introduced, bringing the total value to R$ 68.0 million.

Main and subsidiary depots – Maintenance equipment

2.9.13 This item refers to all heavy and light maintenance equipments required to maintain and overhaul rolling stock, track infrastructure, signalling and telecommunications systems and the electrification system.

2.9.14 A list of the main plant and equipment being considered in this cost is provided in Appendix D.

2.9.15 A global cost for this provision was estimated in R$ 450 million.

2.9.16 The cost for System Elements provided below includes an allowance for those facilities/equipments associated with the Depots. The OLE (Overhead Line Equipment), for instance, includes a 2% uplift to cover for the extra OLE that may be used within depots. Substation costs are also inclusive of depot traction supply. Wherever possible, substations (ATS or ATFS) should be sited as close as possible to the proposed depot in order for the electrified sections to be sectioned from the main high speed running line.

Engineering depot and stabling sidings

2.9.17 The length of single track designed for sidings was estimated in 82km, based on the siding provision detailed in the Proposed Route Layout (Volume 4 - Figure 2-2). The same unit rate applied to plain line track was used at R$ 1.55 million per km of single track.

Locomotives

2.9.18 Three locomotives, used to rescue failed trains, are being considered as a requirement for year 2014. To cope with the increase of fleet size expected in the following years, the addition of one unit in year 2034, bringing the total to four, has also been considered. The cost per unit was estimated in R$ 20.7 million.

Summary of civil construction facilities costs

2.9.19 Table 2-8 below summarises the quantities and rates applied to each of the above items and the corresponding cost obtained.

Table 2-8: Summary of Building and Equipments costs (Year 2014)

No	Item	Unit	Unit Cost (R$)	Quantity	Total Cost (R$ billion)
1	Stations (Eight)	global	709,996,822	1	0.71
2	Maintenance depots				0.71
2a	Civil works	global	68,040,000	1	*0.07*
2b	Maintenance equipment	global	450,000,000	1	*0.45*
2c	Engineering depot and stabling sidings	km	1,556,637	82	*0.13*
2d	Locomotives	unit	20,700,000	3	*0.06*
	TOTAL				**1.42**

2.10 System Elements

2.10.1 System Elements costs are split into 3 categories, as shown below:

- Signalling
- Telecommunications
- Electrification

A description of each category is provided below.

Signalling and Telecommunications

2.10.2 The German firm ISV (Ingenieurgesellschaft für Schienenverkehrstechnik mbH) was appointed by the Consortium to conduct a study on Signalling and Telecommunications applicable for this project. They are a recognised expert by the Eisenbahn-Bundesamt (German Federal Railway Authority). The conclusions of this study can be found in Appendix E.

2.10.3 As part of this study, ISV provided a detailed estimation of Signalling and Telecommunications costs, which was reviewed by Halcrow specialists and then incorporated to the total cost of the project, as shown in Table 2-9.

Electrification

2.10.4 The cost of electrification was estimated by Halcrow specialists, and is broken down into the following subcategories:

- Catenary;
- ATFS: Grid Substations and traction feeder station; and
- ATS: Small Substations/Mid-Point substations.

2.10.5 A study showing the basic assumptions being considered for this project in terms of the electrification can be found in Appendix F.

2.10.6 This cost assumes the traction power will be supplied at an auto-transformed 25kV, supplying 1,104 Single Track Km of OLE (Over Head Line) contact systems from which the train will collect its power. Approximately 12 grid intake substations along the route were also considered to provide the power source to the railway distribution system. At each of these grid intake sites there will be a railway substation site that will control the power coming in and going out onto the railway.

2.10.7 It was also considered that between these substations there will be an approximate 30 intermediate substations that will act as a voltage regulating and sectioning point and/or auto transformer site that will allow electrical interference to be kept to a minimum, as well as, contributing to an efficient electrification distribution system.

System Elements - Summary of costs

2.10.8 Table 2-9 below summarises the quantities and rates applied to each of the above items and the corresponding cost obtained. To facilitate the reading, the costs in this case are provided in millions.

Table 2-9: Summary of System Elements costs

No	Item	Unit	Unit Cost (R$)	Quantity (R$)	Total Cost (R$ million)
A	**Signalling**				
1	CTC (Centralised Traffic Control)	unit	1,894,860	2	3.8
2	Signalling	global	153,040,888	1	153.0
3	ATP (Automatic Train Protection) - ETCS L2	km	312,620	511	159.7
	Subtotal A				316.5
B	**Telecommunications**				
1	Transmission Facilities	global	3,461,150	1	3.5
2	Cables incl. Internal Networks and Cable Components	global	77,102,300	1	77.1
3	Railway Operation Telecommunication System (ROTS)	set	239,250	11	2.6
4	Radio Systems (GSM-R)	global	24,291,850	1	24.3
5	Fire / Unauthorised Access Detection Systems	global	9,426,450	1	9.4
6	CCTV systems	global	1,888,480	1	1.9
7	Passenger Information System - Chronometry System for platforms, OCC and depots	global	311,025	1	0.3

No	Item	Unit	Unit Cost (R$)	Quantity (R$)	Total Cost (R$ million)
8	Data Recollection and Supervision System (SCADA)	global	2,312,750	1	2.3
9	Passenger Information System - Train Destination Display (TD)	global	5,793,040	1	5.8
10	Passenger Information System - Public Address System (Speaker System)	global	4,976,400	1	5.0
11	Ticketing System	global	26,716,250	1	26.7
12	Hot axle box detection unit (HABD)	pc	893,200	12	10.7
13	Overall Systems Components (PS, housing, cable, etc.)	global	144,663,948	1	144.7
	Subtotal B				314.3
C	**Electrification**				
1	Catenary	km	798,461	1,104	881.1
2	ATFS [Grid Substations (+ traction Feeder Station)]	global			375.8
2a	Building Construction	unit	26,100,000	12	*313.2*
2b	Electrical Installations	unit	5,220,000	12	*62.6*
3	ATS [Small Substations / Mid-Point Substations]	unit			104.4
3a	Building Construction	unit	348,000	30	*10.4*
3b	Electrical Installations	unit	3,132,000	30	*94.0*
	Subtotal C				1,361.4
	TOTAL				**1,992.2**

2.11 Socio-environmental Works

2.11.1 All costs shown under this category have been provided by the consultancy Prime Engenharia. Further details of these can be found in the Prime Engenharia's Report. Table 2-10 summarises the quantities and rates applied to each of the above items and the corresponding cost obtained.

Table 2-10: Summary of Socio-environmental costs

No	Item	Unit	Unit Cost (R$)	Quantity (R$)	Total Cost (R$ billion)
1	Land acquisition (excludes constructions and improvements)	global	599,720,000	1	0.6
2	Indemnification for constructions	global	1,630,998,034	1	1.6
3	Resettlement	No. of families	55,000	618	0.03
4	Reurbanisation, TAV crossings	m2 AU	180	1,679,000	0.3
5	Noise protection	m2 AU	150	1,679,000	0.3
6	Native Forest Reclaiming	global	127,316,400	1	0.1
7	Relocation of roads affected by TAV	global	586,000,000	1	0.6
8	Environmental compensation	global	150,000,000	1	0.2
9	Environmental supervision of works	km	415,000	511	0.2
	TOTAL				**3.9**

The following definitions have been provided by Prime Engenharia:

- AC: Área Construída afetada. O custo unitário é a média resultante para todo o TAV.
- AG: Área Geográfica Bruta afetada.
- AU: Área Urbana Bruta afetada.

2.12 Rolling Stock

2.12.1 Based on recent builds of high speed rolling stock, the average purchase cost was estimated in R$ 7.4 million for an 8-car train, equivalent to R$ 65.2 million per train. Table 2-11 below shows the different source of costs analysed to arrive to the previous cost.

Table 2-11: Benchmark of Rolling Stock costs

Designation	Manufacturer	Per Train (R$ million)
TGV	Alstom	56.4
AVE Trainsets	Siemens	64.3
Javelin	Hitachi	34.6
TGV Duplex	Alstom	76.1
AGV Trainsets	Alstom	75.4
ICE3	Siemens	87.0
ICE CHR3	Siemens	62.8

2.12.2 Table 2-12 below summarises the quantities and rates applied to this item and the corresponding cost obtained based on the fleet size, previously estimated in Volume 4, for year 2014.

Table 2-12: Summary of Rolling Stock Cost (Year 2014)

No	Item	Unit	Unit Cost (R$ million)	Quantity	Total Cost (R$ billion)
1	Rolling Stock	train sets	65.2	42	2.7
	TOTAL				**2.7**

2.13 Complementary Services

2.13.1 This category includes the following items:

- Testing and Certification
- Geotechnical Studies
- Utility diversion
- Temporary Works During Construction
- Permanent road access to tunnels and bridges
- Design
- Project Management

2.13.2 A description of each category is provided below.

Complementary Services – Testing and Certification

2.13.3 Testing and certification of the system elements (signalling, telecommunications and electrification) and the rolling stock is required before commencing the commercial operation of the system.

2.13.4 This cost was estimated as 2% of the capital cost of the items mentioned above, which equals to R$ 94.6 million.

Complementary Services - Geotechnical Studies

2.13.5 During the Detailed Design stage of this project, further Geotechnical studies are required to be conducted in order to better identify the geological characteristics of the terrain along the chosen alignment. As mentioned in Volume 2 (Alignment Studies), this information, which includes borehole analysis across the corridor, is considered very relevant.

2.13.6 To estimate the total cost of this item, a rate of R$ 5,000 per track kilometre (km) was applied. This rate, obtained from local sources, only covers the studies required for the detailed design stage of the project. The total cost was therefore estimated in R$ 2.6 million.

Complementary Services – Utility diversion

2.13.7 This item refers to the works required to divert and relocate existing utilities that might become affected during the construction stage.

2.13.8 The relocation of existing power lines, gas/oil pipelines, water pipes and telecommunications ducts are included in this item.

2.13.9 The cost was estimated as a percentage (1%) of the Civil Engineering Works, and the total expense for this item was estimated in R$ 203.6 million.

Complementary Services - Temporary Works during Construction

2.13.10 This cost was estimated as a percentage (2%) of the construction cost, which is comprised by the following items:

- Civil Engineering Works
- Permanent way
- Buildings and equipments
- System elements
- Noise protection

2.13.11 A rail head is considered included in this cost, including the land acquisition, the rail connection and the associated facilities and plant.

2.13.12 The total cost estimated for this item is R$ 523.3 million.

Complementary Services - Permanent Road Access to Tunnels and Bridges

2.13.13 Although the track maintenance is intended to be provided with plants travelling along the track, for safety reasons some locations along the alignment require the provision of a permanent road access. This is the case for long tunnels and viaducts, for instance.

2.13.14 The expenditure of this item was estimated as a fraction (10%) of the cost of Temporary works during construction, as it was considered that some specific road access built during the construction stage could still be operated once the system enters operation.

2.13.15 The total cost estimated for this item is R$ 52.3 million.

Complementary Services – Design

2.13.16 The cost of the design team was estimated as a percentage (2%) of the following items:

- Civil Engineering Works
- Permanent way
- Buildings and equipments
- System elements
- Noise protection
- Utility diversion
- Temporary Works during Construction
- Permanent Road Access to Tunnels and Bridges

2.13.17 The total cost estimated for this item is R$ 538.9 million.

Complementary Services – Project Management

2.13.18 The cost of the project management required to deliver this project was estimated as a percentage (2%) of the following items:

- Civil Engineering Works
- Permanent way
- Buildings and equipments
- System elements
- Socio-environmental works

- Rolling-stock
- Geotechnical studies
- Utility diversion
- Temporary Works during Construction
- Permanent Road Access to Tunnels and Bridges

2.13.19 Legal expenditures and client team costs are included in this factor, which is estimated in R$ 666.6 million.

Complementary Services - Summary of costs

2.13.20 Table 2-13 below summarises the quantities and rates applied to each of the above items and the corresponding cost obtained.

Table 2-13: Summary of Complementary Services Cost

No	Item	Unit	Total Cost (R$ million)
1	Testing and certification	global	94.6
2	Geotechnical studies	global	2.6
3	Utility diversion	global	203.6
4	Temporary works during construction	global	523.3
5	Permanent road access to tunnels and bridges	global	52.3
6	Design	global	538.9
7	Project Management	global	666.6
	TOTAL		**2,081.9**

3 Results and Conclusions

3.1 Introduction

3.1.1 The previous sections described the methodology applied to determine the capital cost of the TAV Project, describing the assumptions adopted and the preliminary results that were obtained.

3.1.2 This section provides an analysis of those results and is structured as follows:

- a description of the Capital Cost estimated for the entire route;
- a description of the Capital Cost estimated for separate sections along the route; and
- an analysis of results obtained from a cost benchmarking exercise

3.2 Capital Cost – Full Route

3.2.1 The total projected capital cost for TAV is R$ 34.6 billion[8]. A breakdown by asset type, obtained from the results shown in the previous section, is provided in Table 3-1. The detailed CAPEX table can be found in Appendix A of this report.

Table 3-1: Capital Costs by Asset Type

Asset	2009 Cost (R$ billion)	% of Total Cost
Civil Engineering Works	20.36	58.8%
Earthworks (fill, cut, etc)	*2.21*	
Structures (tunnels, bridges, etc)	*18.16*	
Permanent Way (track, drainage, etc)	2.14	6.2%
Buildings And Equipments (stations and depots)	1.42	4.1%
System Elements	1.99	5.8%
Signalling	*0.32*	
Telecommunications	*0.31*	
Electrification	*1.36*	
Socio-Environmental Works	3.89	11.2%
Rolling Stock	2.74	7.9%
Complementary Services (utility diversion, design, project management, etc.)	2.08	6.0%
TOTAL	**34.63**	**100%**

[8] Following the analysis of previous sections, the value of the Capital Cost does not include future expansions of the system required to cover growing demands of passengers. The same criterion is applied in subsequent tables and analysis in this volume.

3.2.2 The composition of the Capital Cost is summarised in Figure 3-1 below.

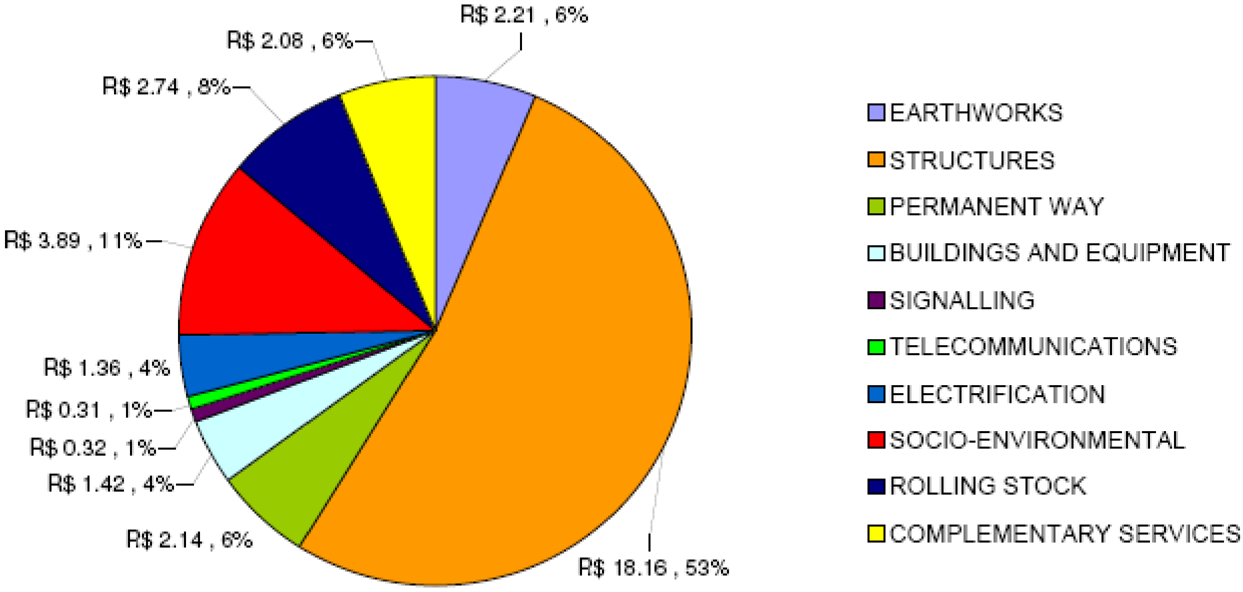


Figure 3-1: Capital Cost Composition (in R$ billion and %)

3.2.3 As expected, the structures (tunnels and bridges mainly) have a significant impact on the overall CAPEX cost, with an estimated share of 53%. In fact, when listing the ranking of the top ten most expensive items related to the TAV construction, the chart shown in Table 3-2 is obtained.

Table 3-2: Ranking of the most expensive items involved in the TAV construction

No	Item	Cost (R$ billion)	% of Total Cost
1	Tunnelling	10.75	31.1%
2	Bridges and viaducts	7.12	20.6%
3	Rolling stock (Initial fleet)	2.74	7.9%
4	Indemnification for buildings	1.63	4.7%
5	Plain line track	1.59	4.6%
6	Cut	1.03	3.0%
7	Catenary	0.88	2.5%
8	Passenger stations	0.71	2.1%
9	Maintenance depots	0.71	2.0%
10	Project Management	0.67	1.9%
	TOTAL	**27.83**	**80.4%**

3.2.4 The top two items of the ranking shown in the above table are part of the Civil Engineering Works, category that represents 58.8% of the total capital cost of the project (see Table 3-1). This provides an indication that the selection of the appropriate construction techniques, equipments and materials will be a key question to increase the cost efficiency of this project.

3.3 Capital Cost – Sections along the route

3.3.1 An analysis was carried out to determine the Capital Cost corresponding to different sections along the TAV route. These sections were defined as follows:

- Section 1: Barão de Mauá (RJ) - Galeão Airport (RJ)
- Section 2: Galeão Airport (RJ) - Barra Mansa / Volta Redonda (RJ)
- Section 3: Barra Mansa / Volta Redonda (RJ) - São José dos Campos (SP)
- Section 4: São José dos Campos (SP) - Guarulhos Airport (SP)
- Section 5: Guarulhos Airport (SP) - Campo de Marte (SP)
- Section 6: Campo de Marte (SP) - Viracopos Airport (SP)
- Section 7: Viracopos Airport (SP) - Campinas (SP)

3.3.2 In the case of stations, for practical purposes, it was considered that one station is located in each of the sections above. However, considering there are eight proposed stations and just seven defined sections, for the purpose of estimating the cost of each for each of the above sections, it was necessary to consider that Section 7 includes two stations (Viracopos Airport and Campinas).

3.3.3 A summary of the results is shown in Table 3-3 and Figure 3-2 on the next page.

3.3.4 Based on Table 3-3, the cost per kilometre can then be obtained for each section as shown in Table 3-4. It can then be concluded the sections with higher rate per kilometre are those with higher proportion of structures (tunnels and bridges). This result is in line with the CAPEX composition that was analysed in Section 3-2.

3.4 Benchmarking

3.4.1 Further to the comments included in Section 2.2 regarding the difficulties associated with the estimation of unit rates, comparing capital costs between a series of high-speed rail services represents a very delicate exercise on its own. In fact, although two HSR services might look similar from a high-level analysis, alternative technologies might have been applied during their construction to cope with the particular constraints and opportunities available in each location.

3.4.2 In any case, benchmarking the cost of a project is still considered a valid exercise, widely used in engineering projects, in particular during the feasibility stage, as it represents an empirical tool that helps assessing the validity of the adopted methodology.

3.4.3 Table 3-5 shows the Capital Cost of 11 international High-Speed Schemes [9], which provides an average cost of £21.8 million per km, equivalent to R$ 75.4 million per km applying a £1 = R$ 3.46 exchange rate.

[9] Source: Based on *High Speed Lines Study – Milestone 8. Cost Model Report.* WS Atkins. April 2002.

Table 3-3: Summary of cost (R$ Million) estimated for each section of the alignment

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
	Barão de Mauá (RJ) - Galeão Airport (RJ)	Galeão Airport (RJ) - Barra Mansa / Volta Redonda (RJ)	Barra Mansa / Volta Redonda (RJ) - São José dos Campos (SP)	São José dos Campos (SP) - Guarulhos Airport (SP)	Guarulhos Airport (SP) - Campo de Marte (SP)	Campo de Marte (SP) - Viracopos Airport (SP)	Viracopos Airport (SP) - Campinas (SP)
Length (km)	**15.2**	**103.1**	**210.4**	**61.8**	**21.8**	**75.4**	**23.2**
Earthworks	27.6	457.9	1,018.1	267.4	27.1	339.8	70.7
Structures	616.6	4,971.2	5,142.1	1,932.4	1,495.8	3,596.0	400.9
Permanent Way	60.0	412.9	927.8	255.0	82.3	302.1	98.3
Buildings And Equipment	92.4	238.1	308.2	130.2	135.5	339.4	173.9
Signalling	9.4	63.9	130.4	38.3	13.5	46.7	14.4
Telecommunications	9.3	63.5	129.4	38.0	13.4	46.4	14.3
Electrification	40.4	274.9	560.7	164.6	58.1	200.8	61.7
Socio-Environmental	357.8	705.3	912.8	267.5	228.1	898.9	523.7
Rolling Stock	81.4	553.2	1,128.4	331.3	117.0	404.2	124.3
Complementary Services	72.4	511.6	665.0	224.6	141.7	391.0	75.5
TOTAL	**1,367.3**	**8,252.6**	**10,923.0**	**3,649.5**	**2,312.6**	**6,565.2**	**1,557.8**

Figure 3-2: Total Capital Cost split into different sections of the route (in R$ billion and %)

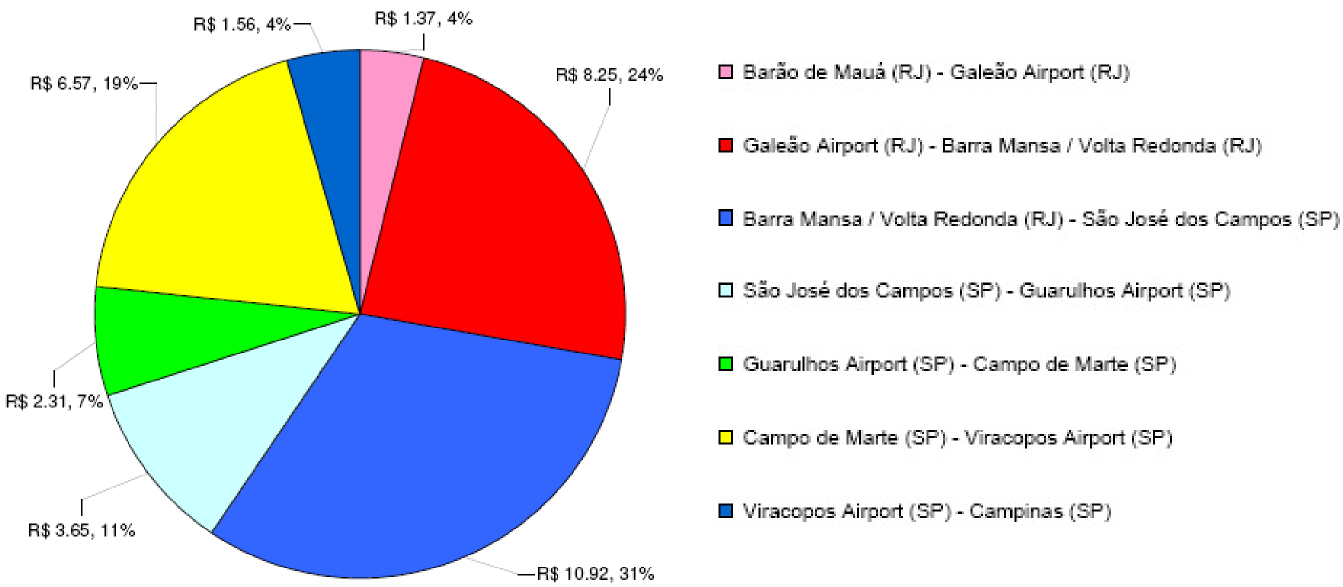


Table 3-4: Cost per km vs. alignment characteristics, for each section along the route

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
	Barão de Mauá (RJ) - Galeão Airport (RJ)	Galeão Airport (RJ) - Barra Mansa / Volta Redonda (RJ)	Barra Mansa / Volta Redonda (RJ) - São José dos Campos (SP)	São José dos Campos (SP) - Guarulhos Airport (SP)	Guarulhos Airport (SP) - Campo de Marte (SP)	Campo de Marte (SP) - Viracopos Airport (SP)	Viracopos Airport (SP) - Campinas (SP)
Length (km)	15.2	103.1	210.4	61.8	21.8	75.4	23.2
Cost (R$ million)	1,367.3	8,252.6	10,923.0	3,649.5	2,312.6	6,565.2	1,557.8
Cost per km (R$ million)	90.2	80.0	51.9	59.1	106.0	87.1	67.2
% of tunnel	22%	26%	6%	11%	81%	28%	10%
% of bridges	34%	24%	22%	21%	0%	22%	7%
% of tunnel + bridges	56%	50%	28%	33%	81%	49%	17%

3.4.4 However, as it can be observed from Table 3-5, there is a very broad range of cost per km, ranging from £8.8m to £48.6m (R$ 30m to R$ 168m). Although this difference can be in part attributed to the characteristics of the route, basically in terms of the proportion of bridges and tunnels, other external factors could be playing a key role in these differences.

3.4.5 In fact, although at a first glance it could be concluded that France has a lower rate compared to the other countries reviewed, the following factors might explain the source of this apparent lower cost [9]:

- it is not clear whether the Government subsidies granted to the TGV are included in these published costs;
- TGV construction makes extensive use of existing lines, although the route is completely overhauled;
- as shown in the tunnel percentage included in Table 3-5, TGV routes use significant grades to enable shorter and straighter routes, thus reducing the need for tunneling;
- TGV routes are predominantly located in rural areas; and
- it has been inferred that SNCF (Société Nationale des Chemins de Fer), the French National Railway, provides some services and resources at little or no cost to the scheme

3.4.6 The average cost per km estimated for TAV is R$ 67.8 million per km, which is vey close to the average cost estimated above.

Table 3-5: Benchmark of HS projects, including TAV

Project	Opening year	Route length (km)	Cost per km (£ million)	Route characteristics	
				Bridge and Viaduct (%)	Tunnel (%)
TGV Sud Est	1983	410	8.8	1	6
TGV Atlantique	1990	320	3.8	1	6
TGV Mediterenee	2001	250	16.7	7	5
CTRL	Phase 1: 2003 Phase 2: 2006	109	48.6	4	25
Shinkansen – Tokaido	1964	515	4.4	33	13
Shinkansen –Sanyo	1975	562	8.5	38	50
Shinkansen – Thoku	1991	501	25.0	72	23
Shinkansen – Joetsu	1982	275	29.0	60	39
Shinkansen – Hokuriku	1998	126	31.8	34	50
TGV Korea – Seoul to Pusan	Phase 1: 2004 Phase 2: 2010	412	29.5	27	46
TGV Taiwan	2005	345	33.7	72	14
TAV PROJECT	**2014** [10]	**511**	**19.6**	**21**	**18**

10 Proposed year

Appendix A – CAPEX Costs

Appendix B – Description of Structures

Appendix C – Station Costs

Appendix D – Maintenance Plant and Equipment – Main components

Appendix E – Signalling and Telecommunications Technical Report

Appendix F – Electrification Technical Report

Appendix G – PROMPT Engenharia CAPEX Analysis