CALIFORNIA High-Speed Rail Authority

DB

CALIFORNIA HIGH SPEED RAIL EARLY TRAIN OPERATOR

Review of the 2018 Capital Costs Estimates Associated with the San Francisco – Bakersfield Section (Valley To Valley Concept)

May 1st, 2019

Approvals				
	Name	Position	Signature	Date
Prepared	Andre Fellner	ETO Task Leader	[signature]	05/01/2019
Verified	Jorge Rios	ETO Project Director	[signature] J. M. Rios	05/01/19
Reviewed	Mark Evans	ETO Lead Commercial Advisor	[signature]	05/01/19
Reviewed	Mark Zehnder	CHSRA Deputy Program Director	[signature]	5/1/2019
Reviewed	Bruce Armistead	CHSRA ETO Contract Manager/ Director of Operations & Maintenance	[signature]	5/1/19
Approved	Frank Vacca	CHSRA Chief of Rail Operations	[signature] F. Vacca	5/1/19

Document ID Number
ETO_MGM_Capital Investment Benchmark_R01.0_20190501_1300

Submission No.
Rev. 1.0

Effective Date: **2019-05-01**

Language: **En**

Revision Log

Revision	Date of Release	Description of Changes
1.0	May 1, 2019	*Initial Release*

Table of Contents

Section	Page

Table of Figures

Table of Tables

1 Introduction

1.1 Executive Summary

The objective of this benchmark report is to compare the budget estimated by the CHSRA with similar high-speed projects constructed and operated by DB as well as with other international HSR projects and to provide a plausibility check of the estimates.

The values from the benchmark figures shall not replace the values calculated by the authority and are only a reference to identify potential opportunities for improvement based on DB's years-long experience in a variety of similar high-speed projects.

1.1.1 Process overview

The process conducted through the ETO for this study is summarized in the following steps (see chapters 1.2 and 1.3 for details):

1. ETO reviewed the available technical specifications of the elements defined by CHSRA as part of the high-speed rail system definition.
2. ETO then selected the most comparable element from the DB Cost Catalogue (DB's actual Cost database of DB high-speed projects).
3. An adjustment was calculated for all comparable elements containing known differences in their technical specifications and if required including a cost escalation.
4. The costs of DB and CHSRA elements were compared, the deviations reviewed and within workshops with expert groups analyzed.

1.1.2 CHSRA Baseline reviewed

For baselining and budget estimation CHSRA uses the calculation of initial allowances for each element as an approach. With an improvement of the level of information detail throughout the rail system´s definition process the budget is updated and a new version of the baseline is released. Considering the current status of this benchmark study the average completion rate of the system´s design is estimated to be approximately 15%. Significant areas of the alignment such as the Environmental Impact Studies not yet being completed, property not yet fully procured and exact locations of the alignment not yet being committed were identified.

The ETO performed this benchmark by comparing it with the "2018 business plan technical supporting documents" dated June 1st, 2018, (see Appendix A Provided documents from CHSRA), which is denominated by CHSRA "Baseline Revision 0".

The ETO's findings and recommendations should be considered as opportunities for improvement of the reliability level for the new baseline revisions. The opportunities are classified in the following ways:

1. Opportunities having a significant impact on the budget and being implemented immediately with the release of the new baseline (Revision 1).

2. Technical recommendations being addressed before the release of relevant procurement processes, regardless of the impact on the budget as they represent challenges for the project and future operations (for details see Chapter 8).
3. Opportunities merely being realized after a more detailed level of design is available.

1.1.3 Improvement opportunities recommended for implementation in the next release of the baseline (Revision 1)

The following is a shortlist containing elements found with a high cost deviation between the ETO´s benchmark values and the CHSRA´s Baseline values. These elements represent major cost drivers of the budget. Many other elements deviate significantly in their costs, but due to their small weight on the budget, the opportunity for improvement is smaller. Therefore they are not included in this shortlist. These elements are explained in the relevant chapters of this report.

The values per mile calculated by the CHSRA are generally higher than comparable elements in the ETO - DB Cost Catalogue with some exceptions displayed in the table below:

Item	Description	Weight in Budget	Deviations to CHSRA in % (Ranges are indicative and vary per section)	Comment
1	Bridges and Viaducts	17%	-61% to -25%	Based on three example structures.
2	Earthwork	4%	-68% to +30%	Data only availble for Section 3. Calculated in USD/cu yard.
3	Tunnels	21%	-56 %	Based on comparison between Finne Tunnel and Pacheco Tunnel No. 2.
4	Retaining Walls	4%	-81% to +119%	Data only availble for Section 2 and 6. Calculated in USD/sq yard.
5	Track (Ballasted)	5%	-42% to -30%	Calculated in Track per Mile.
6	Grade Separations	8%	-39%	Based on one example structure „Project 26 Grade Seperation". Calculcated in USD/sq ft.
7	Overhead Catenary System	3%	+22% to +46%	Total estimated amount for Section 2 to 6 only.

Table 1-1 - Deviations between CHSRA and ETO %

1.1.4 Vehicle analysis

A variety of alternatives for rail vehicles were reviewed and are included in the report as a reference. The unique "Buy America factor" combined with relatively small quantities procured, contribute to the specifity of the project. As to the normal peculiarities of a project this leads it to be non-comparable with other existing DB projects.

1.1.5 Exclusions

The following scope elements are unique to each project, and therefore were not subject of the benchmark review:

1. Utility relocations
2. Environmental mitigation
3. Temporary facilities
4. Real estate acquisition

1.2 Background information

Under Public Utilities Code 185033, the California High-Speed Rail Authority (CHSRA) is required to prepare, publish, adopt, and submit a business plan to the California Legislature every two years. The published Business Plan 2018 is the ninth business plan since the disclosure of the first business plan in 2000. The California High-Speed Rail Authority Business Plan is an overarching policy document intending to inform all stakeholders of the project's implementation status and assist the Legislature in making strategic and operational decisions for the project. Part of the business plan is a technical and financial project progress report and a reconciliation with the previous business plans. In addition, it forecasts ridership levels, capital expenditures (CAPEX), and operational costs (OPEX).

Because the budget increased significantly from the Business Plan 2016 to the Business Plan 2018, CHSRA demanded an independent estimate review of the construction costs from the ETO in February 2018. Its purpose was the identification of areas requiring further refinements of the estimate. The ETO´s focus was supposed to be laid on the newly defined Valley to Valley (V2V) concept, which comprises parts of Phase 1 of the overall California High-Speed Rail Project.

The CHSRA Business Plan 2016 defines the V2V concept as a network starting from San José Diridon Station (Silicon Valley) to either Poplar Avenue Station (an interim station north of Bakersfield) or to the existing Amtrak station located in the Central Valley city of Wasco. The CHSRA Business Plan 2018 redefines the V2V concept. Additional to the defined network, capital investments are to be considered for the extended project section San José Diridon Station to 4^{th} and King Station in San Francisco as well as the extension to the temporary station at Bakersfield F-Street. The new version of the V2V concept connects the cities of San Francisco, San José, and Gilroy in the Peninsula Valley with the Central Valley cities of Madera, Fresno, and Bakersfield (refer to Figure 1-1). With this conceptual change additional technical changes were required, which resulted in an increase of the overall budget. The overall budget for the V2V concept increased by over 21% from the Business Plan 2016 in comparison to the Business Plan 2018. Table 1-2 displays a direct cost comparison of the V2V concept section between Business Plan 2016 and Business Plan 2018.

Section	Network Section	2016 BP (2017 USD, Millions)	2018 BP (2017 USD, Millions)	Change 2016 vs. 2018 (2017 USD, Millions)	Change 2016 vs. 2018 (%)
1	San Francisco to San Jose	3,281	2,380	(901)	-27.5%

Section	Network Section	2016 BP (2017 USD, Millions)	2018 BP (2017 USD, Millions)	Change 2016 vs. 2018 (2017 USD, Millions)	Change 2016 vs. 2018 (%)
2	San Jose to Gilroy	4,579	2,820	(1,759)	-38.4%
3	Gilroy to Carlucci Road	5,738	8,984	3,246	56.6%
4	Carlucci Rd. to Madera Acres (Wye Leg 2)	1,005	2,097	1,092	108.7%
5	Madera Acres to Poplar Ave.	7,229	9,982	2,753	38.1%
6	Poplar Ave. to Bakersfield	2,125	2,805	680	32.0%
Total		**23,957**	**29,068**	**5,111**	**21.3%**
Source: 2018 Business Plan: Capital Cost Basis of Estimate Report, Page 9					

Table 1-2 - CHSRA Business Plan 2016 to Business Plan 2018 - V2V capital cost comparison

Within the Business Plan 2018 CHSRA depicts a reduction of costs in Sections 1 and 2 due to a consideration of shared tracks with Caltrain in Section 1. The existing network in the that section would merely need a moderate upgrade to meet the CHSR´s requirements. B The Diridon station in Section 2 is considered to be an at-grade station instead being an elevated station as previously planned. The UPRR ROW from the Tamien-to-Gilroy station might be an option for usage as well. In contrast costs in Sections 3 to 6 increase in average by 59% per section. This rise is caused by the addition of more required civil structures and price adjustments given in the awarded construction packages.

Furthermore, costs for the planned Heavy Maintenance Facility (HMF) constructed in the Central Valley are declared separately.

Section	Network Section	2016 BP (2017 USD, Millions)	2018 BP (2017 USD, Millions)	Change 2016 vs. 2018 (2017 USD, Millions)	Change 2016 vs. 2018 (%)
5	HMF - Central Valley	1,300	458	-842	-64.8%
Source: 2018 Business Plan: Capital Cost Basis of Estimate Report, Page 9					

Table 1-3 - CHSRA Business Plan 2016 to Business Plan 2018 - HMF capital cost comparison

The cost reduction of over 60% is caused through a relocation from e the originally accounted LMFs in Section 5 to the Central Valley. Within the Business Plan 2018 CHSRA assumes a phased implementation of the HMF enabling the initial accommodation of 16 trainsets. A future expansion and its costs are to be determined by the future trainset manufacturer.

Source: California High-Speed Rail Authority 2018 Business Plan; Page 19

Figure 1-1 - Map of the planned California High-Speed Rail network

For the identification of further areas for refinements of the estimate the ETO team decided to benchmark the given costs of the Business Plan 2018 by referencing it to DB projects. Therefore, ETO Specialists reviewed the CAPEX components outlined in the "Capital Cost Basis of Estimate Report - 2018 BUSINESS PLAN" dated June 1, 2018 and benchmarked them against similar German and international DB reference projects.

During the period from February 9, 2018 to July 26, 2018, several workshops were held in Sacramento. Additional conference calls aiming for a discussion of the assumptions between the experts from both parties and its validation were implemented. These workshops and conference calls were required due to the varying levels of detail for the different UPE cost subcategories provided by CHSRA. Prior agreed assumptions were a requirement in order to perform the requested independent benchmark. Appendix 1 contains a list of all documents provided by CHSRA from February 9, 2019 to August 30, 2018 being considered in this benchmark. A list of assumptions is to be found in Appendix 2.The ETO team used the "VDE 8" project (**V**erkehrsprojekte **D**eutsche **E**inheit: German Unity Transport Project) as its main reference for the calculation of this benchmark. This rail infrastructure project between Nuremberg and Berlin is an important section of the high-speed Trans-European Network (TEN), which reduces the travel time between two metropolitan centers - Munich and Berlin - to about four hours, establishing it to be a competitive means of transport to air travel. The new rail line was put into service in December of 2017.

Figure 1-2 - VDE 8 network overview

The comparison is based on Section VDE 8.2 - Erfurt-Leipzig/Halle - being one out of seven project sites. The reason for the selection is due to its components and geological conditions being similar to the planned California High-Speed Rail line. The Erfurt, Halle, and Leipzig junctions are the central interchange stations for the region. The new double-track line of a length of 123 kilometers (76.4 miles) long is designed for speeds up to 300 km/h (186 mph) and initially runs through the Thuringian Basin. Subsequently, it crosses the Finne mountain range via three tunnels capturing a total length of 15.4 kilometers (9.57 miles). Behind the Querfurt Plate the route splits towards Halle and Leipzig. The branch towards Halle lies uniquely on the Elster-Saale Viaduct. It is the longest railway bridge in Germany with a length of 8.6 kilometers (5.34 miles). Five additional bridges, all constructed regarding the state-of-the-art engineering standards, complete the route. New bridge constructions, a modern safety concept in the tunnels, a train control system without signals on the line, upgraded platforms with disabled access, noise protection, and environmental mitigation measures were considered in this unique DB reference project.

Based on this reference project and the given data from CHSRA the ETO team provides an independent consulting service for benchmarking the CHSRA's current estimated capital costs. The objective of this report is to improve the classification of the estimated capital costs of the California High-Speed Rail Authority within an international context. and the identification of potential cost drivers that CHSRA for further investigation conducted through CHSRA. In addition, the ETO provides recommendations regarding current technical and financial challenges of the project.

1.3 Report Objective and Process Description

Neither an evaluation of the current California High-Speed Rail design's technical functionality nor the assessment of specific technical equipment is within the ETO's scope. Therefore, the current technical solution and its operability are not considered in the benchmark report itself. It should also be noted that the economic conditions (e.g. wages, salaries, taxes, regulations etc.) in the US and Germany differ. These affect the costs of project´s components in different ways and are beyond the agreed upon scope of work for this report. However, if one of these economic factors are identified as a potential cause for the cost deviation, they are pointed out to enable the CHSRA conducting further investigation.

The benchmark itself is executed for the following eight agreed upon Standard Cost Categories (SCCs):

- SCC 10 - Track Structures and Track
- SCC 20 - Stations Terminals and Intermodal
- SCC 30 - Support Facilities, Yard & Shops, Admin, etc.
- SCC 40 - Site Work, Right of Way, Land, Improvements
- SCC 50 - Communication and Signaling
- SCC 60 - Traction Electrification Systems
- SCC 70 - Vehicles
- SCC 80 - Prof Services (associated to categories 10-60)

Per direction of CHSRA the Standard Cost Categories SCC 90 – Unallocated Contingency and SCC 100 – Finance Charges are excluded from the benchmark review.

In order to guarantee an adequate cost comparison the DB cost units are inflation-adjusted to December 31, 2017 and, if necessary, normalized. In addition, as outlined in the "Capital Cost Basis of Estimate Report - 2018 BUSINESS PLAN: TECHNICAL SUPPORTING DOCUMENT", June 1st, 2018, page 12 – Table 6, the review and benchmark is based on a Class 3 Estimate. Class 3 is defined according to Table 1-4:

Table 6 Estimate Classifications by AACE International

	Primary Characteristic	Secondary Characteristic		
Estimate Class	Maturity Level of Project Definition Deliverables (Expressed as % of complete definition)	End Usage (Typical Purpose of estimate)	Methodology (Typical estimating method)	Expected Accuracy Range (Typical variation in low and high ranges) *
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study of feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with forced detailed take-off	L: -3% to -10% H: +3% to +15%

* The state of technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50 percent level of confidence for given scope).

Table 1-4 - Estimate classification by AACE International

The 2018 Business Plan capital cost estimate is predominately a Class 3 estimate based on the level of design maturity in the sections. As defined by the Association for the Advancement of Cost Engineering (see the summary of estimate classifications in Table 1-4), they have advanced to a 15% design level. Exception is the Central Valley considered a Class 1 estimate. Whereas San Francisco over San Jose to Gilroy is to be regarded as a Class 4 estimate relying on a conceptual level of design. Class 3 estimates are typically prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they provide the initial control estimate against which actual costs and resources are monitored. The completion rate for the level of engineering ranges from 10 percent to 40 percent and includes:

- Horizontal and vertical alignments
- Typical cross sections
- Preliminary roadway and structure design
- Preliminary assessment of utility impacts
- Preliminary identification of systems facilities
- Development of environmental footprints and right of way requirements
- Initial constructability reviews

Typical accuracy ranges for Class 3 estimates are -10 percent to -20 percent on the low side and +10 percent to +30 percent on the high side. The accuracy ranges that are applied on the Valley to Valley and Phase 1 estimates vary depending on the complexity of the project´s scope elements, the maturity of underlying technical baseline information and the inclusion of appropriate contingencies.

If the level of design maturity does not allow a calculation of quantity takeoffs, parametric estimating techniques are applied. DB uses its “DB Kostenkennwertekatalog” (“Cost Characteristics Catalogue” (CCC)) as a reference document for benchmarking values. The catalogue reflects DB’s internal standard cost database developed from its existing high-speed rail lines.

The CAPEX review follows the following process steps:

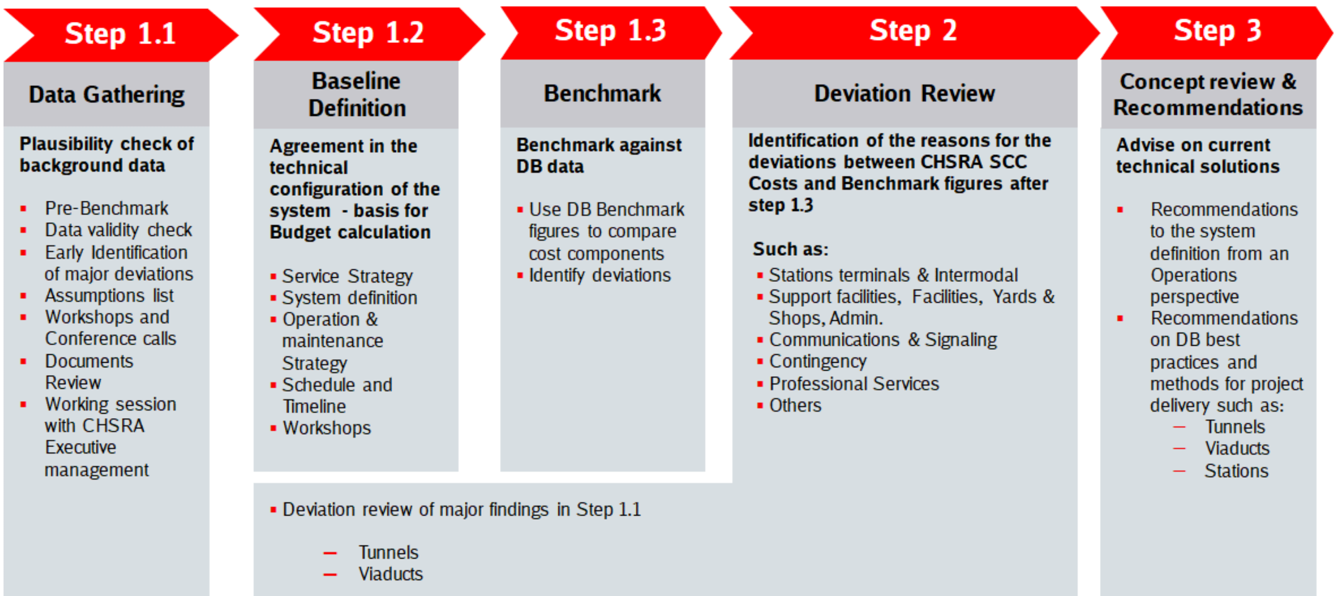


Figure 1-3 - Methodology approach for the report

The first step is gathering available data (Step 1.1) and forming the basis for this report. As mentioned before during several conference calls and workshops held in Sacramento, experts from CHSRA and the ETO team defined the technical baseline of the Valley to Valley concept as described in the Business Plan 2018. Subsequently, the required CAPEX components to run a comparable benchmark are identified. They agreed upon and set baseline definitions for each of the Standard Cost Categories (SCC) as summarized in Step 1.2. In case of obscurities assumptions are made and defined in the agreed Assumption List (0). These assumptions combined with the agreed upon CAPEX components form the basis for the budget benchmark.

In Step 1.3, the ETO Specialists perform the actual benchmark. Previously, the CHSRA and ETO given cost components are described in a qualitative and quantitative context. This is necessary to enable a basis for a similar technical understanding of the SCC by all parties. Unit costs for identified German or international benchmarking elements are transferred to a comparable level of detail and converted to US unit values. This procedure enables to adjust the costs to a specific time frame (31st December 2017) and adapt the requirements given through the CHSRA´s cost components. This assures the comparability of cost components during benchmarking.

The ETO Specialists conduct further SCC analysis, if benchmark results deviate from the expected Estimate Class 3 accuracy range (-20% to +30%). Subsequently, in Step 2 (Chapter 7) the ETO Specialists investigate the reasons causing the deviation between CHSRA SCC costs and the ETO benchmarking figures. The aim is to identify potential cost drivers in CHSRA's budget estimation. Based on the results CHSRA Specialists evaluate engineering specific cost components and identify areas for further refinements of the estimate.

In closing (Step 3 / Chapter 8) the ETO team offeres recommendations to CHSRA from an operational and maintenance perspective as well as methods for project delivery. This allows CHSRA to adjust and optimize upcoming budget reports.

2 Abbreviations

The following acronyms are used in this document.

Acronym	Definition
AFC	Automatic Fare Collection
ATC	Automatic Train Control
Authority	California High Speed Rail Authority, when used alone in the Text
Bn	Billion
CAPEX	Capital Expenditures
CCC	DB Cost Characteristics Catalogue
CCD Shop	Workshop for electronical parts and devices on board the train (e. g. the green panels in computers)
CCTV	Closed-circuit television
CHSRA	California High Speed Rail Authority
COM	Communications
CP	Construction Package
Cu yd	Cubic Yard
CVY	Central Valley
DB	Deutsche Bahn
DTX	Downtown Rail Extension
EA	Each
EMC	Electromagnetic Characteristics
EN	European Standards
ERTMS	European Rail Traffic Management System
ETCS	European Train Control Systems
ETO	Early train Operator (DB and its subcontractors)
EUR	Euro
ft	Feet
HMF	Heavy Maintenance Facility
HOAI	Honorarordnung für Architekten und Ingenieure
HSR	High-speed Rail
Ht	Height
Kip	Kilopound
kV	kilovolt
LCCA	Life Cycle Cost Analysis
LF	Linear feet
LMF	Light Maintenance Facility
LS	Lump Sum
Mil	Million
MoWF	Maintenance of Way Facility
MPH	Miles per hour
OCC	Operations Control Center
OCS	Overhead Catenary System
OFC	Optical Fiber Cable
OPEX	Operational Expenses

Acronym	Definition
PAS	Passenger Announcement System
PIS	Passenger Information System
PS	Paralleling Station
Rd	Rounded
RM	Route Mile (“section length – mile”, independent from the number of tracks on the section.)
SCC	Standard Cost Categories
SIG	Signaling
SWS	Switching Stations
t	Metric ton
TBM	Tunnel Boring Machine
TCS	Train Control Systems
TCS	Train Control System
tf	Track feet
TPSS	Traction Power Supply System
UPEs	Unit Price Elements
UPRR	Union Pacific Railroad
USD	US Dollar
V2V	Valley to Valley
VDE 8.2	Verkehrsprojekt Deutsche Einheit Nr. 8 (German Unity Transport Project 8 – Berlin to Munich HSR Line (VDE 8.2 – Section: Erfurt to Groebers Section)
Vf	Ventricular Fibrillation
Vlf	Vertical line foot

Table 2-1 - Abbreviations

3 List of Appendices

The following documents are appendices to this document.

Appendix 1 - Provided Documents from CHSRA

Appendix 2 – Assumption List

Appendix 3 – Train examples – Overview

4 Methodology

For details of the methodology, scope and budget of the review refer to ETO_MGM_Capex Review Scope 2018 BP_R01.0_20180209_1400.pdf".

5 Agreed Upon Assumptions for the Business Plan Review

5.1 General

To achieve a comparable and sustainable Business Plan review between the California High-Speed Rail Project and DB's reference project, the following general determinations were set:

- Costs of DB's reference projects were escalated to the year-end of 2017. To determine the inflation factor, the web page www.fxtop.com was used. The index: EUCPI2005 (European Union (Eurostat)) was defined as the reference index to calculate the factors.

Table 5-1 shows the inflation factor from the year 2000 through the end of 2017:

Year	Inflation factor to 31-1-.2017	Year	Inflation factor to 31-1-.2017
1998	1.3889	2008	1.1208
1999	1.3651	2009	1.1105
2000	1.3321	2010	1.0865
2001	1.3052	2011	1.0574
2002	1.2762	2012	1.0344
2003	1.2515	2013	1.0258
2004	1.2226	2014	1.0274
2005	1.1960	2015	1.0251
2006	1.1735	2016	1.0136
2007	1.1386	2017	0

Table 5-1 - EUR inflation factor for the last 20 years

- The exchange rate from USD to EUR is defined as: USD 1 = EUR 0.819100
- Imperial units are used. If reference units were not provided, the following conversion table (Table 5-2) applies:

Conversion from / to	Original unit		Conversion factor	Converted unit	
Mile to km	1	m	"="	1.609340	km
Square foot to square meter (m^2)	1	SF	"="	0.092903	m^2
Cubic yard to cubic meter (m^3)	1	CY	"="	0.764555	m^3
Square yard to square meter (m^2)	1	SY	"="	0.836127	m^2
Lump sum	1	LS	"="	1	LS
Linear foot to meter	1	LF	"="	0.304800	m
Stone to kilograms	1	st	"="	6.35029318	kg
route foot to meter	1	RF	"="	0.304800	m
track foot to meter	1	TF	"="	0.304800	m
miles in feet	1	mile	"="	5280.00	ft.

Table 5-2 - Conversion of imperial units

- The available level of detail for the different UPE sub-categories varies substantially. Further assumptions to compare the data given by CHSRA with DB cost components were necessary. In addition, the data given by CHSRA was partially incomplete and could not be further verified by the ETO Specialists. The cost data provided by CHSRA for the total V2V network, was, in some cases, not available or contradictory. This impacted the validity of the overall benchmark.
- Statements regarding contingencies and risks are only made on a general approach. CHSRA did not provide an official risk register to the ETO team at the time the report was finalized.
- For an easier, more comfortable understanding of the specific Valley to Valley line section, the ETO team produced the following schematic track and stations diagram:

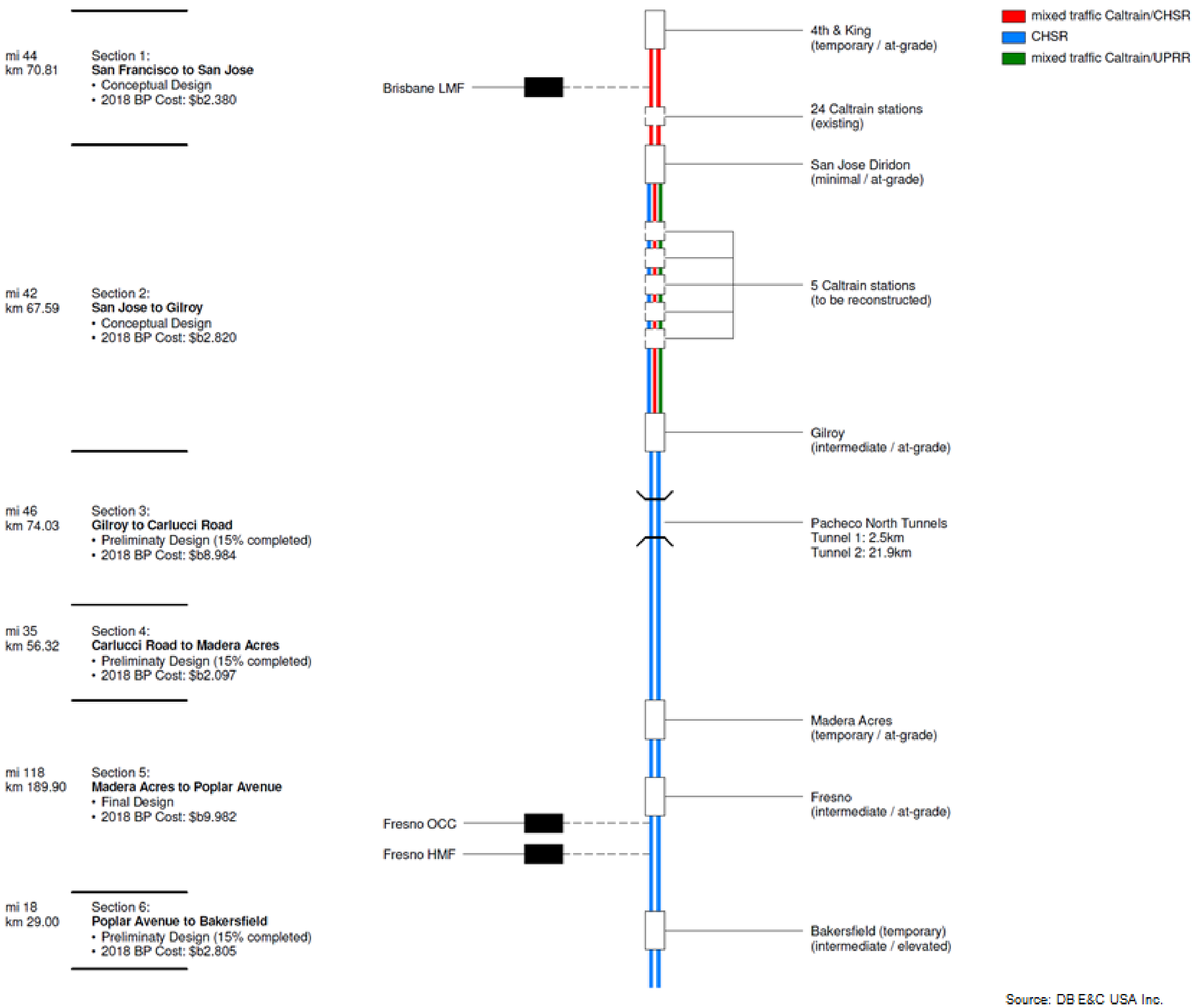


Figure 5-1 - Schematic overview of the V2V concept

5.2 SCC 10 - Track Structures and Track

This section includes the following SCC subcategories:

- Viaducts and bridges (10.01, 10.02, 10.03)
- Earthwork and drainage (10.04, 10.05, 10.06)
- Tunnels (10.07)
- Retaining walls (10.08)
- Track (10.09, 10.10, 10.14)
- CHSRA Cost Component

5.2.1 Qualitative description

5.2.1.1 Qualitative description

For the baseline definition and benchmarking, the following data is used:

- The provided lists of Unit Price Elements (UPE). The UPEs include aggregated quantities by section and unit costs for various SCC subcategories. UPEs are available for the following sections:
  - 3 - Gilroy to Carlucci Road
  - 4 - Carlucci Road to Madera Acres
  - 6 - Poplar Avenue to Bakersfield
- Cost calculations for specific construction elements according to the level of design maturity.
- Drawings and plans according to the level of design maturity.
- Workshops with CHSRA; cost estimators for viaducts, bridges, and tunnels.

If no additional information is available at the current stage of design, the benchmarking of costs for track structures and track will be limited to the comparison of unit cost. UPEs are not yet available for all sections of the Valley to Valley line. In addition, it is not possible to find comparable elements for all given UPEs.

The available level of detail for the different UPE subcategories varies substantially. Unit costs for identified German or International benchmarking elements will be transferred to a comparable level of detail and converted to Imperial units.

<u>Viaducts and bridges</u> (SCC 10.01, 10.02 and 10.03)

In accordance with the current design of alignment, for each section the summary of civil construction elements was provided to ETO. For general benchmarking of elevated structures, cost estimates of Sections 3, 4 and 6 have been submitted for analysis. In addition, the cost estimation in Section 3 (Gilroy to Carlucci Road) was given to ETO for more detailed benchmarking.

No	Section	Data Status
S01	San Francisco to San Jose)	No data available
S02	San Jose to Gilroy)	No data available
S03	Gilroy to Carlucci Road	provided
S04	Carlucci Road to Madera Acres	provided
S05	Madera Acres to Poplar Avenue)	not provided – under construction
S06	Poplar Avenue to Bakersfield	provided

Table 5-3 – Data availability for SCC 10.01, 10.02 and 10.03

Data for bridges and civil structures on a 15% design level were provided for the following sections:

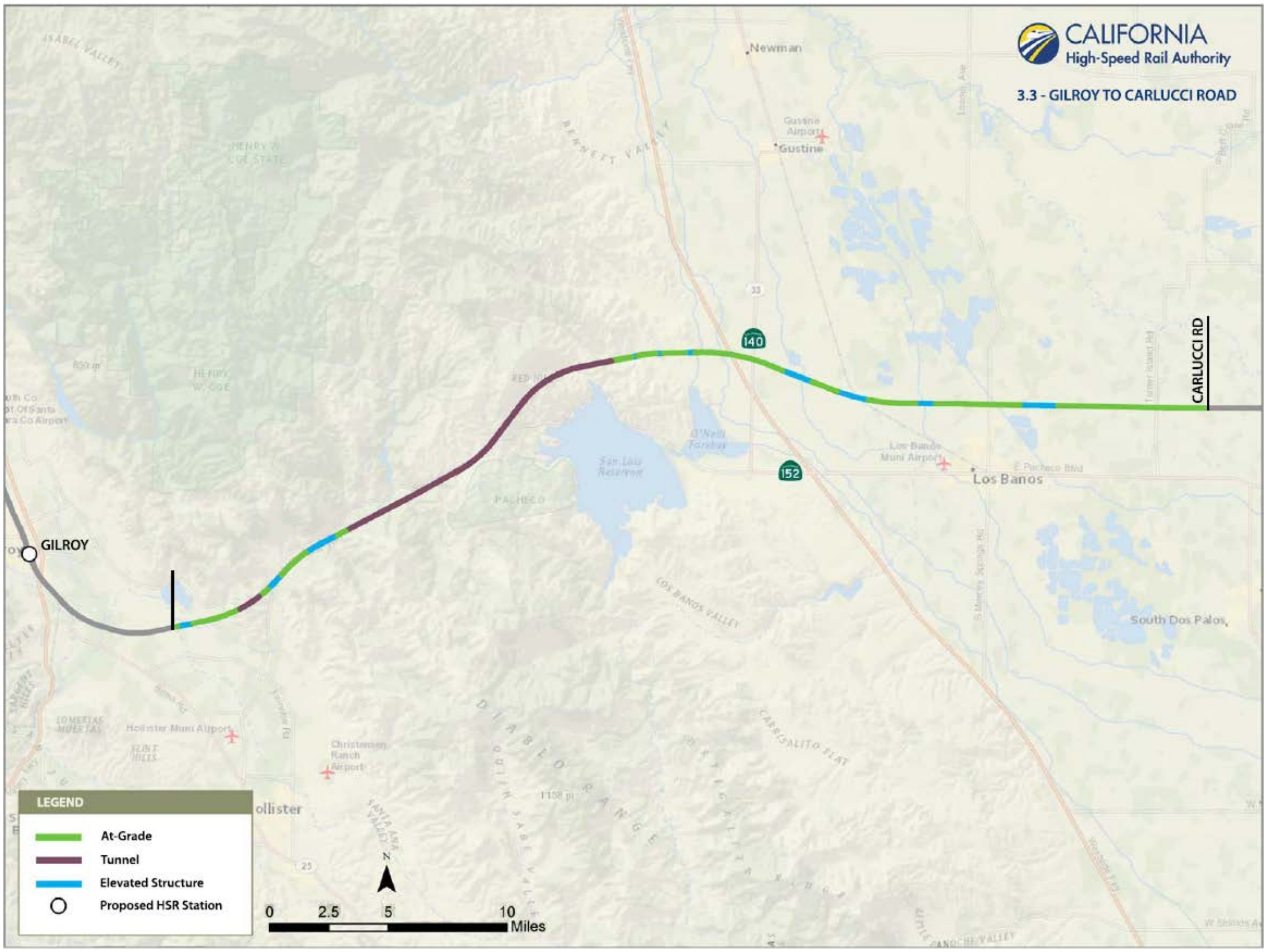


Figure 5-2 - Section 3 - Gilroy to Carlucci Road

Figure 5-3 - Section 4 - Carlucci Road - Madera Acres (CVY)

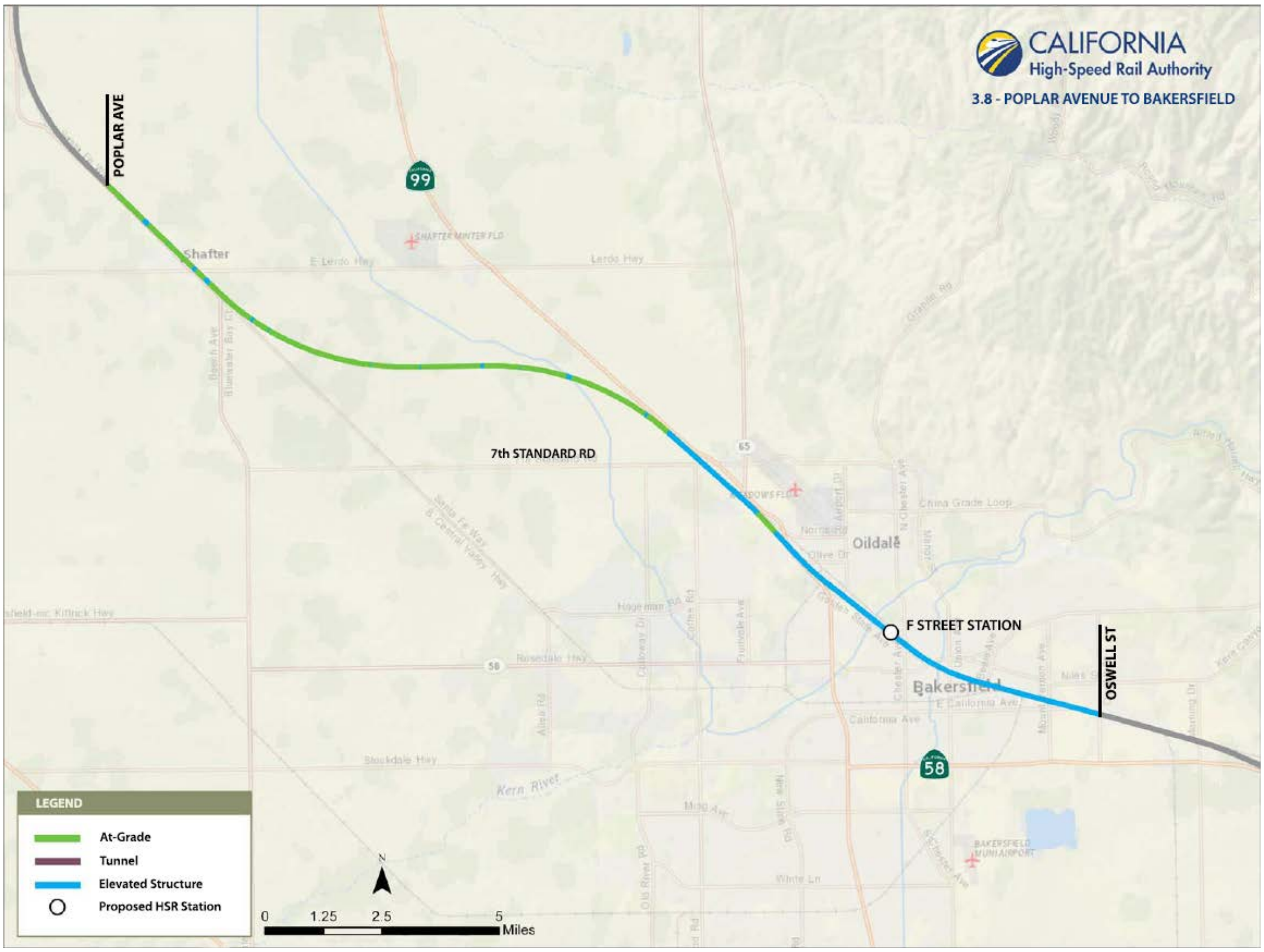


Figure 5-4 - Section 6 - Poplar to Bakersfield

Benchmarking for viaducts and bridges is divided into two steps:

Step 1: General comparison of delivered data in sections 3, 4 and 6 of CHSRA with DB line "VDE 8.2".

Step 2: Specific comparison of selected structures of CHSRA with equivalent specific structures from DB line "VDE 8.2". Three Civil Structures were chosen by CHSRA, and data was given to ETO for detailed benchmarking.

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

UPEs for earthwork and drainage include costs for the following:

- Topsoil
- Cut
- Embankment
- Sub-ballast
- Transitions between construction elements and earthwork
- Trackbed infill for different numbers of tracks and fill heights

UPEs are available in USD per cu yd summarized for three subsections of the Gilroy to Carlucci Road section. No information was given for individual construction elements.

Tunnels (SCC 10.07)

The following information provided by CHSRA was used for baseline definition and benchmarking of tunnels.

The alignment between Gilroy and the Central Valley through the Pacheco Pass contains two tunnel sections with lengths of 1.57 miles (Pacheco Tunnel 1) and 13.62 miles (Pacheco Tunnel 2). Both tunnels are twin tube, single-track tunnels, with a center-to-center spacing between tunnels of 66 feet for Tunnel 1 and 132 feet for Tunnel 2. In accordance with NFPA 130 standards, cross passages between adjacent tunnels allow safe egress in the event of an emergency. The maximum spacing between cross passages is 800 feet.

The tunnel design considerations mention two different numbers for the finished inner diameter for the single-track tunnels (29.5 feet vs. 28 feet), whereas, all provided drawings show 28 feet. In the following it was agreed with CHSRA representatives to use a finished inner diameter of 28 feet.

Considering the expected ground conditions and the proposed tunnel length, excavation by Tunnel Boring Machines (TBM) was selected for both tunnels at this design stage. The TBM type- single-or double-shielded TBMs or EPB (earth pressure balance) TBM-will need to be specified after more detailed geotechnical information is available.

The inner lining consists of bolted and gasketed precast concrete segments. The segmental lining is expected to resist a maximum hydrostatic head of approximately up to 1,000 ft (equivalent to 435psi). Refer to Conceptual Tunnel Design Chapter 5.1.2.1.

UPEs are available in USD for nine major items and various sub-categories for Pacheco Tunnel 1 and Pacheco Tunnel 2. Refer to Table 5-13 in Section 5.2.1.2 for more detail.

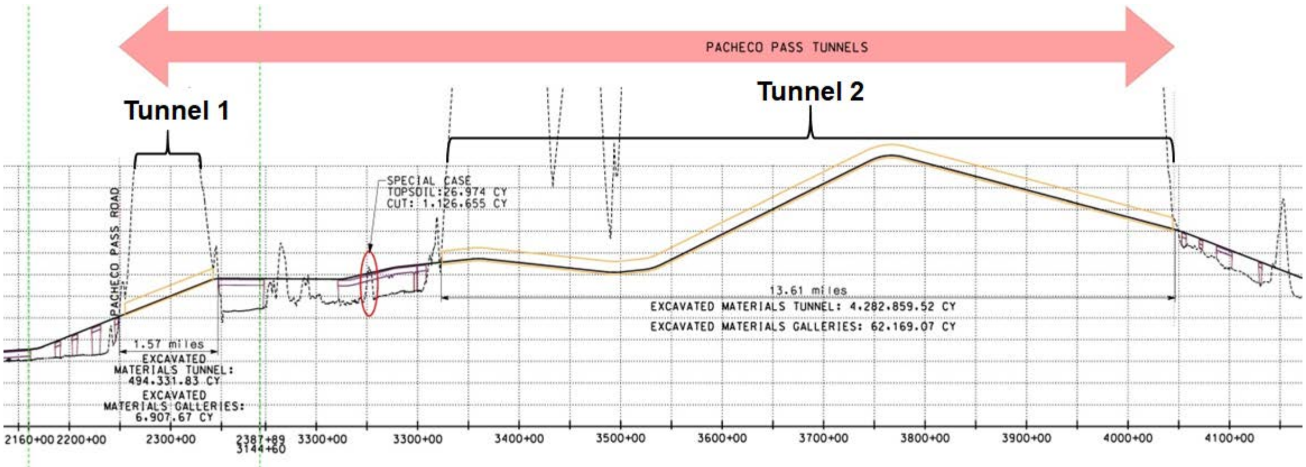


Figure 5-5 - Longitudinal section of Pacheco Pass tunnels

Construction		
Principle	2 x Single Track Tunnels	
Length		
Tunnel 1	1.572	mi
Tunnel 2	13.62	mi
Design Speed	200	mph
TBMs	4	
Type of TBMs	Single or double shield	
Distance between centers of tunnel tubes		
Tunnel 1	66	ft
Tunnel 2	132	ft
Distance of cross passages	800	ft
Number of cross passages	89	
Internal diameter of single track tunnel section	28	ft
Maximum groundwater pressure		
Tunnel 1	250	ft
Tunnel 2	1000	ft

Table 5-4 - Summary of tunnel parameters for Pacheco Pass tunnels

Retaining walls (SCC 10.08)
UPEs are available in USD per route mile for various wall heights and different applications (Retained Cut and Retained Fill). UPEs were provided for Section 2 (San Jose to Gilroy) and Section 6 (Poplar to Bakersfield) only. However, no information was provided for individual construction elements.

The UPEs are benchmarked with the DB CC, which serves as a basis for DB's cost estimations during the planning phase.

Track (SCC 10.09, 10.10, 10.14)
The current design for the CHSRA comprises ballasted track as well as track with direct fixation (Slab Track). Both systems can meet the California High Speed Rail requirements, but each has advantages and disadvantages. No decision on the final track technology to be used for CHSRA has been made.

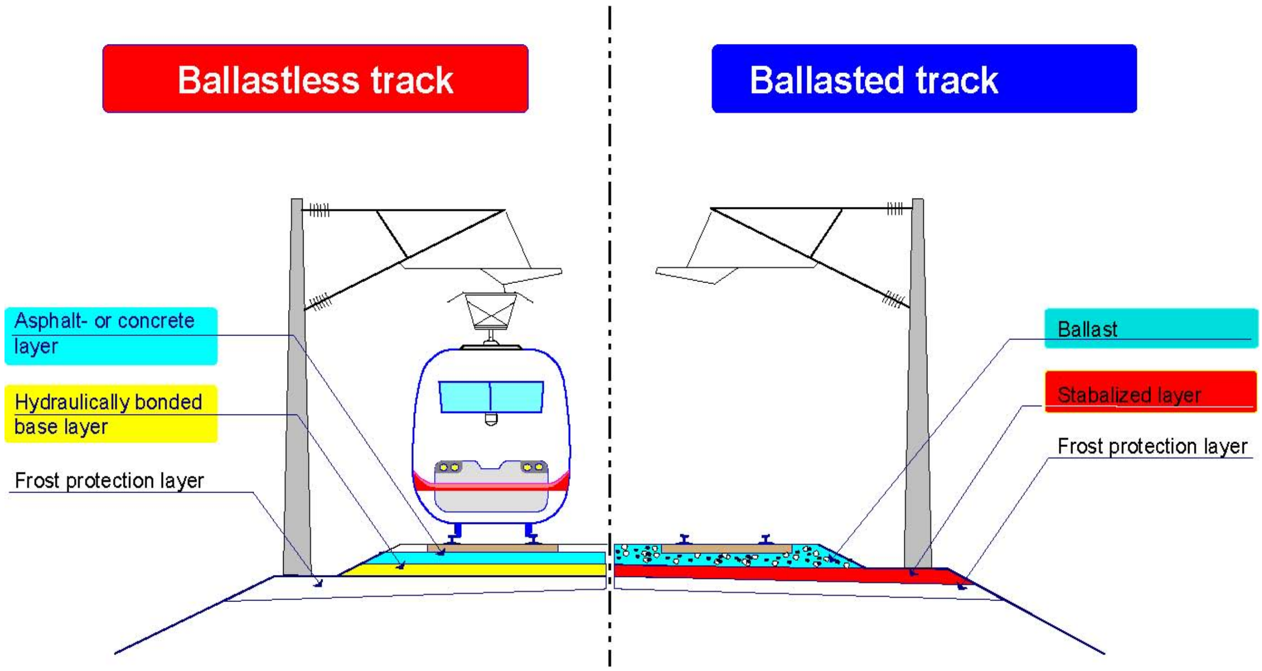


Figure 5-6 - Typical track section - ballasted track vs direct fixation ballastless track) - Source: Michael Missler, DB Systemtechnik

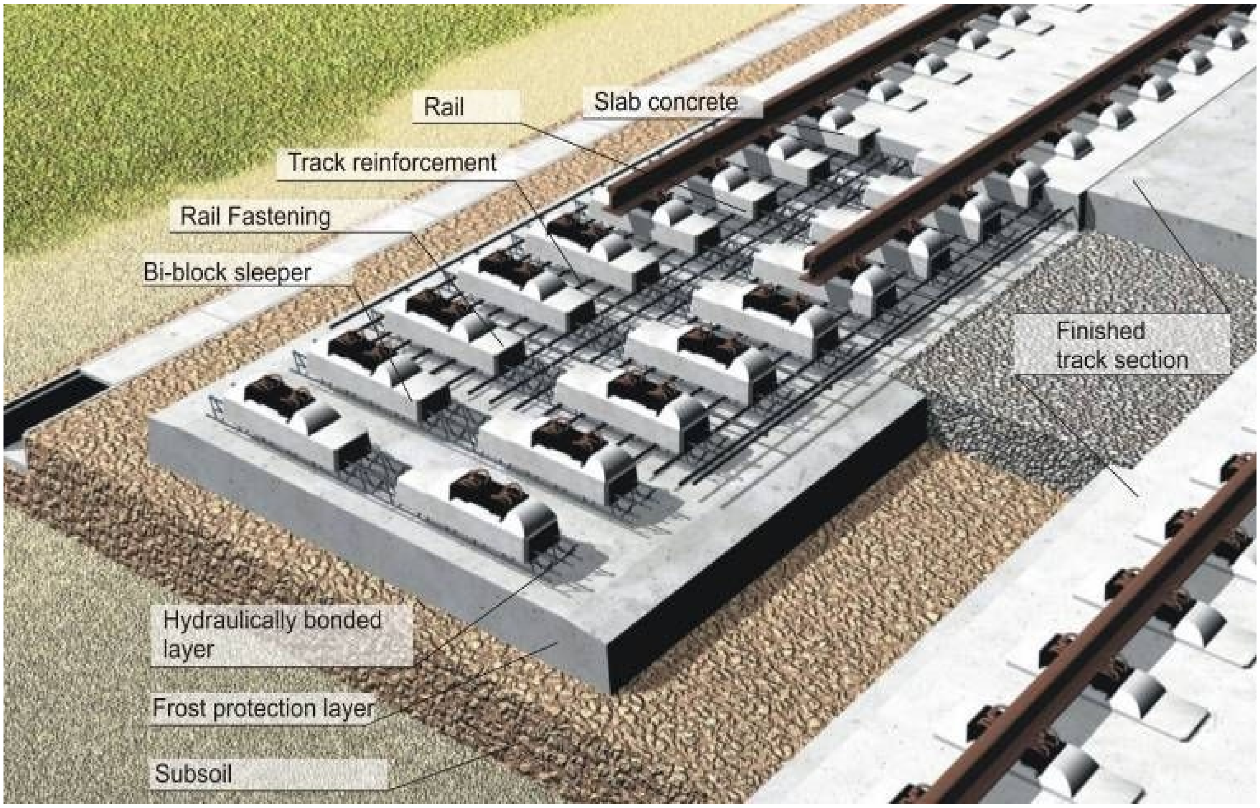


Figure 5-7 - Example of direct fixation type Rheda 2000 – Source: Rail One

Costs for track systems include the following elements:

- Rail
- Fastenings
- Sleepers
- Ballast or concrete slab, respectively
- Turnouts
- Construction work

UPEs are available in USD per route mile for four out of the six sections, for different numbers of tracks, and for two different technologies. The provided data also includes costs for turnouts with various branch speeds.

More detailed data is available for a 12.89-mile section of ballasted double track. These unit costs were used for an in-depth comparison with costs of DB reference projects.

5.2.1.2 Quantitative estimation

Viaducts and bridges (SCC 10.01, 10.02, 10.03)

For initial benchmarking, CHSRA has provided an overview of viaducts and bridges in section 3, 4 and 6, with their UPEs as shown below. Sections 1, 2 and 5 were not considered for benchmarking, because no UPEs were available.

In the following tables, the summarized costs of bridges and viaducts for Sections 3, 4 and 6 are shown as given from CHSRA. The corresponding UPEs are specified depending on the length in road miles. CHSRA pointed out that the length in road miles does not equal the length of a single bridge. In the elevated structure rows, individual structures with the same parameters (e.g. pier spacing) have been combined. As a result, the elevated structure rows show a summary of structures for the same bridge type. The corresponding unit for UPE, in that case, is the length of a bridge type.

Section 3	**Gilroy to Carlucci Road**	**Original values**			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.01.001	Topsoil	267,679	cu yd	899,402	3.36
10.01.002	Cut	4,408,766	cu yd	46,909,271	10.64
10.01.004	Over break in embankment	141,150	cu yd	2,213,225	15.68
10.01.005	Embankment	1,919,792	cu yd	30,102,337	15.68
10.01.006	Over break fill-in cut	55,866	cu yd	875,977	15.68
10.01.007	Over break fill-in embankment	141,150	cu yd	2,213,225	15.68
10.01.008	Sub ballast	141,150	cu yd	1,636,337	11.59
10.01.122	Elevated Structure -1 Track (20 ft Avg. Pier Ht) -110 ft Spacing	0.11	RM	9,891,860	89,926,000
10.01.123	Elevated Structure -1 Track (30 ft Pier Ht) - 110 ft Spacing	0.06	RM	5,414,462	90,241,028
10.01.124	Elevated Structure - 1 Track (40 ft Avg. Pier Ht)	0.25	RM	23,117,802	92,471,208
10.01.125	Elevated Structure - 1 Track (5O ft Avg. Pier Ht) -110 ft Spacing	0.03	RM	2,541,187	84,706,227
10.01.126	Elevated Structure - 1 Track (50 ft Avg. Pier Ht) -11O ft Spacing	1.71	RM	166,083,176	97,124,664
10.01.127	Elevated Structure - 1 Track (7O ft Avg. Pier Ht) -110 ft Spacing.	0.07	RM	6,515,695	93,081,351
10.01.222	Elevated Structure - 2 Track (20 ft Avg. Pier Ht)	0.04	RM	4,697,808	117,445,203
10.01.223a	Elevated Structure -1 Track (30 ft Pier Ht) - 110 ft Spacing	0.10	RM	13,227,229	132,272,287
10.01.001	Topsoil	891,490	cu yd	2,995,405	3.36
10.01.002	Cut	6,877,720	cu yd	73,178,941	10.64
10.01.004	Over break in embankment	1,186,173	cu yd	18,599,193	15.68
10.01.005	Embankment	12,772,729	cu yd	200,276,391	15.68
10.01.006	Over break fill-in cut	112,893	cu yd	1,770,162	15.68

Section 3	Gilroy to Carlucci Road	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.01.007	Over break fill-in embankment	1,186,173	cu yd	18,599,193	15.68
10.01.008	Sub ballast	180,765	cu yd	8,503,186	47.04
10.01.122	Elevated Structure -1 Track (20 ft Avg. Pier Ht) -110 ft Spacing	0.60	RM	55,062,381	91,770,635
10.01.123	Elevated Structure -1 Track (30 ft Avg. Pier Ht) -110 ft Spacing	0.38	RM	35,545,586	93,541,016
10.01.123a	Elevated Structure -1 Track (30 ft Avg. Pier Ht) -150 ft Spacing	0.08	RM	8,248,029	103,100,362
10.01.124	Elevated Structure -1 Track (40 ft Avg. Pier Ht)	0.30	RM	27,834,263	92,780,875
10.01.124a	Elevated Structure -1 Track (40 ft Avg. Pier Ht) -150 ft Spacing	0.50	RM	51,335,099	102,670,197
10.01.125a	Elevated Structure -1 Track (50 ft Avg. Pier Ht) -150 ft Spacing	2.42	RM	253,464,704	104,737,481
10.01.126a	Elevated Structure -1 Track (60 ft Avg. Pier Ht) -150 ft Spacing	0.02	RM	1,983,297	99,164,835
10.01.127	Elevated Structure -1 Track (70 ft Avg. Pier Ht) -110 ft Spacing	0.23	RM	22,467,906	97,686,547
10.01.127a	Elevated Structure -1 Track (70 ft Avg. Pier Ht) -180 ft Spacing	0.07	RM	7,028,690	100,409,863
10.01.223c	Elevated Structure -2 Track (30 ft Avg. Pier Ht) -150 ft Spacing	0.15	RM	16,786,871	111,912,477
10.01.124b	Elevated Structure -2 Track (40 ft Avg. Pier Ht) -150 ft Spacing	0.13	RM	14,335,883	110,276,027
10.02.033	BC 180-300-180 - Pacheco	0.50	RM	48,801,274	97,602,548
10.02.034	BC 225-450-225 span Cal Aqueduct	0.34	RM	23,699,037	69,703,050
10.02.035	BC 150 -300 -150 Delta Mendota	0.23	RM	18,494,568	80,411,166
10.01.001	Topsoil	442,435	cu yd	1,486,582	3.36
10.01.002	Cut	32,495	cu yd	345,742	10.64
10.01.004	Over break in embankment	570,940	cu yd	8,952,339	15.68
10.01.005	Embankment	1,967,173	cu yd	30,845,273	15.68
10.01.006	Over break fill-in cut	24,776	cu yd	388,488	15.68
10.01.007	Over break fil- in embankment	570,940	cu yd	8,952,339	15.68
10.01.008	Sub ballast	136,395	cu yd	6,416,021	47.04
10.01.222a	Elevated Structure - 2Track (20 ft Avg. Pier Ht) 120 ft Spacing	2.48	RM	290,570,906	117,165,688
10.01.223b	Elevated Structure - 2 Track (30 ft Avg. Pier Ht) 120 ft Spacing	1.63	RM	195,778,268	120,109,367
10.01.224a	Elevated Structure - 2 Track (40 ft Avg. Pier Ht) -120 ft Spacing	0.67	RM	81,964,132	122,334,526
10.02.036	BC - 150-275-150 - Cherokee	0.11	RM	11,211,149	101,919,535
10.02.037	BC - 200-350-200 - San Luis	0.14	RM	12,695,785	90,684,179

Section 3	Gilroy to Carlucci Road	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.02.038	BC -120-220-120 ~an - Los Banos	0.09	RM	10,710,880	119,009,779

Table 5-5 – Costs of bridges and viaducts for Section 3

Section 4	Carlucci Road - Madera Acres (CVY)	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.01.200A	Elevated Structure - 2 Track Abutment	16.00	EA	5,261,780	328,861.23
10.01.222A	Elevated Structure - 2 Track (20 ft Avg. Pier Ht), with CIDH Piles	0.36	RM	15,362,506	42,673,627.53
10.01.223A	Elevated Structure - 2 Track (30 ft Avg. Pier Ht), with CIDH Piles	0.18	RM	10,100,195	56,112,192.72
10.01.223B	Elevated Structure - 2 Track (30 ft Avg. Pier Ht), with Pipe Piles	0.21	RM	11,814,169	56,257,946.67
10.01.223C	Balanced Cantilever Structure (200 ft MS) - 2 Track (30 ft Avg. Pier Ht)	0.21	RM	14,373,932	68,447,293.67
10.01.224A	Elevated Structure - 2 Track (40 ft Avg. Pier Ht), with Pipe Piles	0.02	RM	1,283,379	64,168,925.00
10.01.224B	Balanced Cantilever Structure (296 ft MS) - 2 Track (40 ft Avg. Pier Ht)	0.12	RM	6,523,028	54,358,566.92
10.01.422A	Elevated Structure - 2 Track (20 ft Avg. Pier Ht), with CIDH Piles	0.05	RM	1,883,044	37,660,876.20
10.01.423A	Elevated Structure - 2 Track (30 ft Avg. Pier Ht), with CIDH Piles	0.14	RM	6,665,051	47,607,503.64
10.01.424A	Elevated Structure - 2 Track (40 ft Avg. Pier Ht), with Pipe Piles	0.03	RM	1,778,676	59,289,213.33
10.01.425A	Elevated Structure - 2 Track (50 ft Avg. Pier Ht),v with Pipe Piles	0.06	RM	4,331,366	72,189,441.17
10.02.023A	Bridge Structure - 1 span with 2 Tracks	0.09	RM	4,140,136	46,001,508.11
10.02.023B	Bridge Structure - 3 span with 2 Track (20 ft Avg. Pier Ht) w/ CIDH Piles	0.09	RM	4,953,005	55,033,393.67

Table 5-6 – Costs of bridges and viaducts for Section 4

Section 6	Poplar to Bakersfield	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.01.222	Elevated Structure - 2 Track (20 ft Avg. Pier Ht)	1.08	RM	44,982,778	41,805,555
10.01.223	Elevated Structure - 2 Track (30 ft Avg. Pier Ht)	1.37	RM	70,574,861	51,589,811
10.01.224	Elevated Structure - 2 Track (40 ft Avg. Pier Ht)	1.13	RM	59,189,360	52,519,396
10.01.225	Elevated Structure - 2 Track (50 ft Avg. Pier Ht)	1.12	RM	59,809,411	53,448,982
10.01.226	Elevated Structure - 2 Track (60 ft Avg. Pier Ht)	2.73	RM	192,108,030	70,446,656
10.01.227	Elevated Structure - 2 Track (70 ft Avg. Pier Ht)		RM		71,995,915
10.01.228	Elevated Structure - 2 Track (80 ft Avg. Pier Ht)		RM		82,170,952
10.01.249A	Elevated Structure - 3 Track at Station - 3 Columns (40 ft Avg. Pier Ht)	0.07	RM	8,166,556	123,735,696
10.01.250A	Elevated Structure - 4 Track at Station - 2 Columns (40 ft Avg. Pier Ht)	0.32	RM	41,581,919	129,538,689
10.01.255	Elevated Structure - 4 Track at Station - 4 Columns (40 ft Avg. Pier Ht)	0.06	RM	11,043,065	175,286,742
10.01.255A	Elevated Structure - 4 Track at Station - 4 Columns (50 ft Avg. Pier Ht)	0.20	RM	36,398,598	182,907,530
10.01.255B	Elevated Structure - 5 Track at Station - 3 Columns (40 ft Avg. Pier Ht)	0.11	RM	21,552,756	203,327,890
10.01.255 C	Elevated Structure - 5 Track at Station - 3 Columns (50 ft Avg. Pier Ht)	0.38	RM	79,530,760	210,398,836
10.01.256	Elevated Structure - 6 Track at Station - 2 Columns (30 ft Avg. Pier Ht)		RM		202,436,966
10.01.423	Elevated Structure (LS) - 2 Track (30 ft Avg. Pier Ht)		RM		56,924,480
10.01.424	Elevated Structure (LS) - 2 Track (40 ft Avg. Pier Ht)	0.39	RM	22,777,238	57,957,350
10.01.425	Elevated Structure (LS) - 2 Track (50 ft Avg. Pier Ht)	0.50	RM	29,259,109	58,990,139
10.01.426	Elevated Structure (LS) - 2 Track (60 ft Avg. Pier Ht)	0.20	RM	14,132,357	69,617,525
10.01.427	Elevated Structure (LS) - 2 Track (70 ft Avg. Pier Ht)		RM		70,975,143
10.01.524	Elevated Structure Straddle over 2 RR - 2 Track (40 ft Avg. Pier Ht)		RM		81,833,163
10.01.527	Elevated Structure Straddle over 2 RR - 2 Track (70 ft Avg. Pier Ht)		RM		86,691,328
10.01.724	Elevated Deck Structure - 2 Columns - 2 Track (40 ft Avg Ht)		RM		193,120,934
10.01.825	Elevated Structure Straddle - 2 Track (50 ft Avg. Pier Ht)	0.28	RM	22,766,893	82,488,742
10.01.999	Maintenance Of Traffic	5 %	LS	35,693,685	
10.02.014	Bridge Structure - Single span concrete structure with 2 Track		RM		59,094,590

Section 6	Poplar to Bakersfield	Original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
10.02.023	Bridge Structure - 3 span concrete structure with 2 Track	0.05	RM	2,874,653	61,162,831
10.02.023A	Bridge Structure - 2 span concrete structure with 2 Track	0.13	RM	5,843,900	44,271,969
10.02.023B	Bridge Structure - 4 span concrete structure with 2 Track	0.15	RM	5,110,359	34,069,061
10.02.023 C	Bridge Structure - 2 span precast girder structure with 2 Track	0.07	RM	6,311,133	92,810,780
10.02.044	Bridge Structure - 2 Track Steel Truss Bridge	0.31	RM	43,067,404	137,595,539
10.02.044A	Bridge Structure - 2 Track Steel Truss Bridges - 60 to 80 ft high		RM		152,523,983
10.02.060	Concrete Bridge Structure - Single Span Simply supported - 2 Track	0.09	RM	3,980,394	43,740,589
10.02.060B	Bridge Structure - Two Span Steel Plate Girder Structure with 2 Tracks + 1 Future Track for BNSF -	0.05	RM	8,353,430	177,732,549
10.02.060 C	Bridge Structure - Three Span Steel Plate Girder Structure with 2 Tracks + 1 Future Track for BNSF	0.04	RM	6,856,387	163,247,303
10.02.060 D	Bridge Structure - Two Span Steel Plate Girder Structure with 2 Tracks + 1 Future Track for BNSF -	0.02	RM	4,568,356	207,652,524
10.02.060E	Bridge Structure - Two Span Steel Plate Girder Structure with 2 Tracks + 1 Future Track for BNSF -	0.05	RM	7,753,930	164,977,245
10.02.999	Maintenance Of Traffic	5 %	LS	4,735,997	

Table 5-7 – Costs of bridges and viaducts for Section 6

The data has been prepared for further consideration, as shown in Figure 5 8, which illustrates the total costs given in Table 5 3, and Table 5 4 in relation to the accumulated lengths of bridge types.

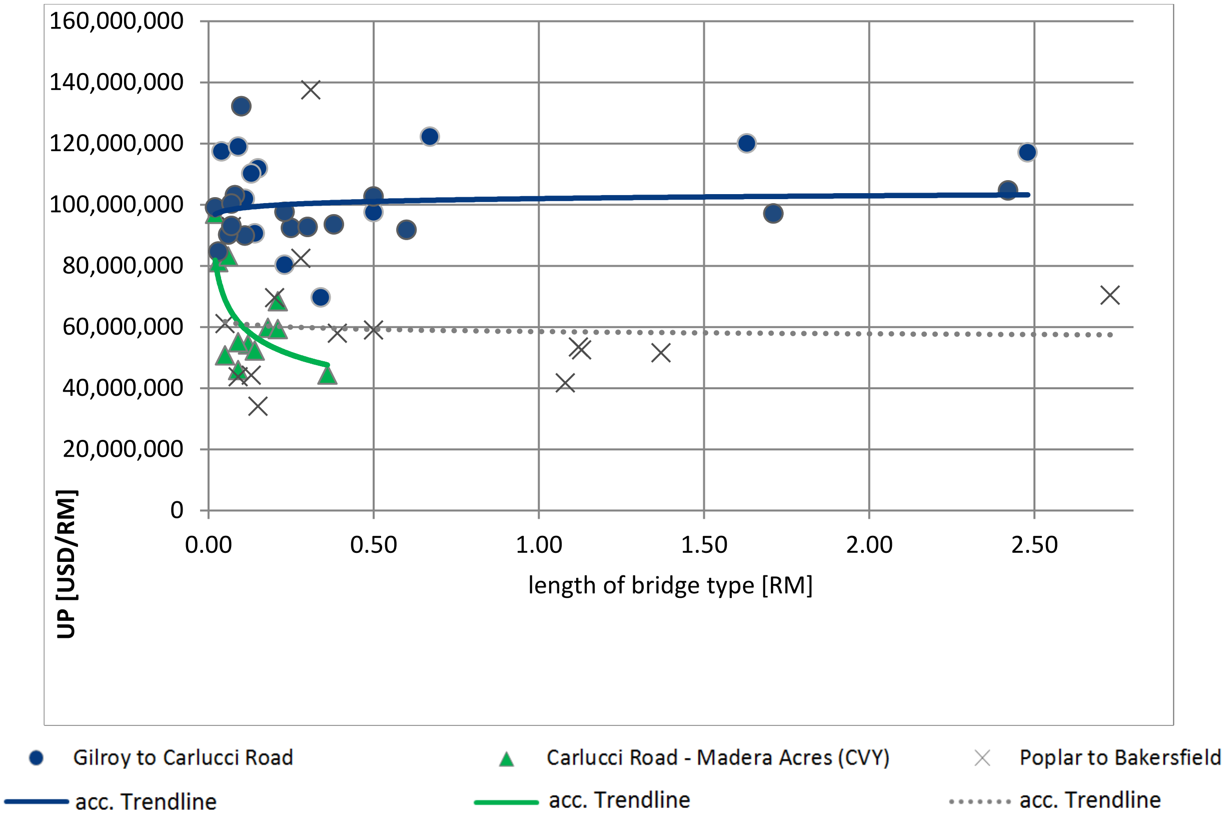


Figure 5-8 – Summary of UPEs for viaducts and bridges for initial benchmarking

In Figure 5-8, three trend lines have been included, which demonstrate the influence of the different seismic frame conditions per section. The graph shows that costs increase with increased seismic activity, because construction for higher seismic resistance is more complex and more expensive to build.

For a more detailed benchmark of individual parts of the bridge (foundations, substructure, and superstructure), it was decided to analyze specific constructions in more detail. Therefore, three main types of elevated structures have been analyzed and compared to reference bridges of the VDE 8.2 project in Germany.

CHSRA and DB representatives agreed to further investigate the following three typical bridge types:

- Elevated Structure – 2 Track
  High Seismicity Zone
- Wasco Viaduct – 2 Track
  Moderate Seismicity Zone
- Elevated Structure – 1 Track
  Moderate Seismicity Zone

Table 5-6, Table 5-7 and Table 5-8 show the UPEs for several structural components and parameters of these selected elevated structures. For a better comparison in the benchmark, all parties agreed to split the structure into three major sub-components: Foundations, Substructure and Superstructure.

Description	Total Cost per RM in USD	% of Total
Reinforcing Steel	4,142,771	4%
Structural Concrete, In Place, Aerial Footing	17,083,736	15%
Structural Excavation	888,352	1%
Haul and Dispose of Excavated Material	891,568	1%
Structural Backfill	234,320	0%
Steel Sheet Piling, Drive, Extract and Salvage	9,840,232	9%
Drilled Shaft, 120 in Dia, un-cased in soft rock	30,750,720	27%
Site Demolition Allowance	258,336	0%
Site Restoration Allowance	30,528	0%
Foundation costs	**64,120,563**	**56%**
Reinforcing Steel	4,142,771	4%
Structural Concrete, In Place, Aerial Pier	6,168,968	5%
Multirotational Bearing (1500 Kip)	425,776	0%
Substructure costs	**10,737,515**	**9%**
Reinforcing Steel	4,142,771	4%
Structural Concrete, In Place, Parapet Wall	709,632	1%
Structural Concrete, In Place, OCS Pole Base	44,944	0%
Precast Segmental Box Girder, Double (10.5 ft depth)	31,933,440	28%
Service/Safety Walkway	1,419,264	1%
Metal Pipe & Cable Railing	354,816	0%
Corrosion Control, Aerial	29,568	0%
Walkway Lighting, Allowance	354,816	0%
Trackway Drainage Allowance, Aerial	402,128	0%
Cable Duct, Aerial Guideway	437,608	0%
Superstructure costs	**39,828,987**	**35%**
TOTAL:	**114,687,065**	**100%**

Table 5-8 – Costs components of elevated structure - two track (40 ft avg. pier ht, 150 ft span) high seismicity zone

Description	Total Cost per RM in USD	% of Total
Reinforcing Steel	3,880,293	6%
Bridge Foundation	18,708,443	29%
Structural Excavation	50,887	0%
Structural Backfill	34,594	0%
Foundation costs	**22,674,217**	**36%**
Reinforcing Steel	3,880,293	6%
Substructure	2,912,380	5%
Multirotational Bearing (1500 Kip)	1,690,005	3%
Substructure costs	**8,482,678**	**13%**
Reinforcing Steel	3,880,293	6%
Falsework	4,074,236	6%
Cast-in-Place Box Girder	8,591,405	14%
Precast Beams	9,249,372	15%
Bridge Barrier	2,513,507	4%
Expansion Joint Assemblies	487,715	1%
Approach Slabs	24,408	0%
Equipment Support	3,609,736	6%
Superstructure costs	**32,430,672**	**51%**
TOTAL:	**63,587,567**	**100%**

Table 5-9 – Costs components Wasco Viaduct - two track (40 ft avg. pier ht, 150 ft span) moderate seismicity zone

Description	Total Cost per RM in USD	% of Total
Reinforcing Steel	3,769,500	4%
Structural Concrete, In Place, Aerial Footing	12,841,900	13%
Structural Excavation	673,500	1%
Haul and Dispose of Excavated Material	671,100	1%
Structural Backfill	181,550	0%
Steel Sheet Piling, Drive, Extract and Salvage	8,253,950	8%
Drilled Shaft, 120 in Dia, Un-cased in Soft Rock	28,537,600	29%
Site Demolition Allowance	194,200	0%
Site Restoration Allowance	22,800	0%
Foundation costs	**55,146,100**	**56%**
Reinforcing Steel	3,769,500	4%
Structural Concrete, In Place, Aerial Pier	7,306,700	7%

Description	Total Cost per RM in USD	% of Total
Multirotational Bearing (1500 Kip)	395,100	0%
Substructure costs	**11,471,300**	**12%**
Reinforcing Steel	3,769,500	4%
Structural Concrete, In Place, Parapet Wall	658,550	1%
Structural Concrete, In Place, OCS Pole Base	20,850	0%
Precast Segmental Box Girder, Double (10.5 ft depth)	26,342,400	27%
Service/Safety Walkway	658,550	1%
Metal Pipe & Cable Railing	329,300	0%
Corrosion Control, Aerial	27,450	0%
Walkway Lighting, Allowance	164,650	0%
Trackway Drainage Allowance, Aerial	373,200	0%
Cable Duct, Aerial Guideway	203,050	0%
Superstructure costs	**32,547,500**	**33%**
TOTAL:	**99,164,900**	**100%**

Table 5-10 – Costs components of elevated structure - one track (60 ft avg. pier ht, 120 ft span)/moderate seismicity zone

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

UPEs, including costs per cubic yard for cut, embankment, sub ballast, and trackbed infill for different numbers of tracks and fill heights, are summarized below.

UPE for Section 3 (Gilroy to Carlucci Road)	Quantity	Unit	Grand Total in USD	Unit Price in USD
Topsoil	1,601,604	cu yd	5,381,389	3.36
Cut	11,512,515	cu yd	123,468,580	10.72
Embankment	20,456,219	cu yd	320,753,514	15.68
Sub ballast	317,160	cu yd	14,919,206	47.04

Table 5-11 - UPEs for earthwork

The at-grade trackbed infill shows the material needed for subsoil improvement beneath the track. UPEs were given for construction elements with a specific length, number of tracks, and depth of infill.

SCC	Description of UPEs for Section 4 and 6	Quantity in RM	Grand Total in USD	Unit Price in USD	No of Tracks	Depth of Infill in ft
10.05.221A	At-grade trackbed infill - 2 Track (5 ft Avg. Exc Depth) - without fence	9.60	30,238,285	3,149,821	2	5
10.05.222A	At-grade trackbed infill - two track (10 ft avg. exc depth) - without fence	6.88	38,725,543	5,628,713	2	10
10.05.223A	At-grade trackbed infill - two track (15 ft avg. exc depth) - without Fence	3.76	31,452,944	8,365,145	2	15
10.05.224A	At-grade trackbed infill - two track (20 ft avg. exc depth) - without fence	5.39	82,033,864	15,219,641	2	20
10.05.226	At-grade trackbed infill - two track (40 ft avg. exc depth) - without fence	4.01	152,379,226	37,999,807	2	40
10.05.241A	At-grade trackbed infill - four track (5 ft avg. exc depth) - without fence	0.44	2,400,100	5,454,772	4	5
10.05.242	At-grade trackbed infill - four track (10 ft avg. exc depth) - without fence	1.03	8,770,498	8,515,047	4	10
10.05.212	At-grade trackbed infill - one track (10 ft avg. fill ht)	0.34	593,897	1,772,828	1	10
10.05.214	At-grade trackbed infill - one track (40 ft avg. fill ht)	0.68	2,280,407	3,368,400	1	40
10.05.215A	At-grade trackbed infill - one track (30 ft avg. fill ht)	0.58	3,310,680	5,708,069	1	30
10.05.221	At-grade trackbed infill - 2 track (5 ft avg. fill ht -(0 ft-7 ft))	0.00	0	1,778,525	2	5
10.05.221A	At-grade trackbed infill - two track (5 ft avg. fill ht -(0 ft-7 ft)) BNSF	0.92	1,436,163	1,562,745	2	5
10.05.222	At-grade trackbed infill - two track (10 ft avg. fill ht -(7 ft-12 ft))	0.19	463,411	2,451,912	2	10
10.05.222A	At-grade trackbed infill - two track (10 ft avg. fill ht t-(7 ft-12	0.24	513,536	2,166,819	2	10

SCC	Description of UPEs for Section 4 and 6	Quantity in RM	Grand Total in USD	Unit Price in USD	No of Tracks	Depth of Infill in ft
	ft)) BNSF					
10.05.223	At-grade trackbed infill - two track (15 ft avg. fill ht -(12 ft-17 ft))	0.19	625,456	3,309,292	2	15
10.05.224A	At-grade trackbed infill - two track (20 ft avg. fill ht -(17 ft-25 ft))	1.93	8,001,993	4,150,411	2	20
10.05.225A	At-grade trackbed infill - two track (30 ft avg. fill ht -(25 ft-35 ft))	8.84	53,693,562	6,075,994	2	30
10.05.226	At-grade trackbed infill - two track (40 ft avg. fill ht -(30 ft-50 ft))	0.52	4,801,475	9,269,257	2	40
10.05.251A	At-grade trackbed infill - five track (5 ft avg. fill ht -(0 ft-7 ft)) BNSF	1.38	4,094,846	2,960,843	5	5

Table 5-12 - UPEs for trackbed infill

Tunnels (SCC 10.07)

Table 5-11, below, summarizes the provided cost estimate for the 13.62-mile-long Pacheco Tunnel 2 by major cost elements. Since the available cost structures of Pacheco 1 and Pacheco 2 are very similar, only the costs of Pacheco Tunnel 2 were used for comparison.

The main cost elements are:

- Site work allowances (includes site and portal development)
- Single-track tunnel (includes all costs for TBM procurement, mobilization and demobilization of four TBMs, TBM mining, mucking operation, segmental lining, walkways, Saturday maintenance shift)
- Cross passages (all construction costs for 89 cross passages)
- Paralleling station (all costs for a proposed paralleling station in the Pacheco Tunnel 2 because of the total tunnel length)
- TBM diversions & burial
  Because of the total tunnel length, four TBMs will operate simultaneously, launching from both portals. The TBM shields are planned to be buried in the ground after completing the tunnel mining. The costs include all expenses for TBM diversions and burial.
- Fault chambers
  The tunnel will be excavated through the active Ortigalita Fault zone. Therefore, a fault chamber is planned. The fault chamber design was not detailed or available at the time of this benchmark report.

- Mechanical ventilation (required because of tunnel length and alignment)
- All costs include the following markup:
  - Direct costs
  - Indirect costs 33% (fixed rate)
  - Bonds 1% and insurance 5%
  - Home office overhead 3%
  - Markup (profit + risk) (15% of total or 50% of labor costs)

Description	Total Cost in USD	Total Cost per RM in USD	% of Total
Pacheco Pass Tunnel No.2 (13.61 Mi)			
Site Work Allowances	52,390,498	3,849,412	2%
Site Development	1,866,238	137,123	
Portal Development	50,524,260	3,712,290	
Single Track Tunnel	2,186,903,110	160,683,550	70%
Procurement & Mob-Demob	312,076,959	22,929,975	10%
Starter Tunnels	2,746,000	201,763	0%
PCC Segment Procurement	889,722,330	65,372,691	28%
TBM Mining	390,084,621	28,661,618	12%
Mucking Operation	56,316,737	4,137,894	2%
Clean up Tunnel	8,659,549	636,264	0%
Invert Concrete	42,289,046	3,107,204	1%
Walkway & Bench Concrete	88,442,153	6,498,321	3%
Sat. Maintenance Shift	6,535,709	480,214	0%
Support	390,030,007	28,657,605	12%
Cross Passages	220,877,670	16,229,072	7%
Remove Portion of PCC	20,571,585	1,511,505	
F&I Crown Bars	21,290,766	1,564,347	
X-Passage Excavation	51,265,934	3,766,784	
X-Passage Concrete	101,185,804	7,434,666	
F&I Rebar	22,238,951	1,634,015	
F&I Waterproofing	4,324,630	317,754	
Paralleling Station & ATC	14,890,630	1,094,095	0%
Remove Portion of PCC	1,386,848	101,899	
F&I Crown Bars	1,435,330	105,461	
Excavation	3,456,134	253,941	
Concrete	6,821,515	501,213	
Rebar	1,499,254	110,158	

Description	Total Cost in USD	Total Cost per RM in USD	% of Total
Waterproofing	291,549	21,422	
Tbm Diversions & Burial	34,115,664	2,506,662	1%
Diversions	16,263,225	1,194,947	
Lining Removals	3,375,557	248,020	
Lining Repairs	284,512	20,905	
Bulkheads & Backfill	5,470,432	401,942	
Cip Lining	8,721,939	640,848	
Fault Chambers	251,566,452	18,483,942	8%
Pre-Excavation Grouting	6,048,555	444,420	
Lining Removals	26,596,794	1,954,210	
Excavation & Support (Fault Chambers)	55,932,214	4,109,641	
Waterproofing	13,129,449	964,691	
Reinforcement (Fault Chambers)	44,593,802	3,276,547	
Invert Concrete	21,508,636	1,580,355	
Walls & Arch Concrete (Fault Chambers)	43,817,436	3,219,503	
Surface Support	39,939,564	2,934,575	
Mechanical Ventilation	367,884,792	27,030,477	12%
Ventilation Equipment Allowance	367,884,792	27,030,477	
Total:	3,128,628,817	229,877,209	100%

Table 5-13 - Pacheco Tunnel cost estimate (CSHRA)

Retaining walls (SCC 10.08)

The UPE includes the cost for two track sections, with walls on one or both sides and different wall heights.

Section 2	San Jose to Gilroy	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.08.221	Retained Cut, Trench - 2 Track (10 ft Avg. Exc Depth)	0.28	RM	16,635,124	59,411,157
10.08.222	Retained Cut, Trench - 2 Track (20 ft Avg. Exc Depth)	0.38	RM	39,502,179	103,953,101
10.08.222a	Retained Cut, Trench - 2 Track (20 ft Avg. Exc Depth	0.10	RM	13,216,706	132,167,063
10.08.223	Retained Cut, Trench - 2 Track (30 ft Avg. Exc Depth)	0.23	RM	33,183,549	144,276,298
10.08.223a	Retained Cut, Trench - 2 Track Spacing (30 ft Avg. Exc Depth)	0.11	RM	19,284,591	175,314,468
10.08.224a	Retained Cut, Staged Trench - 2 Track (40 ft Avg. Exc Depth	0.29	RM	80,963,019	279,182,825
10.08.421	Retained Fill, Walls Both Sides - 2 Tracks (10 ft Avg. Wall Ht)	12.23	RM	124,684,231	10,194,949
10.08.422	Retained Fill, Walls Both Sides - 2 Tracks (20 ft Avg. Wall Ht	6.00	RM	101,589,019	16,931,503
10.08.423	Retained Fill, Walls Both Sides - 2 Tracks (30 ft Avg. Wall Ht)	0.63	RM	10,700,672	16,985,194

Table 5-14 - UPE for retaining walls

Section 6	Poplar to Bakersfield	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.08.422	Retained Fill, Walls Both Sides - 2 Tracks (20 ft Avg. Wall Ht)	0.00	RM	0	24,655,757
10.08.422B	Retained Fill, Walls One Side - 2 Tracks (20 ft Avg. Wall Ht) BNSF	0.49	RM	6,863,354	13,949,907
10.08.423	Retained Fill, Walls Both Sides - 2 Tracks (30 ft Avg. Wall Ht)	0.00	RM	0	43,250,203
10.08.423A	Retained Fill, Walls One Side - 2 Tracks (30 ft Avg. Wall Ht)	0.83	RM	21,107,248	25,553,569
10.08.423B	Retained Fill, Walls One Side - 2 Tracks (30 ft Avg. Wall Ht) BNSF	1.60	RM	37,745,790	23,605,872
10.08.423C	Retained Fill, Walls Both Sides - 2 Tracks (30 ft Avg. Wall Ht) Verdugo Ln	0.01	RM	11,692	1,461,506
10.08.960	HST Structure Box Culvert - 30 ft x 16.5 ft Opening	1.00	EA	663,259	663,259

Section 6	Poplar to Bakersfield	Original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
10.08.960A	HST Structure Box Culvert - 10 ft x 10 ft Opening	3.00	EA	627,254	209,085
10.08.999	Maintenance Of Traffic	0.05	LS	3,350,930	0

Table 5-15 - UPE for retaining walls

Track (SCC 10.09, 10.10, 10.14)

UPEs include cost per route mile for ballasted track and for tracks with direct fixation (ballastless track) for up to six parallel tracks. Also included are unit costs for turnouts and crossovers.

Section 3	Gilroy - Carlucci Road	Original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
10.09.110	Ballasted track -one track	2.02	RM	3,766,492	1,864,600
10.09.120	Ballasted track -two track	1.33	RM	4,959,836	3,729,200
10.10.110	Direct fixation track - one track	5.28	RM	9,496,948	1,798,664
10.09.110	Ballasted track - one track	13.64	RM	25,401,595	1,862,287
10.09.120	Ballasted track- two track	1.67	RM	6,147,514	3,681,146
10.10.110	Direct fixation track - one track	31.57	RM	56,732,521	1,797,039
10.09.120	Ballasted track - two track	12.98	RM	47,789,985	3,681,817
10.10.120	Direct fixation track - two track	5.14	RM	18,344,989	3,569,064
10.14.305	Ballasted crossover (80 mph)	2.00	EA	2,540,160	1,270,080

Table 5-16 - UPEs for track and turnouts for Section 3

Section 4	Carlucci Road - Madera Acres (CWY)	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.09.122	Ballasted Track (Track Laying Machine- two track	33.10	RM	70,831,600	2,139,927
10.10.120	Direct fixation track - two track	0.71	RM	2,350,219	3,310,168
10.14.215	Ballasted Turnout (150 mph)	4.00	EA	8,012,700	2,003,175

Table 5-17 - UPEs for track and turnouts for Section 4

Section 5	Madera - Poplar	Original values			
	based on other source: track and system estimate 26/9/17				
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
	Ballasted track - two track	110.000	RM	355,664,058	3,233,309.00
	Ballasted track - four track	2.000	RM	13,429,398	6,714,699.00
	Japanese switch	56.000	EA	116,535,937	2,080,998.00

Table 5-18 - UPEs for track and turnouts for Section 5

Section 6	Poplar to Bakersfield	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
10.09.122	Ballasted track (track laying machine) - two track	13.11	RM	47,998,832	3,660,401
10.09.820	Ballasted freight track - two track	4.79	RM	18,675,062	3,897,133
10.09.830	Ballasted freight track - three track	1.38	RM	8,054,696	5,857,960
10.09.910	Ballasted track relocation - one track (temporary)	3.10	RM	5,372,080	1,735,168
10.09.920	Ballasted track relocation - one track (permanent) - spur	0.59	RM	1,421,758	2,409,759
10.09.922	Ballasted track relocation - two track (permanent) - mainline		RM		5,598,842
10.10.110	Direct fixation track - one track	0.19	RM	411,303	2,142,205
10.10.120	Direct fixation track - two track	9.13	RM	39,120,943	4,284,410
10.10.140	Direct fixation track - four track	0.29	RM	2,533,986	8,619,002

Section 6	Poplar to Bakersfield	Original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
10.10.145	Direct fixation track - five track	0.59	RM	6,337,968	10,778,858
10.10.150	Direct fixation track - six track		RM		13,074,973
10.14.105	Direct fixation turnout (80 mph)	2.00	EA	1,406,350	703,175
10.14.110	Direct fixation turnout (110 mph)	2.00	EA	1,978,739	989,369
10.14.140	Direct fixation crossover (110 mph)	4.00	EA	7,346,997	1,836,749
10.14.199	Ballasted turnout (25 mph)	8.00	EA	2,599,040	324,880
10.14.200	Ballasted Turnout (60 mph)	2.00	EA	883,463	441,732
10.14.310	Ballasted Crossover (110 mph)	1.00	EA	1,530,234	1,530,234
10.14.400	Terminal - bumping post	2.00	EA	61,912	30,956

Table 5-19 - UPEs for track and turnouts for Section 6

The following table includes unit costs for eight sub-categories of UPE 10.09.120. and was used for an in-depth benchmark for ballasted track sections.

Description	Takeoff Quantity		Grand Total in USD	Grand Total Unit Price	
Sub-ballast, place, spread & compact	105,567.00	cu yd	4,965,872	47.04	USD/cu yd
Ballast, place, spread & compact	112,422.00	cu yd	6,547,457	58.24	USD/cu yd
Unload track material & distribute	137,100.00	tf	1,074,864	7.84	USD/tf
Electric (flash butt) welding	3,427.50	EA	1,727,460	504	USD/EA
Install rail on ties, 141 RE	137,100.00	tf	19,961,760	145.6	USD/tf
Align & tamp	137,100.00	tf	4,299,456	31.36	USD/tf
Rail grinding	137,100.00	tf	460,656	3.36	USD/tf
Concrete cross ties	68,550.00	EA	8,752,464	127.68	USD/EA
10.09.120 ballasted track - two track	12.98	RM	47,789,989	3,681,817.33	USD/RM

Table 5-20 - Detailed cost estimation for 12.98 RM of a double track ballasted route section

The CHSRA takeoff quantities are in line with European standard cross sections and will be used for further calculations without change.

5.2.1.3 Escalation of costs

All CHSRA unit costs originate in the year 2017. Therefore, no cost escalation had to be performed. Depending on the structure of the received data, unit costs are normalized to achieve comparability with DB figures.

Viaducts and bridges (SCC 10.01, 10.02, 10.03)
No normalization necessary.

Earthwork and drainage (SCC 10.04, 10.05, 10.06)
Unit costs for trackbed infill are provided in USD per mile. To enable benchmarking with DB values, the unit costs for trackbed infill were converted from USD per mile to USD per cubic yard. Therefore, it was necessary to define the specific width of the trackbed depending on the number of tracks with the following assumptions:

No of tracks	Width of trackbed (ft)
1	30
2	50
4	100
5	125

Table 5-21 – Assumed width of trackbed

The final unit cost is calculated using the following equation:

Unit Cost (USD/cu yd) = Grand Total (USD) / ((Quantity (Route Miles) x Depth of Infill (feet) x Width of Trackbed (feet))

SCC	Description of UPEs for Section 4 and 6	Quantity in RM	Grand Total in USD	Unit Price in USD	No of Tracks	Depth of Infill in feet	Width of Track bed in feet	Quantity in cubic yards	Unit Price in USD/cubic yards
10.05.221A	At-grade trackbed infill - two track (5 ft avg. exc depth) - without fence	9.60	30,238,285	3,149,821	2	5	50	469,331	64.43
10.05.222A	At-grade trackbed infill - two track (10 ft avg. exc depth) - without fence	6.88	38,725,543	5,628,713	2	10	50	672,708	57.57
10.05.223A	At-grade trackbed infill - two track (15 ft avg. exc depth) - without fence	3.76	31,452,944	8,365,145	2	15	50	551,464	57.04
10.05.224A	At-grade trackbed infill - two track (20 ft avg. exc depth) - without fence	5.39	82,033,864	15,219,641	2	20	50	1,054,040	77.83
10.05.226	At-grade trackbed infill - two track (40 ft avg. exc depth) - without fence	4.01	152,379,226	37,999,807	2	40	50	1,568,349	97.16
10.05.241A	At-grade trackbed infill - four track (5 ft avg. exc depth) - without fence	0.44	2,400,100	5,454,772	4	5	100	43,022	55.79
10.05.242	At-grade trackbed infill - four track (10 ft avg. exc depth) - without fence	1.03	8,770,498	8,515,047	4	10	100	201,421	43.54
10.05.212	At-grade trackbed infill - one track (10 ft avg. fill ht)	0.34	593,897	1,772,828	1	10	30	19,947	29.77
10.05.214	At-grade trackbed infill - one track (40 ft avg. fill ht)	0.68	2,280,407	3,368,400	1	40	30	159,573	14.29
10.05.215A	At-grade trackbed infill - one track (30 ft avg. fill ht)	0.58	3,310,680	5,708,069	1	30	30	102,080	32.43
10.05.221	At-grade trackbed infill - 2 Track (5 ft avg. fill ht -(0 ft-7 ft))	0.00	0	1,778,525	2	5	50	0	0.00
10.05.221A	At-grade trackbed infill - two track (5 ft avg. fill ht - (0 ft-7 ft)) BNSF	0.92	1,436,163	1,562,745	2	5	50	44,978	31.93
10.05.222	At-grade trackbed infill - two track (10 ft avg. fill ht - (7 ft-12 ft))	0.19	463,411	2,451,912	2	10	50	18,578	24.94
10.05.222A	At-grade trackbed infill - two track (10 ft avg. fill ht - (7 ft-12 ft)) BNSF	0.24	513,536	2,166,819	2	10	50	23,467	21.88
10.05.223	At-grade trackbed infill - two track (15 ft avg. fill ht - (12 ft-17 ft))	0.19	625,456	3,309,292	2	15	50	27,867	22.44

SCC	Description of UPEs for Section 4 and 6	Quantity in RM	Grand Total in USD	Unit Price in USD	No of Tracks	Depth of Infill in feet	Width of Track bed in feet	Quantity in cubic yards	Unit Price in USD/cubic yards
10.05.224A	At-grade trackbed infill - two track (20 ft avg. fill ht - (17 ft-25 ft))	1.93	8,001,993	4,150,411	2	20	50	377,421	21.20
10.05.225A	At-grade trackbed infill - two track (30 ft avg. fill ht - (25 ft-35 ft))	8.84	53,693,562	6,075,994	2	30	50	2,593,055	20.71
10.05.226	At-grade trackbed infill - two track (40 ft avg. fill ht - (30 ft-50 ft))	0.52	4,801,475	9,269,257	2	40	50	203,377	23.61
10.05.251A	At-grade trackbed infill - five track (5 ft avg. fill ht - (0 ft-7 ft)) BNSF	1.38	4,094,846	2,960,843	5	5	125	168,666	24.28

Table 5-22 - Unit costs at-grade trackbed Infill

The unit costs vary widely, ranging from 14.29 USD/cu yd to 97.16 USD/cu yd, with a weighted average of 51.31 USD/cu yd.

At-grade trackbed infill	USD/cu yd
Minimum	14.29
Maximum	97.16
Weighted average	51.31

Table 5-23 - Unit costs at-grade trackbed infill (Min, Max, Weighted Average)

<u>Tunnels (SCC 10.07)</u>

The following cost components used in the CHSRA cost estimate are not commonly found on DB tunnel projects and were omitted from the benchmark.

- Paralleling station
- TBM diversions & burial. Costs for demobilization of TBMs are included in “single track tunnel”
- Fault chamber (DB tunnel projects are not designed for seismic conditions)
- Mechanical ventilation (DB tunnel projects are shorter in length and therefore, only require natural ventilation)

The escalated costs for the Pacheco Tunnel 2 (13.61 mi) without the omitted cost components are:

Description	Total Cost in USD	Total Cost per RM in USD	% of Total
Site Work Allowances	52,390,498	3,849,412	2%
Site Development	1,866,238	137,123	
Portal Development	50,524,260	3,712,290	
Single Track Tunnel	2,186,903,110	160,683,550	89%
Procurement & Mob-Demob	312,076,959	22,929,975	13%
Starter Tunnels	2,746,000	201,763	
PCC Segment Procurement	889,722,330	65,372,691	36%
Tbm Mining	390,084,621	28,661,618	16%
Mucking Operation	56,316,737	4,137,894	2%
Cleanup Tunnel	8,659,549	636,264	
Invert Concrete	42,289,046	3,107,204	2%
Walkway & Bench Concrete	88,442,153	6,498,321	4%
Sat. Maintenance Shift	6,535,709	480,214	
Support	390,030,007	28,657,605	16%
Cross Passages	220,877,670	16,229,072	9%
Remove Portion of PCC	20,571,585	1,511,505	
F&I Crown Bars	21,290,766	1,564,347	
X-Passage Excavation	51,265,934	3,766,784	
X-Passage Concrete	101,185,804	7,434,666	
F&I Rebar	22,238,951	1,634,015	
F&I Waterproofing	4,324,630	317,754	
Total:	2,460,171,278	180,762,034	100%

Table 5-24 – Escalated costs for Pacheco Tunnel 2

Retaining walls (SCC 10.08)

UPEs for CHSRA include the wall construction as well as the corresponding earthwork (fill and cut). The benchmark values from DB's CCC do not include earthwork. Hence, the comparability of the UPEs and the CCC is limited.

To allow for a rough benchmarking, the UPEs were sorted based on their application: retained fill and retained cut. They were then multiplied by the wall height in order to obtain the unit cost in USD per square yard (of wall).

Unit Cost (USD/sq yd) = Grand Total (USD) / (Quantity (Route Miles) x Factor for one/both sides x Height (feet)

	UPE for Section 2 and 6	Quantity in RM	Grand Total in USD	Unit Price in USD	One side (1) Both sides (2)	Height in feet	Quantity in square yards	Unit Price in USD/ square yard
10.08.221	Retained Cut, Trench - 2 Track (10 ft Avg. Exc Depth)	0.28	16,635,124	59,411,157	2	10	3,285	5,063
10.08.222	Retained Cut, Trench - 2 Track (20 ft Avg. Exc Depth)	0.38	39,502,179	103,953,101	2	20	8,917	4,430
10.08.222a	Retained Cut, Trench - 2 Track (20 ft Avg. Exc Depth	0.10	13,216,706	132,167,063	2	20	2,347	5,632
10.08.223	Retained Cut, Trench - 2 Track (30 ft Avg. Exc Depth)	0.23	33,183,549	144,276,298	2	30	8,096	4,099
10.08.223a	Retained Cut, Trench - 2 Track Spacing (30 ft Avg. Exc Depth)	0.11	19,284,591	175,314,468	2	30	3,872	4,981
10.08.224a	Retained Cut, Staged Trench - 2 Track (40 ft Avg. Exc Depth	0.29	80,963,019	279,182,825	2	40	13,611	5,949
	Total Retained Cut		202,785,168				40,128	
10.08.421	Retained Fill, Walls Both Sides - 2 Tracks (10 ft Avg. Wall Ht)	12.23	124,684,231	10,194,949	2	10	143,498	869
10.08.422	Retained Fill, Walls Both Sides - 2 Tracks (20 ft Avg. Wall Ht	6.00	101,589,019	16,931,503	2	20	140,800	722
10.08.423	Retained Fill, Walls Both Sides - 2 Tracks (30 ft Avg. Wall Ht)	0.63	10,700,672	16,985,194	2	30	22,176	483
10.08.422	Retained Fill, Walls Both Sides - 2 Tracks (20 ft Avg. Wall Ht)	0.00	0	24,655,757	2	20	0	1,051
10.08.422B	Retained Fill, Walls One Side - 2 Tracks (20 ft Avg. Wall Ht) BNSF	0.49	6,863,354	13,949,907	1	20	5,749	1,189
10.08.423	Retained Fill, Walls Both Sides - 2 Tracks (30 ft Avg. Wall Ht)	0.00	0	43,250,203	2	30	0	1,229
10.08.423A	Retained Fill, Walls One Side - 2 Tracks (30 ft Avg. Wall Ht)	0.83	21,107,248	25,553,569	1	30	14,608	1,452
10.08.423B	Retained Fill, Walls One Side - 2 Tracks (30 ft Avg. Wall Ht) BNSF	1.60	37,745,790	23,605,872	1	30	28,160	1,341
	Total Retained Fill		302,690,314				354,991	

Table 5-25 - Unit cost for retaining walls - USD/sq yd

	Retained Cut in USD/square yard	Retained Fill in USD/square yard
Minimum	4,099	483
Maximum	5,949	1,452
Weighted average	5,053	853

Table 5-26 - Min, max, and weighted average unit cost for retaining walls - USD/sq yd

Track (SCC 10.09, 10.10, 10.14)

To allow for benchmarking, the UPEs were sorted by technology type and number of tracks. The average costs per mile of track with ballast and direct fixation was then calculated.

	Quantity	Unit	Grand Total in USD	Unit Price in USD	Per single track USD/mi
Ballasted Track -1 Track	2.02	RM	3,766,492	1,864,600	1,862,585
	13.64	RM	25,401,595	1,862,287	
Total	15.66	RM	29,168,087		
Ballasted Track -2 Track	1.33	RM	4,959,836	3,729,200	1,548,847
	1.67	RM	6,147,514	3,681,146	
	12.98	RM	47,789,985	3,681,817	
	33.10	RM	70,831,600	2,139,927	
	110.00	RM	355,664,058	3,233,309	
	13.11	RM	47,998,832	3,660,401	
Total	172.19	RM	533,391,824		
Ballasted Track - 4 Track	2.00	RM	13,429,398	6,714,699	1,678,675
Ballasted Freight Track - 2 Track	4.79	RM	18,675,062	3,897,133	1,949,380
Ballasted Freight Track - 3 Track	1.38	RM	8,054,696	5,857,960	1,945,579
Total Ballasted Track (Route)	196.02	RM			
Total Ballasted Track (Track)	381.76	TM	602,719,067		1,578,791

Table 5-27 - Average cost for ballasted track

	Quantity	Unit	Grand Total USD	Unit Price USD	Per single track USD/mi
Direct Fixation Track - 1 Track	5.28	RM	9,496,948	1,798,664.38	1,799,157
	31.57	RM	56,732,521	1,797,039.00	
	0.19	RM	411,303	2,142,205.00	
Total	37.04	RM	66,640,772		
Direct Fixation Track - 2 Track	5.14	RM	18,344,989	3,569,064.00	1,996,534
	0.71	RM	2,350,219	3,310,168.00	
	9.13	RM	39,120,943	4,284,410.00	
Total	14.98	RM	59,816,151		
Direct Fixation Track - 4 Track	0.29	RM	2,533,986	8,619,002.00	2,184,471
Direct Fixation Track - 5 Track	0.59	RM	6,337,968	10,778,858.00	2,148,464
Total direct fixation (Route)	52.90	RM			
Total direct fixation (Track)	71.11	TM	135,328,877		1,903,092

Table 5-28 - Average cost for track with direct fixation

For turnouts, the available UPEs were sorted by type of construction type (ballasted/direct fixation) and by operating speed.

UPE	Branch Speed	Unit	Unit Price in USD	No. of Turnouts	Unit Price in USD per Turnout
Ballasted Turnout	25	mph	324,880	1	324,880
Ballasted Turnout	60	mph	441,732	1	441,732
Ballasted Crossover	80	mph	1,270,080	2	635,040
Ballasted Crossover	110	mph	1,530,234	2	765,117
Ballasted Turnout	150	mph	2,003,175	1	2,003,175
Direct Fixation Turnout	80	mph	703,175	1	703,175
Direct Fixation Turnout	110	mph	989,369	1	989,369

Table 5-29 - Unit costs for turnouts

Figure 5-9 - Typical high-speed turnout – Source DB AG

For benchmarking purposes, the detailed cost estimates for ballasted track (**Table 5-18**) were converted to USD per yard for a two-track line.

Description	Takeoff Quantity / Unit		Grand Total in USD	Grand Total Unit Cost / Unit		Grand Total Unit Cost CHSRA per yard 2-track line in USD	%Grand Total Unit Cost CHSRA per yard 2-track line in % of total
Sub-ballast, Place, Spread & Compact	105,567.00	cu yd	4,965,872	47.04	USD/cu yd	217.37	10.4
Ballast, Place, Spread & Compact	112,422.00	cu yd	6,547,457	58.24	USD/cu yd	286.61	13.7
Unload Track Material & Distribute	137,100.00	tf	1,074,864	7.84	USD/tf	47.05	2.2
Electric (Flash Butt) Welding	3,427.50	EA	1,727,460	504	USD/EA	75.62	3.6
Install Rail on Ties, 141 RE	137,100.00	tf	19,961,760	145.6	USD/tf	873.80	41.8
Align & Tamp	137,100.00	tf	4,299,456	31.36	USD/tf	188.20	9.0
Rail Grinding	137,100.00	tf	460,656	3.36	USD/tf	20.16	1.0
Concrete Cross Ties	68,550.00	EA	8,752,464	127.68	USD/EA	383.13	18.3
10.09.120 Ballasted Track - 2 Track	12.98	RM	47,789,989	3,681,817	USD/RM	2,092	100

Table 5-30 - Detailed cost estimate for ballasted track - USD/yd – 2 tracks

5.2.2 DB Cost Component

5.2.2.1 Qualitative description

Viaducts and bridges (SCC 10.01, 10.02, 10.03)

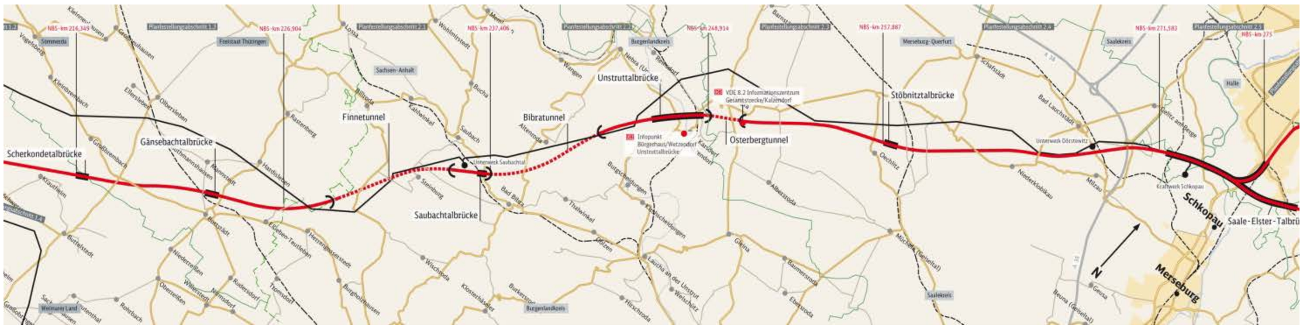


Figure 5-10 - Layout plan of "VDE 8.2", Source: DB Netz AG

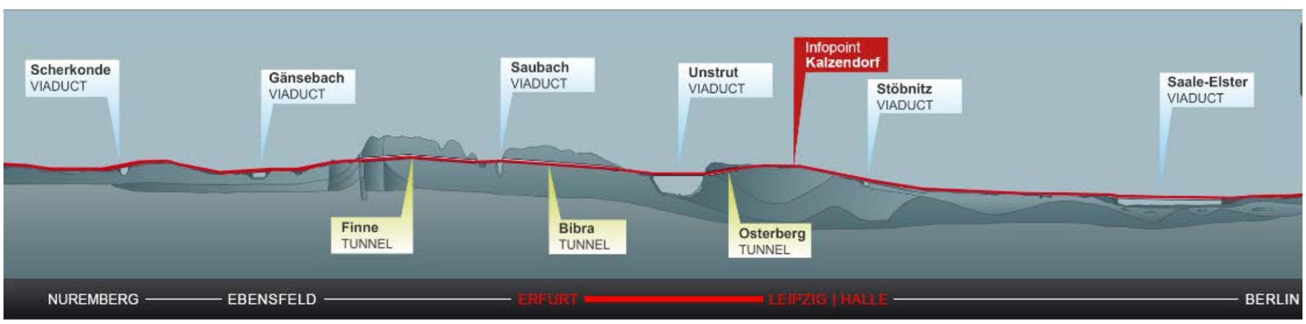


Figure 5-11 – Corresponding profile of VDE 8.2, Source: DB Netz AG

Because of its variable terrain, the VDE 8.2 reference project includes a variety of structure types using different construction methods. Foundations include either pile or shallow foundations, depending on the geotechnical conditions. Piers consist of hollow columns, which is the standard DB design in Germany. Superstructures were built as prestressed concrete hollow box girders with bearings on each pier.

Figure 5-12 shows an example of a conventional type of bridge with a 2 x 1 track configuration; Figure 5-13 a conventional type of superstructure with a two-track configuration.

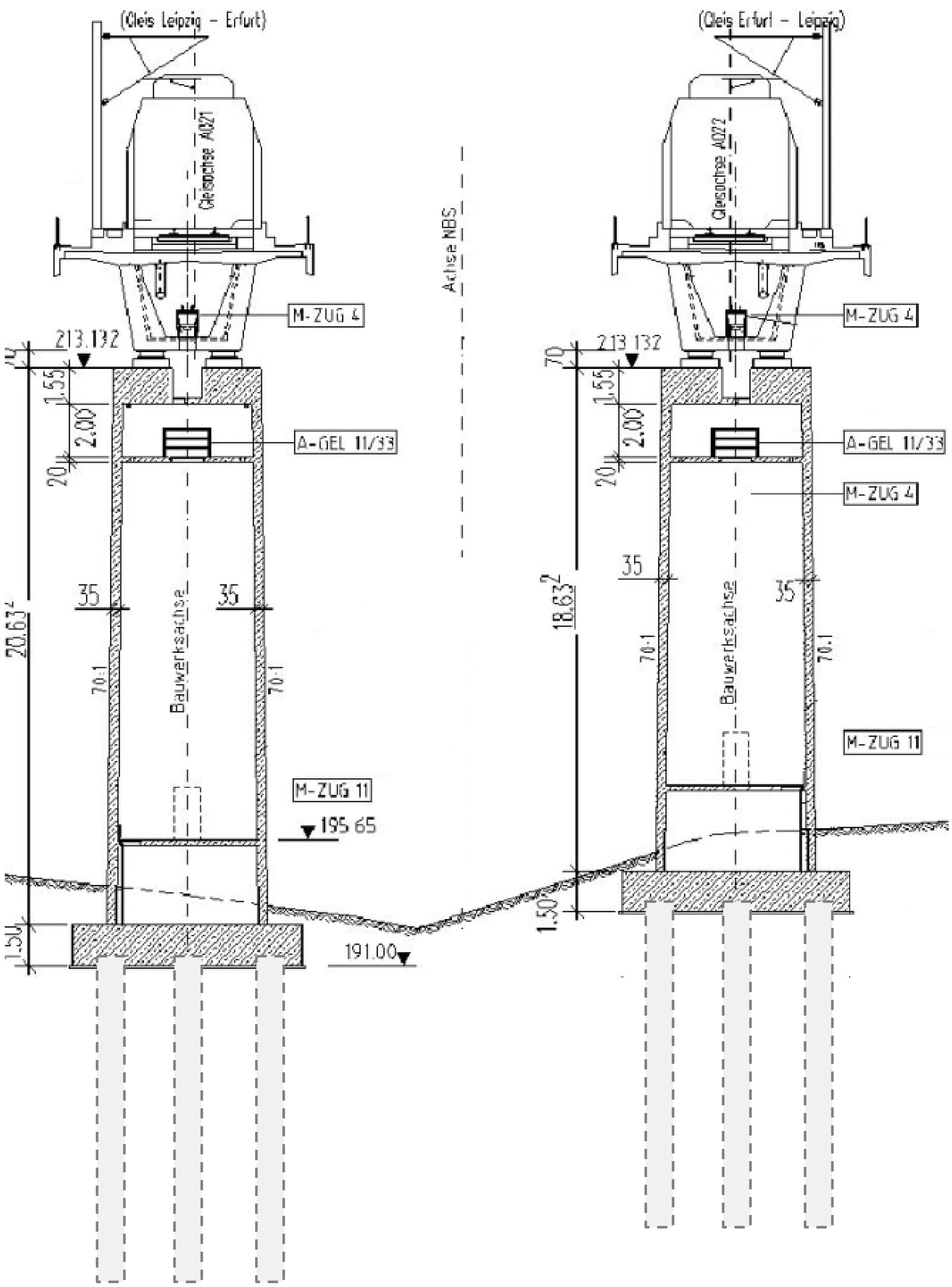


Figure 5-12 - Conventional type of bridge (Saubach Viaduct with 2x 1 track-system configuration), dimensions in m - Source: official as-completed drawing of DB Netz AG

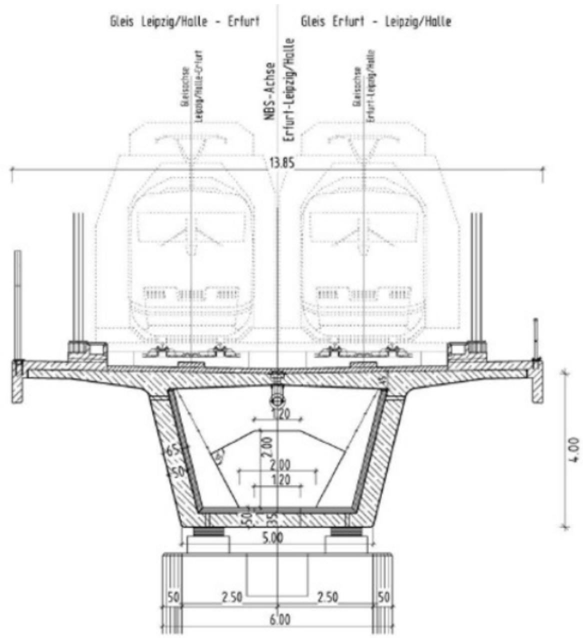


Figure 5-13 - Conventional type of superstructure (two-track system configuration), dimensions in m - Source: official as-completed drawing of DB Netz AG

During the bid phase, the contractors value engineered four of the six viaducts and submitted alternate designs as (semi-) integral structures for consideration. DB subsequently accepted the ultimate designs for construction.

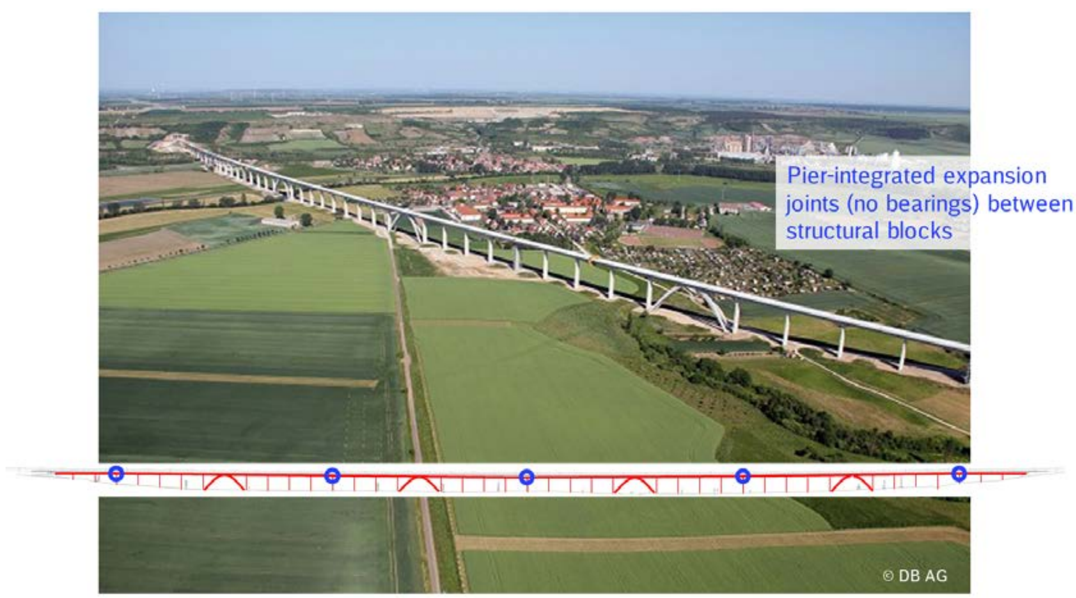


Figure 5-14 - Integral type of bridge (Unstrut viaduct with 2x 1-track system configuration) – Source: DB AG

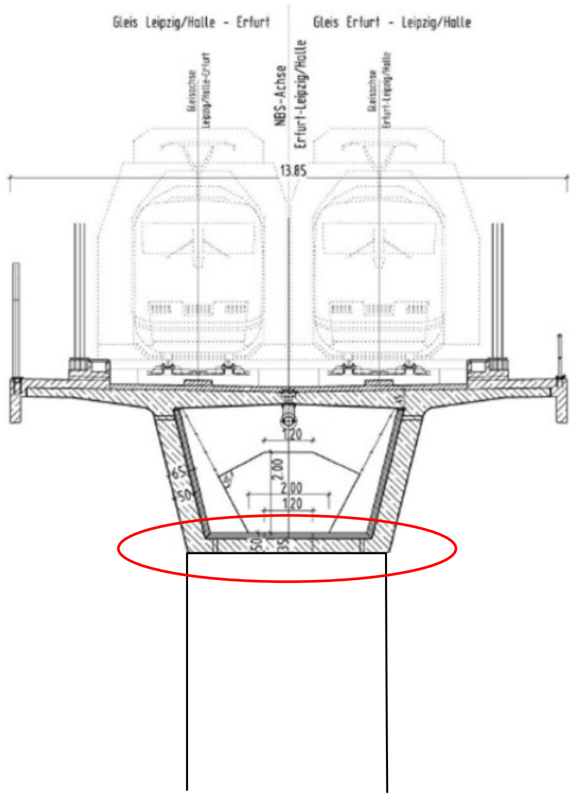


Figure 5-15 - Cross section of Unstrut viaduct, two-track system, showing bearingless construction - Source: official as-completed drawing of DB Netz AG

Various construction methods were used for bridge erection depending on site-specific conditions, e.g. the launch girder, conventional scaffolding, and Incremental launching methods.

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

For benchmarking purposes, unit costs for earthwork were taken from the VDE 8.2 project and the Cost Characteristics Catalogue (CCC). No information on soil classes, transport distances, and other cost-relevant factors for the UPEs was available. Therefore, the highest and lowest values from the CCC were taken into account.

No corresponding value for CHSRA was provided for drainage pipes. In consequence, these were excluded from the benchmarking.

Tunnels (SCC 10.07)

To identify DB projects comparable to the Pacheco Tunnel, the following criteria were specified:

- Single track tunnels with cross passages
- TBM excavation, single shield, double shield, or EPB
- similar ground conditions
- Detailed cost data available
- Current tunnel projects with few years in operation or under construction
- Tunnels of extensive length

There are no tunnel projects in Germany with comparable length to the Pacheco Tunnel No. 2. The following four tunnel references were selected because they closely match the criteria above:

1. Kaiser-Wilhelm-Tunnel
2. Albvorland Tunnel
3. Katzenberg Tunnel
4. Finne Tunnel

The characteristics for each tunnel project are summarized briefly below.

1. Kaiser-Wilhelm-Tunnel

Figure 5-16 - North portal of the Kaiser-Wilhelm-Tunnel - Source: Nezan Zupanjac, DB E&C

The Kaiser-Wilhelm-Tunnel is a historical 19th Century tunnel next to the river Mosel. The old tunnel was refurbished, and a new, second, single-track tunnel, 2.61 miles long and 29.5 feet in internal diameter, was excavated by TBM in parallel. In addition, eight cross passages between the new tunnel and the existing, refurbished tunnel were constructed. As shown in **Figure 5-16,** the Northern tunnel portal is in the urban area of Cochem. The construction site was very constricted and in close proximity to the operational railway.

The tunnel geology was mostly rock with lay shale, siltstone, and sandstone; but some shear zones and soft ground conditions were also encountered. The TBM consisted of a dual-mode, single-shield, which could be changed from open mode with belt conveyors to closed/EPB mode with a screw conveyor. The outer diameter of the TBM was 33.1 ft.

Figure 5-17 - Kaiser-Wilhelm-Tunnel TBM - Source: DB Projektbau GmbH

The new tunnel was placed in service in 2014, while the refurbishment of the old tunnel was completed in 2017.

1. Katzenberg Tunnel

Figure 5-18 – Katzenberg Tunnel – tunnel segmental lining - Source: www.karlsruhe-basel.de /Gerhard Hehl

The Katzenberg Tunnel consists of two single-track tunnels, each of which is 5.83 miles long, and with an internal diameter of 30.8 ft on the new railway line between Karlsruhe and Basel, with a maximum speed of 155 mph. Nineteen cross passages were constructed between the two tunnels.

The gasketed, precast, and segmental lining must resist a maximum hydrostatic head of up to 300 ft. The tunnel was excavated in strong weathered sandstone, limestone, and claystone by two EPB TBMs, with an outer diameter of 36.5 ft. The Katzenberg Tunnel has been in service since 2012.

Figure 5-19 – Katzenberg Tunnel EPB TBM - Source: DB AG

2. Albvorland Tunnel

Figure 5-20 - Eastern portal of the Albvorland Tunnel with segmental lining production site - Source: www.bahnprojekt-stuttgart-ulm.de/Armin Kilgus

The Albvorland Tunnel consists of two single-track tunnels, each of which is 5.08 miles long, and with an internal diameter of 31.5 ft, on the new railway line between Ulm and Stuttgart. Sixteen cross passages connect the two single-track tunnels.

The tunnel has been under construction since 2016. Two EPB TBMs, with an outer diameter of 35.66 ft, are used for tunnel excavation. The tunnel geology consists of slightly-to-severely weathered rock. The gasketed precast segmental lining was designed to resist a maximum hydrostatic head of up to 150 ft.

3. Finne Tunnel

Figure 5-21 – Finne Tunnel portal - Source: DB AG

The Finne Tunnel consists of two single-track tunnels, each of which is 4.33 miles long, and with an internal diameter of 31.5 ft, on the new railway line VDE 8.2 between Erfurt and Leipzig/Halle. There are 13 cross passages between the two tunnels.

The gasketed, precast, and segmental lining was designed to resist a maximum hydrostatic head of up to 200 ft. The tunnel geology consists mostly of rock—sandstone and limestone—but some soft ground was also encountered, which required dewatering during construction. The tunnel was excavated by two dual-mode, single-shield TBMs with an outer diameter of 35.7 ft. The Finne Tunnel has been in service since 2015.

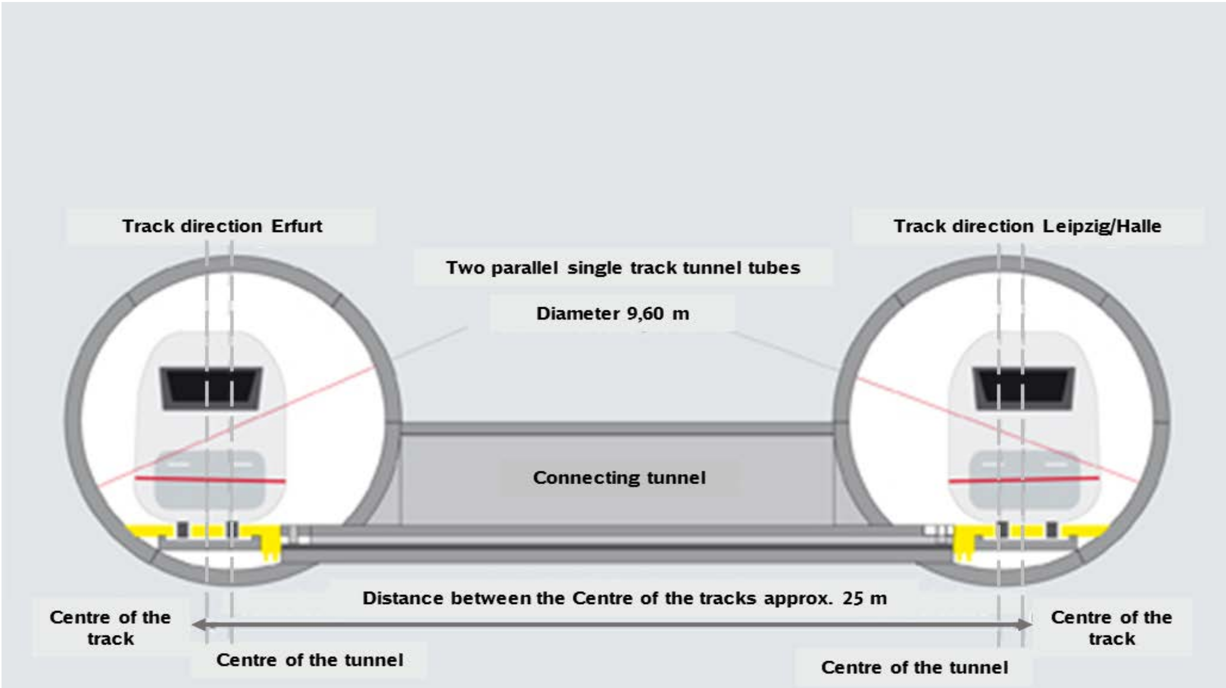


Figure 5-22 – Finne Tunnel – typical tunnel cross section - Source: DB AG

Figure 5-23 – Finne Tunnel - dual-mode TBM - Source: DB AG

Table 5-31, below, summarizes key characteristics of the four DB tunnels.

Construction	Unit	Kaiser-Wilhelm-Tunnel	Katzenberg Tunnel	Albvorland Tunnel	Finne Tunnel
Principle		2 x Single Track Tunnels			
Length	mi	2.61	5.83	5.08	4.33
Design speed	mph	100	155	155	186
Internal diameter of single track tunnel section	ft	29.5	30.8	31.5	31.5
Distance between centers of tunnel tubes	ft	85	85	55-98	82
Max. distance of cross passages	ft	1640			
Number of cross passages		8	19	16	13
Number of TBMs		1	2	2	2
Geology		Rock/soft ground	Rock, slightly to strong weathered	Rock, slightly to strongly weathered	Rock / soft ground
Type of TBMs		Dual mode (open/EPB)	EPB	EPB	Dual mode (open/mixed)
Outer diameter shield	ft	33.1	36.5	35.66	35.7
Status		In service since 2017	In service since 2012	Under construction since 2016	In service since 2015

Table 5-31 - DB tunnels – key characteristics

<u>Retaining walls (SCC 10.08)</u>

To allow for benchmarking, bore pile walls were compared with retained cut and cantilever retaining walls with retained fill, respectively. The UPE were benchmarked with the DB Cost Characteristics Catalogue, which serves as a basis for DB's cost estimations during the planning phase. For illustration, two typical retaining wall types used on DB projects are shown in Figure 5-24 and Figure 5-25. Costs from the CCC do not include earthwork.

Figure 5-24 - Bore pile wall – Tunnel Augustaburg – Source: Störfix, 2007, CC BY-SA 3.0

Figure 5-25 - Cantilever retaining wall

(Source: http://bfh-betonfertigteilhandel.de/projects/giro-stuetzwand-in-coevorden)

Track (SCC 10.09, 10.10, 10.14)

For the purpose of benchmarking track unit costs at a high level, several sources of data were used: The DB Cost Characteristics Catalogue (CCC)

- Track cost from VDE 8.2
- Estimations from internal sources of DB
- Track cost published by the SBB (Swiss National Railway) and UIC

Turnouts were benchmarked with comparable unit costs from the CCC.

The detailed cost estimates for ballasted track were benchmarked using data from DB Bahnbau, DB's track construction subsidiary, for a German-standard high-speed track.

5.2.2.2 Quantitative estimation

Viaducts and bridges (SCC 10.01, 10.02, 10.03)
Table 5-32 shows an overview of representative “VDE 8.2” viaducts. This data was used in the pre-benchmarking process. Nominalization was done for the time duration between 2006-2017 with an inflation factor of 1.1735.

Cost 2017 (€) = Cost 2006 (€) * 1.1735

Cost 2017 USD/RM = Cost 2017 (€) * 1.22 (conversion € to $) / Length (RM)

	Arrangement of track and superstructure	Costs at date of construction (~ 2006) in EUR	Current costs 2017 (inflation-adjusted) in EUR	Length [RM]	Type of structure	Type of super-structure	Costs (2017) [USD/RM]
Saale-Elster Viaduct	2-track	223,539,000	262,323,000	4,017	Conventional bridge	Prestressed concrete/ steel	57,988,761
Unstrut Viaduct (Alt. Prop.)	2-track	64,596,000	75,803,000	1,658	Integral bridge	Prestressed concrete	55,201,794
Saubach Viaduct	2x 1-track	9,617,000	11,286,000	0,154	Conventional bridge	Prestressed concrete	89,409,070
Stöbnitz Viaduct (Alt. Prop.)	2-track	7,265,000	8,526,000	0,185	Integral bridge	Prestressed concrete	52,842,265
Scherkonde Viaduct (Alt. Prop.)	2-track	11,496,000	13,491,000	0,355	Semi-integral bridge	Prestressed concrete	44.176.301
Gänsebach Viaduct (Alt. Prop.)	2-track	19,346,000	22,703,000	0,622	Integral bridge	Prestressed Concrete	42.807.442

Table 5-32 – Overview of representative viaducts of DB line VDE 8.2

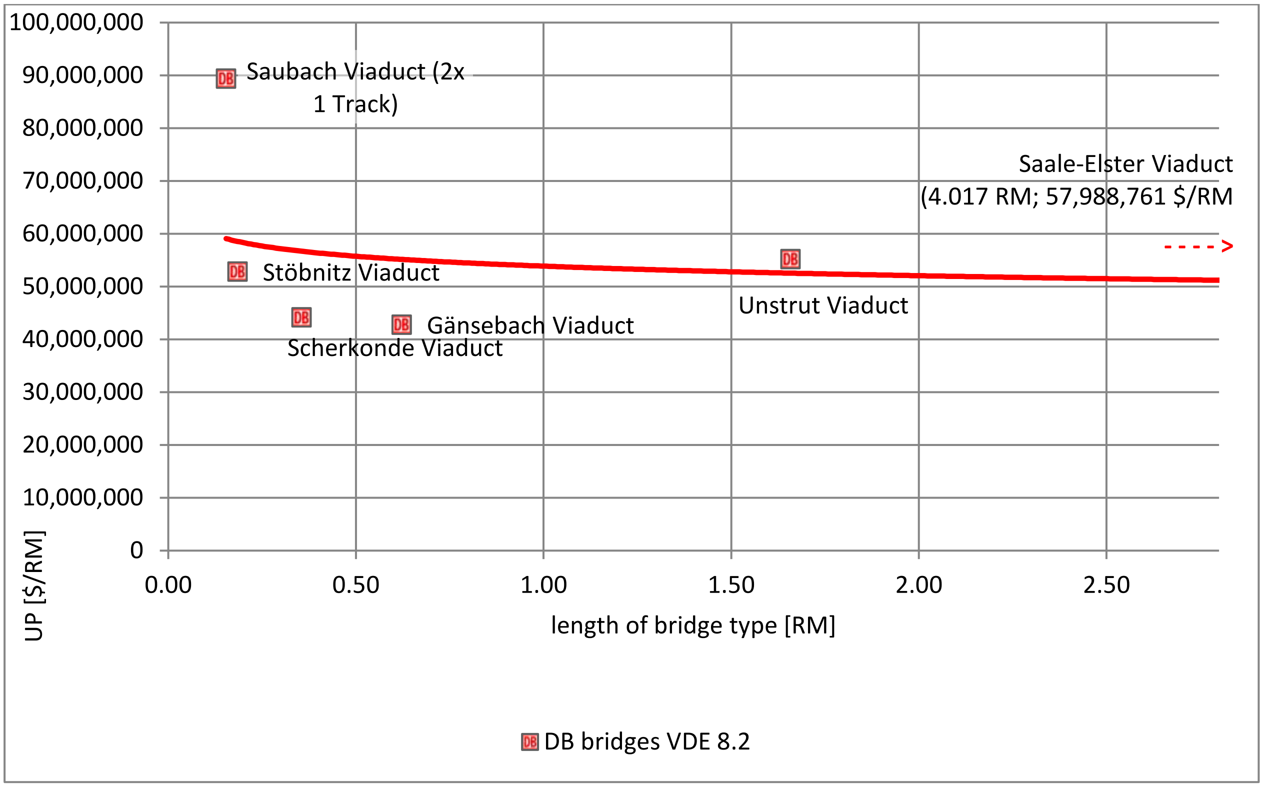


Figure 5-26 - Representative Viaducts in section “VDE 8.2” as basis for initial benchmarking

In the next step, the costs of the following DB structures were adjusted for direct comparability to equivalent CHSRA structures.

- Gänsebach Viaduct – two-track (50 ft average pier height, 144 ft span) The original design (conventional design) was used so as to compare it directly to equivalent CHSRA structures.
- Saubach Viaduct – one-track (60 ft average pier height, 135 ft average span) The original design costs were used so as to compare it directly to equivalent.

Description	Total Cost per RM in USD	% of Total
Reinforcing steel	0	0%
Structural concrete, In place, aerial footing	2,069,083	5%
Structural excavation	319,262	1%
Haul and dispose of excavated material	686,291	2%
Structural \backfill	357,646	1%
Steel sheet piling, drive, extract and salvage	904,168	2%
Drilled shaft, 120 inches Dia, un-cased in soft rock	3,621,548	8%
Site demolition allowance	319,262	1%
Site restoration allowance	319,262	1%
Foundation costs	**8,596,522**	**19%**
Reinforcing steel	0	0%
Structural concrete, in place, aerial pier	5,778,089	13%
Multirotational bearing (1500 Kip)	1,358,446	3%
Substructure costs	**7,136,535**	**16%**
Reinforcing steel	0	0%
Structural concrete, in place, parapet wall	2,289,666	5%
Structural concrete, in place, OCS pole base	703,229	2%
Precast segmental box girder, double (10.5 ft. depth)	21,683,980	48%
Service/safety walkway	1,726,815	4%
Metal pipe & cable railing	319,262	1%
Corrosion control, aerial	319,262	1%
Walkway lighting, allowance	563,290	1%
Trackway drainage allowance, aerial	922,678	2%
Cable duct, aerial guideway	651,902	1%
Superstructure costs	**29,180,084**	**65%**
TOTAL:	**44,913,141**	**100%**

Table 5-33 - Costs components of Gänsebachtal Viaduct – 2 track (50 ft. average pier height, 144 ft. span equivalent to CHSRA's Elevated Structure in High and Moderate Seismicity Zone (see Tables 5-6 and 5-7)

Description	Total Cost per RM in USD	% of Total
Reinforcing Steel	0	0%
Structural Concrete, In Place, Aerial Footing	3,085,598	6%
Structural excavation	1,120,116	2%
Haul and dispose of excavated material	757,376	2%
Structural backfill	892,461	2%
Steel sheet piling, drive, extract and salvage	1,698,944	3%
Drilled shaft, 120 inches Dia, un-cased in soft rock	1,331,884	3%
Site demolition allowance	1,168,035	2%
Site restoration allowance	652,114	1%
Foundation costs	**10,706,528**	**22%**
Reinforcing steel	0	0%
Structural concrete, in place, aerial pier	3,291,613	7%
Multirotational bearing (1500 Kip)	1,410,517	3%
Substructure costs	**4,702,130**	**9%**
Reinforcing steel	0	0%
Structural concrete, in place, parapet wall	3,483,030	7%
Structural concrete, in place, OCS pole base	652,114	1%
Precast segmental box girder, double (10.5 ft depth)	24,046,476	48%
Service/safety walkway	1,353,462	3%
Metal pipe & cable railing	703,861	1%
Corrosion control, aerial	652,114	1%
Walkway lighting, allowance	1,107,548	2%
Trackway drainage allowance, aerial	1,605,244	3%
Cable duct, aerial guideway	703,861	1%
Superstructure costs	**34,307,710**	**69%**
TOTAL:	**49,716,368**	**100%**

Table 5-34 - Costs components of Saubachtal Viaduct - 1-track (60 ft. average pier height, 135 ft. average span) equivalent to CHSRA's Elevated Structure 1-track (see Table 5-10)

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

Table 5-35 and Table 5-36 summarize DB unit costs for earthwork and trackbed infill from the reference documents and years as shown.

	CCC min in EUR/m³	CCC max in EUR/m³
Year	2016	2016
Topsoil	included	included
Cut	14	24.5
Embankment	14	28
Sub-ballast	n/a	n/a

Table 5-35 - Unit costs DB – earthwork

	CCC min in EUR/m³	CCC max in EUR/m³
Year	2016	2016
At-grade trackbed infill	20	34

Table 5-36 - Unit costs DB – at-grade trackbed infill

Tunnels (SCC 10.07)

Table 5-37 shows the main cost components of the DB tunnels chosen previously for benchmarking.

	Length	Diameter	TBM			Total cost		Total cost per RM in USD	Year of cost basis
Tunnel	mi	ft.	ft.	EUR	USD	EUR	USD	USD/RM	
Kaiser-Wilhelm Tunnel	2.61	29.53	33.14	18,000,000	21,597,480	105,000,000	125,985,300	48,274,780	2011
Katzenberg Tunnel	5.83	30.84	36.48	20,000,000	23,997,200	340,000,000	407,952,400	34,977,997	2004
Albvorland Tunnel	5.08	31.50	35.66	21,572,000	25,883,380	380,000,000	455,946,800	44,873,817	2015
Finne Tunnel	4.33	31.50	35.66	18,735,000	22,479,377	258,000,000	309,563,880	35,738,575	2007

Table 5-37 - DB tunnel cost components

The most detailed costs are available for the Finne Tunnel. Therefore, its costs were used for the cost benchmark of Pacheco Tunnel No. 2. Table 5-38 shows the cost components of the Finne Tunnel with cost basis 2007.

Total Cost (2007) in USD	309,563,657
Site work allowances	22,769,230
Site development	7,166,992
Portal development	15,602,239
Single T-Track Tunnel	270,129,296
Tbm procurement & mob-demob	92,943,319
Starter tunnels	198,618
PCC segment procurement	66,622,320
TBM mining	55,334,354
Mucking operation	36,145,709
Cleanup tunnel	0
Invert concrete	10,223,892
Walkway & bench concrete	4,206,599
Sat. maintenance shift	0
Support	0
Cross Passages	10,282,188
Remove portion of PCC	0
F&I crown bars	0
X-passage excavation	8,448,134
X-passage concrete	1,232,095
F&I rebar	0
F&I waterproofing	601,959
Other	6,382,943

Table 5-38 – Finne Tunnel costs (2007)

The component "Other" is the sum of all other costs which are not comparable with the cost estimate of the Pacheco Tunnel No. 2, e.g. roads.

Retaining walls (SCC 10.08)

Table 5-39 summarizes DB unit costs for both cantilever retaining wall and bored pile wall from the CCC reference document dated 2016.

Cost from the CCC do not include earthwork.

	CCC	CCC
	Cantilever Retaining Wall in EUR/m³	Bored Pile Wall in EUR/m³
Year	2016	2016
Minimum	1,540	870
Maximum	2,618	1,044

Table 5-39 – Unit cost of retaining walls of DB AG

Track (SCC 10.09, 10.10, 10.14)

High level benchmarking of DB track unit costs is as follows:

	CCC	VDE 8.2	UIC/SBB
Year	2016	2009	1999
Ballasted Track (2 Tracks) - EUR/m	950	1,035	700
Direct Fixation (2 Tracks) - EUR/m	1,960	1,741	n/a

Table 5-40 - High-level unit costs of track in Germany

Turnouts:

UPE	Maximum branch speed in mph	Maximum branch speed km/h	Equivalent turnout DB	Maximum branch speed km/h
Ballasted turnout	25	40	EW -190-1:9	40
Ballasted turnout	60	97	EW -1200-1:18.5	100
Ballasted crossover	80	129	EW -2500-1:26.5	130
Ballasted crossover	110	177	EW -10000/4000-1:39	160
Ballasted turnout	150	241	n/a	
Direct fixation turnout	80	129	EW -2500-1:26.5	130
Direct fixation turnout	110	177	EW -10000/4000-1:39	160

Table 5-41 - Equivalent turnouts DB

Detailed cost estimations for ballasted trackwork from DB Bahnbau in 2017 are as follows:

Track component	Unit price DB minimum		Unit price DB maximum	
Sub-ballast, place, spread & compact	25	EUR/m³	30	EUR/m³
Ballast, place, cpread & compact	32	EUR/m³	35	EUR/m³
Unload track material & distribute	8	EUR/track-m	10	EUR/track-m
Electric (Flash Butt) welding	180	EUR/EA	200	EUR/EA
Install rail on ties, 141 RE	104	EUR/track-m	121	EUR/track-m
Align & tamp	15	EUR/track-m	20	EUR/track-m
Rail grinding	9	EUR/track-m	11	EUR/track-m
Concrete cross ties	50	EUR/EA	70	EUR/EA

Table 5-42 - German cost for track components by DB Bahnbau 2017

All costs are direct costs without overhead. The unit costs reflect average transport distances in Germany.

5.2.2.3 Escalation of costs

<u>Viaducts and bridges (SCC 10.01, 10.02, 10.03)</u>
Done in 5.3.2.2

<u>Earthwork and drainage (SCC 10.04, 10.05, 10.06)</u>
All costs were escalated to the year 2017 and converted to imperial units.
The used formula to adjust the costs is:
Unit cost 2017 = Unit cost (original year) x Inflation factor

Escalation to 2017	CCC minimum	CCC maximum
Original year	2016	2016
Inflation factor	1.0136	1.0136
Unit	EUR/m³	EUR/m³
Topsoil	included	included
Cut	14.19	24.83
Embankment	14.19	28.38
Sub-ballast	n/a	n/a

Table 5-43 - Unit costs DB – earthwork – escalation to 2017 cost

Unit cost (USD/cu yd) = Unit cost (EUR/m^3) / 1.09

Conversion to imperial units	CCC minimum	CCC maximum
Year	2017	2017
Unit	USD/cu yd	USD/cu yd
Topsoil	included	included
Cut	13.02	22.78
Embankment	13.02	26.04
Sub-ballast	n/a	n/a

Table 5-44 - Unit costs DB – earthwork – escalation to imperial units

Escalation to 2017	CCC min	CCC max
Original year infill	2016	2016
Inflation factor	1.0136	1.0136
Unit	EUR/m³	EUR/m³
At-grade trackbed infill inflated to year-end 2017	20.27	34.46

Table 5-45 - At-grade trackbed infill – escalation to 2017 cost

Conversion to imperial units	CCC min	CCC max
Year	2017	2017
Unit	USD/cu yd	USD/cu yd
At-grade trackbed infill	18.60	31.61

Table 5-46 - At-grade trackbed infill – escalation to imperial units

Tunnels (SCC 10.07)

The costs for Finne Tunnel were normalized to compare it to the Pacheco Tunnel 2 cost estimate.

Construction	Unit	Pacheco Tunnel No. 2	Finne Tunnel
Length	mi	13.62	4.33
Internal diameter of single-track tunnel section	ft	28	31.5
Distance between centers of tunnel tubes	ft	66	82
Number of cross passages		89	13
Number of TBMs		4	2

Table 5-47 - Comparison of tunnel characteristics - Pacheco Tunnel No. 2 and Finne Tunnel

- Nominalization
  - Because the price basis of the Finne Tunnel is from 2007, the costs were adjusted for inflation by a factor of 1.1386 to the year-end of 2017.
- Tunnel length
  - All tunnel-related costs were increased by a factor of 3.1455 (13.62 miles / 4.33 miles = length of Pacheco Tunnel 2 / length of Finne Tunnel).
  - On the Finne Tunnel project, 2 TBMs were used to excavate 4.33 miles of tunnel length. On the Pacheco Tunnel, four TBMs are specified to excavate 6.81 miles of tunnel length each, meaning an additional 2.48 miles (equivalent to a 36.4% increase in length), compared to the Finne Tunnel. This has an impact on logistics. The longer the tunnel, the more time is required to transport segments and tunneling muck. Therefore, an assumed escalation factor of 30% was applied to all tunnel-length-related costs. The escalation factor is equivalent to 0.636 + 0.3641 * 1.3 = 1.109.
- Internal diameter
  - Segmental lining - Costs were not escalated
  - TBM mining - Costs were not escalated
  - Mucking operation, invert concrete - Costs are in relation to area: The formula to calculate the factor is:

    $(28ft/2)^2$ at Pacheco Tunnel 2 / $(31.5ft/2)^2$ at Finne Tunnel = 0.79
- Number of cross passages
  - The relationship between the number of cross passages at the Pacheco Tunnel 2 and the number of cross passages at the Finne Tunnel - All costs are escalated by a factor of 6.846, calculated with the following formula:

    89 cross passages at the Pacheco Tunnel / 13 cross passages at the Finne Tunnel = Ratio Factor

- Only a few costs of the cross passages are length related, so they will not be escalated
- Number of TBMs
  - On the Finne Tunnel project, 2 TBMs were used. For the Pacheco Tunnel 2, 4 TBMs are planned. To adjust the DB reference costs to CHSRA estimated costs, the number of TBMs are doubled.

All other costs were not escalated.

Adjusted cost components (2017)	USD
Total escalated cost (2017)	1,092,295,348
Site work allowances	29,652,369
Site development	9,333,573
Portal development	20,318,795
Single-track tunnel	970,971,662
TBM procurement & mob-demob	242,080,169
Starter tunnels	258,660
PCC segment procurement	302,657,912
TBM mining	251,377,917
Mucking operation	131,364,802
Cleanup tunnel	0
Invert concrete	37,156,818
Walkway & bench concrete	6,075,384
Saturday maintenance shift	0
Support	0
Cross passages	91,671,317
Remove portion of PCC	0
F&I crown bars	0
X-passage excavation	75,319,722
X-passage concrete	10,984,801
F&I rebar	0
F&I waterproofing	5,366,794
Other	0

Table 5-48 – Finne Tunnel escalated costs (2017)

Retaining walls (SCC 10.08)

All costs were escalated to the year 2017 and converted to imperial units.
Cost from the CCC do not include earthwork.

Escalation to 2017	CCC	CCC
	Cantilever retaining wall	Bored pile wall
Year of original cost	2016	2016
Factor Inflation	1.0136	1.0136
2017 Minimum	1,561	882
2017 Maximum	2,654	1,058

Table 5-49 – Escalated costs of a cantilever retaining wall and bored pile wall in EUR

Imperial Units in 2017	CCC	CCC
	Cantilever retaining wall	Bored pile wall
Year	2017	2017
Minimum	1,566	885
Maximum	2,662	1,062

Table 5-50 - Escalated costs of a cantilever retaining wall and bored pile wall in USD

Track (SCC 10.09, 10.10, 10.14)

All costs were escalated to the year 2017 and converted to imperial units. High-level benchmarking of track unit costs is as follows:

Unit Cost 2017 = Unit Cost Year of origin x Inflation Factor to the year-end 2017

Escalation to 2017	CCC	VDE 8.2	UIC/SBB
Year of original price	2016	2009	1999
Inflation factor	1.0136	1.1105	1.3651
Inflation-adjusted ballasted track (two tracks) in EUR/m	963	1,149	956
Inflation-adjusted direct fixation (two tracks) in EUR/m	1,987	1,933	n/a

Table 5-51 – High-level unit costs of track in Germany – escalation to 2017

Unit cost 2017 (USD/mile) = Unit cost 2017 (EUR/m) / 0.52 / 1000

Imperial units – two-track line	CCC	VDE 8.2	UIC/SBB
Year	2017	2017	2017
Ballasted track in USD/mi	1,859,384	2,219,412	1,845,191
Direct fixation in USD/mi	3,836,203	3,733,329	n/a

Table 5-52 – High-level unit costs of track in Germany – conversion to imperial units

All prices given in the CCC represent turnouts in ballasted track. Therefore, the costs for turnouts with direct fixation were adjusted by adding the differential cost for slab track (505 EUR/track-m), multiplied by the length of the turnout.

Benchmark DB adjustment for direct fixation = length of turnout * additional cost of slab track	CCC cost 2016 EUR	Length of turnout m	Additional cost EUR/m	CCC cost 2016 EUR
EW -190-1:9	83,500	0.00	0.00	83,500
EW -1200-1:18,5	170,000	0.00	0.00	170,000
EW -2500-1:26,5	320,000	0.00	0.00	320,000
EW -10000/4000-1:39	330,000	0.00	0.00	330,000
EW -2500-1:26,5	320,000	94.31	505.00	367,627
EW -10000/4000-1:39	330,000	136.95	505.00	399,160

Table 5-53 - Equivalent turnouts DB – cost adjustment for direct fixation

Unit Cost 2017 = Unit Cost Year 2016 x 1.0136

USD = EUR * 1.19986

Benchmark DB Escalation to 2017	CCC Price 2016 EUR	Inflation factor	CCC total cost 2017 EUR	CCC total cost 2017 USD
EW -190-1:9	83,500	1.0136	84,636	101,551
EW -1200-1:18,5	170,000	1.0136	172,312	206,751
EW -2500-1:26.5	320,000	1.0136	324,352	389,177
EW -10000/4000-1:39	330,000	1.0136	334,488	401,339
EW -2500-1:26.5	367,627	1.0136	372,626	447,100
EW -10000/4000-1:39	399,160	1.0136	404,588	485,450

Table 5-54 - Equivalent turnouts DB – cost escalation to 2017 and conversion to imperial units

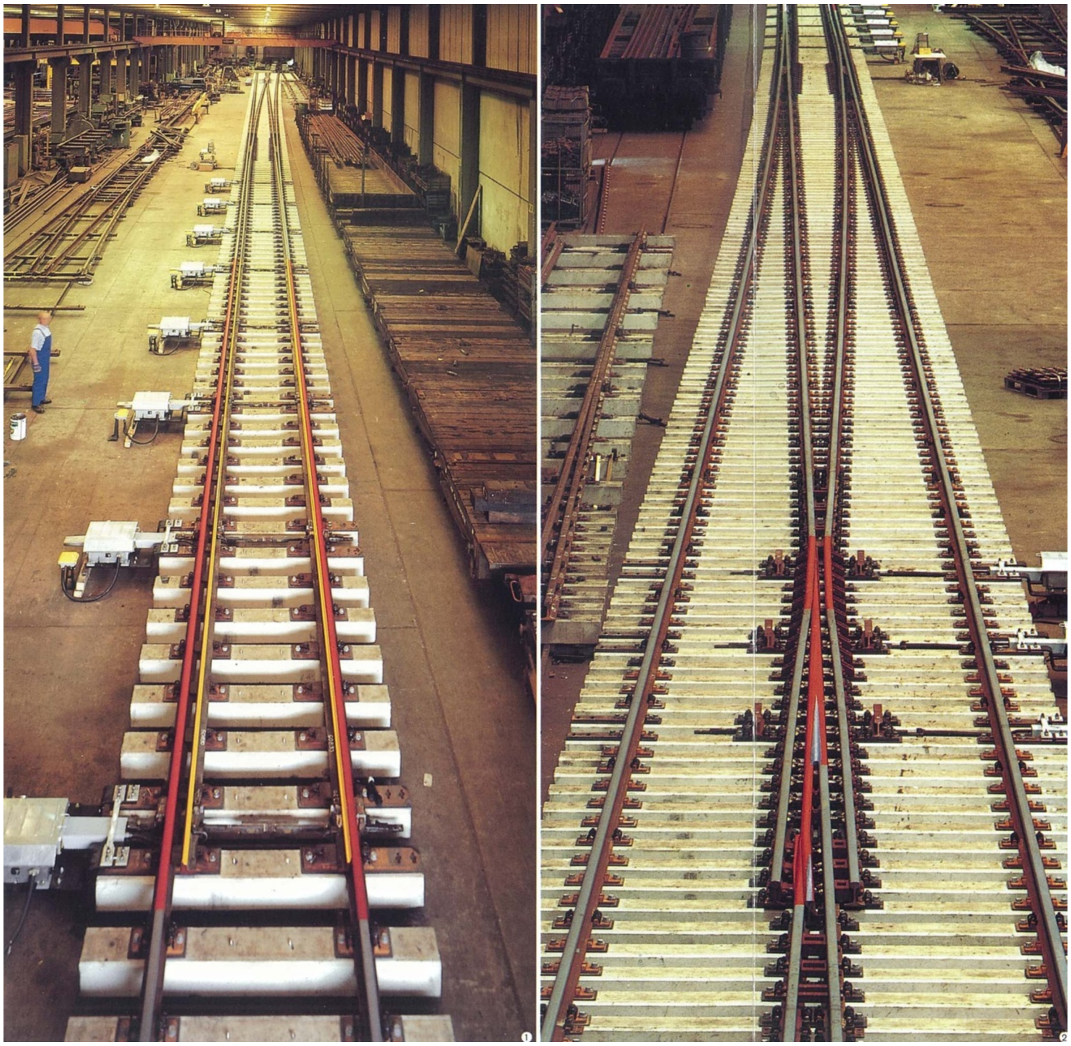


Figure 5-27 - Switch UIC 60, radius: 32,800 ft/13,100 ft/∞, diverging speed: 100 mph, length: 433 ft., moveable frog

(Source: Butzbach Weichenwerk, Germany)

Detailed cost estimations for ballasted track:

According to DB Bahnbau, a 10% surcharge for overhead and administration, as well a 4% mark-up for site installation services, must be added.

Surcharge for indirect cost	Unit per cost DB minimum		Unit per cost DB maximum	
Indirect cost company	10	%	10	%
Indirect cost site	4	%	4	%
Sub-ballast, place, spread & compact	28.5	EUR/m³	34.2	EUR/m³
Ballast, place, spread & compact	36.48	EUR/m³	39.9	EUR/m³
Unload Track Material & Distribute	9.12	EUR/track-m	11.4	EUR/track-m
Electric (flash butt) welding	205.2	EUR/EA	228	EUR/EA
Install rail on ties, 141 RE	118.56	EUR/track-m	137.94	EUR/track-m
Align & tamp	17.1	EUR/track-m	22.8	EUR/track-m
Rail grinding	10.26	EUR/track-m	12.54	EUR/track-m
Concrete cross ties	57	EUR/EA	79.8	EUR/EA

Table 5-55 – German cost of ballasted track – including indirect cost – Source: DB Bahnbau 2017

Imperial Units	Unit cost DB minimum		Unit cost DB maximum	
Sub-ballast, place, spread & compact	26.14	USD/cu yd	31.37	USD/cu yd
Ballast, place, spread & compact	33.47	USD/cu yd	36.60	USD/cu yd
Unload track material & distribute	3.34	USD/tf	4.17	USD/tf
Electric (flash butt) welding	246.21	USD/EA	273.57	USD/EA
Install rail on ties, 141 RE	43.36	USD/tf	50.45	USD/tf
Align & tamp	6.25	USD/tf	8.34	USD/tf
Rail grinding	3.75	USD/tf	4.59	USD/tf
Concrete cross ties	68.39	USD/EA	95.75	USD/EA

Table 5-56 - German cost of ballasted track – conversion to imperial units

Using the given takeoff quantities for the 12.98 route-mile, double-track section, comparable unit costs in USD/yard were calculated:

Grand Total Unit Price DB min per yard two-track = Grand Total DB / Section Length (12.98 RM) / Conversion factor Miles to Yards (1760)

Unit Costs per yard of two-track line	Takeoff quantity		Grand Total DB minimum in USD	Unit Price DB minimum		Grand Total Unit Price DB min per yard two-track line		Share in %
Sub-ballast, place, spread & compact	105,567	cu yd	2,760,024.18	26.14	USD/cu yd	120.82	USD/yd	13.92
Ballast, place, spread & compact	112,422	cu yd	3,762,235.56	33.47	USD/cu yd	164.69	USD/yd	18.97
Unload track Material & distribute	137,100	tf	457,275.96	3.34	USD/tf	20.02	USD/yd	2.31
Electric (flash butt) welding	3,427	EA	843,890.18	246.21	USD/EA	36.94	USD/yd	4.26
Install rail on ties, 141 RE	137,100	tf	5,944,587.48	43.36	USD/tf	260.22	USD/yd	29.98
Align & tamp	137,100	tf	857,392.42	6.25	USD/tf	37.53	USD/yd	4.32
Rail grinding	137,100	tf	514,435.45	3.75	USD/tf	22.52	USD/yd	2.59
Concrete cross ties	68,550	EA	4,688,278.79	68.39	USD/EA	205.22	USD/yd	23.64
10.09.120 Ballasted track - two-track	12.98	RM	19,828,120.03	1,527,590	USD/RM	867.95	USD/yd	100.00

Table 5-57 - German cost of ballasted track - USD/yd – two tracks – minimum cost

Unit costs per yard of two-track line	Takeoff quantity		Grand Total DB maximum in USD	Unit Price DB maximum		Grand Total Unit Price DB maximum per yard two-track line		Share In %
Sub-ballast, place, spread & compact	105,567.00	cu yd	3,312,029.02	31.37	USD/cu yd	144.98	USD/yd	13.69
Ballast, place, spread & compact	112,422.00	cu yd	4,114,945.14	36.60	USD/cu yd	180.13	USD/yd	17.01
Unload track material & distribute	137,100.00	tf	571,594.95	4.17	USD/tf	25.02	USD/yd	2.36
Electric (flash butt) welding	3,427.50	EA	937,655.76	273.57	USD/EA	41.04	USD/yd	3.88
Install rail on ties, 141 RE	137,100.00	tf	6,916,298.89	50.45	USD/tf	302.75	USD/yd	28.59
Align & tamp	137,100.00	tf	1,143,189.90	8.34	USD/tf	50.04	USD/yd	4.73
Rail grinding	137,100.00	tf	628,754.44	4.59	USD/tf	27.52	USD/yd	2.60
Concrete cross ties	68,550.00	EA	6,563,590.30	95.75	USD/EA	287.31	USD/yd	27.14
10.09.120 Ballasted Track - two-track	12.98	RM	24,188,058	1,863,486	USD/RM	1,058.80	USD/yd	100.00

Table 5-58 - German cost of ballasted track - USD/y – 2 tracks – maximum cost

5.3 SCC 20 - Stations Terminals and Intermodal

5.3.1 CHSRA Cost Component

5.3.1.1 Qualitative description

The UPE provided for the Fresno and Bakersfield stations are aggregated into separate allowances. The structure and composition of these allowances do not correspond with the DB reference price elements and are so distinct that the DB costs cannot be converted appropriately to match the UPE. CHSRA and DB therefore agreed, on 29-Jun-2018, that the UPE will not be considered further for benchmarking.

Thus, benchmarking can only be done by comparing assumed functions and applying the provided lump sum costs.

1.1.1.1 Quantitative estimation

The costs for the following stations were reviewed through benchmarks:

Section 1: San Francisco to San Jose	Total USD 42 Mil
Transbay Transit Center (TTC)	USD 550 Mil contribution in Phase I, not part of V2V
4th & King	USD 42 Mil allowance, not to be further evaluated

Section 2: San Jose to Gilroy	Total USD 242 Mil
San Jose Diridon	USD 61 Mil
5 Caltrain stations, tracks, etc. upgrades	USD 121 Mil contribution, not to be further evaluated
Gilroy	USD 61 Mil

Section 5: Madera Acres to Poplar Avenue	Total USD 153 Mil
Madera Acres (temporary)	USD 30 Mil allowance, not to be further evaluated
Fresno	USD 86 Mil

Section 6: Poplar Avenue to Bakersfield	Total USD 196 Mil
Poplar Avenue	USD 31 Mil allowance, not to be further evaluated
Bakersfield	USD 165 Mil

Section 6.1: Poplar Avenue to Bakersfield F Street Station	Total USD 47 Mil
Poplar Avenue	USD 31 Mil allowance, not to be further evaluated
Bakersfield F Street (temporary)	USD 47Mil

The total cost for Section 6, as stated in the '2018 Baseline Estimate Optimization 7.2 (V2V)', includes the cost for the Poplar Avenue Station. CHSRA has since stated that the station is no longer needed, as Valley to Valley extends to Bakersfield. Because the total costs have yet to be updated, the costs for Poplar Avenue Station are still included in the Business Plan. However, they will be disregarded for Benchmarking.

Temporary stations are to be seen as given costs and not further evaluated, as directed by CHSRA.

1.1.1.2 Escalation of costs

Since only lump sum costs for the year 2017 were provided, no escalation of the CHSRA costs was necessary.

The station costs were only provided as lump sums for individual stations. The station requirements are stated by the Design Criteria Manual. Station designs are only provided for Fresno and Bakersfield at a feasibility study design maturity. The provided requirements and functions were taken as given and not further adjusted.

1.1.2 DB Cost Component

1.1.2.1 Qualitative description

The detailed descriptions of station requirements presented in the Design Criteria Manual were used to deduce a CHSRA station archetype. This archetype then served as the basis for comparing typical stations to the DB benchmark. Only a lump sum is given for the station cost; therefore, the benchmarking was performed by comparing station requirements, available facilities, station size, and number of platforms.

The DB benchmark stations are located in Kassel-Wilhelmshöhe, Leipzig/Halle Airport, Montabaur and Limburg Süd. The selected stations are the most recent, newly built, intermediate stations, serving as the areas' transport hubs for intermodal interchange.

Figure 5-28 - Location of benchmark stations

5.3.1.2 Quantitative estimation

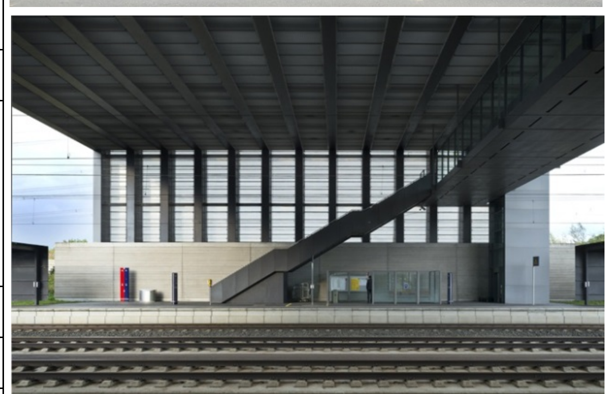
Limburg Süd (unstaffed station)

The concourse building, encompassing 3,230 sq. ft., houses the waiting area and vending machines. The concourse building's upper floor has been mainly vacant for future commercial opportunities.

Within the station building, the pedestrian overpass spans all four tracks, making both platforms accessible through stairs and elevators.

The station building's roof spans all four tracks at 36 ft. high and 120 ft. wide.

Station type	Minimal
Year Of construction	2002
Level	At-grade
Station access	Elevators Stairwells Pedestrian overpass
Customer service	Ticket vending machine
Public facilities	Public restrooms Waiting areas
Commercial facilities	Vending machines
Staff areas	Station control room Storage room Garbage collection room Cleaning, supply
Technical rooms	Included
Parking spaces EA	306
Intermodal Interchange	Regional bus station Taxi Bicycle storage racks



Limburg Süd (unstaffed station)		
Platforms	2	
Through tracks	2	
Platform length [ft]	1,330	
Platform width [ft]	12	
Platform height [ft]	2 ft. 6 in.	
Platform canopy [ft]	980	
Cost in year of construction [2002]	USD 18 Mil	
Escalated Cost [2017]	+27.62%	USD 22 Mil

Table 5-59 - Limburg Süd (unstaffed station)

Leipzig/Halle airport (unstaffed station)

Station type	Minimal
Year of construction	2002
Level	At-grade
Station access	Elevators Escalators Stairwells Pedestrian overpass (airport terminal)
Customer service	Ticket vending machine
Public facilities	Public restrooms Waiting areas on platform
Commercial facilities	None Available in airport
Staff areas	Station control room Storage room Garbage collection room cleaning, supply
Technical rooms	Included
Parking spaces [EA]	None 5,000-space airport parking

The station has been fully incorporated into the airport terminal, being positioned directly under the terminal building. Accessible via escalators and elevators, the terminal houses commercial facilities and serves as passenger overpass to reach both platforms.

Awnings suspended from a steel substructure cover each platform over a length of 985 ft.

Leipzig/Halle airport (unstaffed station)		
Intermodal Interchange	Air travel Regional trains Regional bus station Taxi Bicycle storage racks	
Platforms	2	
Through tracks	2	
Platform length [ft.]	1,345	
Platform width [ft.]	16	
Platform height [ft.]	2 ft. 6 in.	
Platform canopy [ft.]	985	
Cost in year of construction [2002]	USD 13 Mil	
Escalated Cost [2017]	+27.62%	USD 16 Mil

Table 5-60 - Leipzig/Halle Airport (unstaffed station)

Montabaur ICE station (staffed station)

Montabaur ICE station (staffed station)	
Station type	Intermediate
Year of construction	2002
Level	At-grade / embankment
Station access	Elevators Stairwells/Escalator Passenger underpass
Customer service	Ticketing office Ticket vending machine Information desk
Public facilities	Public restrooms Waiting areas
Commercial facilities	Concession areas
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning supply
Technical rooms	Included
Parking spaces [EA]	1,100

The station platforms are located on a 50 ft. high embankment with platform access through the concourse building, below the platforms. The two-story concourse building houses 7,550 sq. ft. of commercial facilities, customer services, and public facilities.

Access to the platforms is provided by escalators and elevators, with additional waiting areas on the platform.

The station plaza serves as a transfer point for buses and other modes of transportation.

Montabaur ICE station (staffed station)		
Intermodal Interchange	Regional trains Regional bus station Taxi Bicycle storage racks	
Platforms	3	
Through tracks	2	
Platform length [ft.]	1,330	
Platform width [ft.]	25	
Platform height [ft.]	2 ft. 6 in.	
Platform canopy [ft.]	660	
Cost in year of construction [2002]	USD 28 Mil	
Escalated Cost [2017]	+27.62%	USD 36 Mil

Table 5-61 - Montabaur ICE station (staffed station)

Kassel-Wilhelmshöhe (staffed station)	
	
Station type	Intermediate
Year of construction	1991
Level	At-grade
Station access	Elevators Stairwells
Customer service	Ticketing office Ticket vending machine Information desk
Public facilities	Public restrooms Waiting areas
Commercial facilities	Concession areas two-story concourse building
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room Garbage collection room Cleaning, supply
Technical rooms	Included
Parking spaces [EA]	462

Originally constructed in 1849, the station underwent major reconstruction in the late 20th Century to accommodate HSR trains.

The station now houses an elevated parking facility covering the majority of the platforms and a 720-foot-long, two-story concourse building. The main access to the platforms is provided through the concourse building.

The station plaza is covered at a height of 50 ft. by a 300 x 220 ft canopy, to accommodate the bus and tram stations.

Kassel-Wilhelmshöhe (staffed station)		
Intermodal Interchange	Regional trains Tram Regional bus station Taxi Bicycle storage racks	
Platforms	8	
Through tracks	2	
Platform length [ft.]	1,330	
Platform width [ft.]	30	
Platform height [ft.]	2 ft. 6 in.	
Platform canopy [ft.]	985	
Cost in year of construction [1991]	USD 184 Mil	
Escalated Cost [2017]	+42%	USD 260 Mil

Table 5-62 - Kassel-Wilhelmshöhe (staffed station)

With respect to the requirements given in the Design Criteria Manual for intermediate stations on the Valley to Valley line, the benchmark station 'Montabaur' complies with the necessary functions and facilities. Furthermore, it is comparable in building size, with a number of tracks and platforms similar to what is planned according to the Systemwide Alignment Schematic. Therefore, the benchmark station 'Montabaur' serves as an archetype for all intermediate CHSRA stations.

1.1.2.2 Escalation of costs

The escalation of costs is based on an evaluation of necessary functions and requirements for each station.

In the following tables, the reviewed stations are set in direct comparison to their respective benchmarks, showing their functions and facilities as well as lump sum costs. The specifics of the benchmark station are then adjusted to tailor it to the respective CHSRA station. The costs of the benchmark station, including adjustments, are then escalated to costs in the year 2017 for direct comparison with the CHSRA stations.

Contingencies of the CSHRA stations are stated according to '2018 Baseline Estimate Optimization 7.1 (V2V)'. The contingencies given are allocated to the following cost categories:

- Station buildings: Intercity passenger rail only (21%)
- Station buildings: Joint use (commuter rail, intercity bus) (21%)

- Pedestrian / bike access and accommodation, landscaping, parking lots (21%)
- Automobile, bus, and van accessways including roads (21%)

For the DB Benchmark station, the contingencies are included, because the stations have been built.

Parking structures are not part of the Valley to Valley budget at any station and are therefore not further considered for benchmarking (result of the conference call with CHSRA on 27 June 2018).

The costs for 4th & King, in Section 1 'San Francisco to San Jose,' and the Caltrain stations in Section 2 'San Jose to Gilroy' are an allowance that is not to be evaluated (result of the conference call with CHSRA on 27 June 2018).

The temporary stations, Madera Acres in Section 5 'Madera Acres to Poplar Avenue', and Bakersfield F-Street in Section 6, 'Poplar Avenue to Bakersfield', are to be taken as given costs without any further review for benchmarking (result of the conference call with CHSRA on 27 June 2018).

CHSRA stated an allowance for seismic risks as a cost increase of 10% to 50%, depending on the building component. The allowances are allocated as follows:

Non-structural	+10%
Structural	+50%
Mechanical	+20%
Electrical	+20%
Plumbing	+20%
Fire protection	+30%
Information communications technology	+10%

For benchmarking purposes, the given allowances were applied to the DB Reference Cost Calculation for Fresno Station, and thereby aggregated to a general allowance for seismic risks, which is then applied to the Benchmark Station as an adjustment.

The general allowance amounts to a cost increase of 27%.

Bakersfield Station was given an allowance of 50% to represent the higher seismic risk, given the construction type as elevated station.

Section 2: San Jose to Gilroy
San Jose Diridon

Station Name	San Jose Diridon	Montabaur ICE-Station	Adjustment to Benchmark	
Station type	Minimal	Intermediate		
Station design	Not available	Built (2002)		
Level	At-grade	At-grade / embankment		
Station access	Elevators Stairwells Provision for escalators	Elevators Stairwells Escalator Passenger underpass	-4 escalators	-USD 1.2Mil
Customer service	Ticketing office Ticket vending machine Information desk	Ticketing office Ticket vending machine Information desk		
Public facilities	Public restrooms Waiting areas	Public restrooms Waiting areas		
Commercial facilities	Concession areas	Concession areas		
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply		
Technical rooms	Included	Included		
Parking spaces [EAc]	*(surface)* 990	*(surface)* 1,100	-110	USD - 0.6 Mil
Intermodal Interchange	Regional bus station Taxi Bicycle storage racks	Regional bus station Taxi Bicycle storage racks Regional trains		
Platforms	4	3	+1	USD + 2.7 Mil
Through tacks	-	2		
Platform length [ft]	1,410	1,330	+80	

Station Name	San Jose Diridon		Montabaur ICE-Station	Adjustment to Benchmark	
Platform width [ft]	30		25	+5	USD + 1.8 Mil
Platform height [ft]	TBD		2 ft 6 in		
Platform canopy [ft]	TBD		660		
Allowance for seismic risks	Included		Included according to German conditions	+27%	USD +7.6 Mil
Contingencies	21%	USD 10.6 Mil	included, station built		
Cost in year of construction (2002)			USD28 Mil	USD +10.3 Mil	
Escal. to 2017			USD + 8 Mil	USD +2.8 Mil	
Subtotal			USD36 Mil	USD +13.1 Mil	
Total Cost [2017]	USD 61 Mil		USD 49 Mil (rd)		

Table 5-63 – Adjustment from Montabaur Station to San Jose Diridon Station

Gilroy

Station Name	Gilroy	Montabaur ICE-Station	Adjustment to Benchmark	
Station type	Intermediate	Intermediate		
Station design	Not available	Built (2002)		
Level	At-grade	At-grade / embankment		
Station access	Elevators Stairwells Provision for escalators	Elevators Stairwells Escalator Passenger underpass	-4 escalators	USD -1.2 Mil
Customer service	Ticketing office Ticket vending machine Information desk	Ticketing office Ticket vending machine Information desk		
Public facilities	Public restrooms Waiting areas	Public restrooms Waiting areas		
Commercial facilities	Concession areas	Concession areas		

Station Name	Gilroy		Montabaur ICE-Station	Adjustment to Benchmark	
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply		Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply		
Technical rooms	included		included		
Parking spaces [EA]	*(surface)* 900		*(surface)* 1,100	-200	USD - 1 Mil
Intermodal Interchange	Regional bus station Taxi Bicycle storage racks		Regional bus station Taxi Bicycle storage racks Regional trains		
Platforms	2		3	-1	USD - 2.1 Mil
Through tracks	2		2		
Platform length [ft]	1,400		1,330	+70	USD - 0.7 Mil
Platform width [ft]	20		25	-5	
Platform Height [ft]	TBD		2 ft 6 in		
Platform canopy [ft]	TBD		660		
Allowance for seismic risks	Included		Included according to German conditions	+27%	USD +7.6 Mil
Contingencies	21%	USD 10.6 Mil	Included, station built		
Cost in year of construction (2002)			USD 28 Mil	USD +2.6 Mil	
Escal. to 2017			USD + 8 Mil	USD +1 Mil	
Subtotal			USD 36 Mil	USD +3.6 Mil	
Total Cost [2017]	USD 61 Mil		USD 40 Mil (rd)		

Table 5-64 - Adjustment from Montabaur Station to Gilroy Station

Section 5: Madera Acres to Poplar Avenue

Fresno

Station Name	Fresno	Montabaur ICE-Station	Adjustment to Benchmark	
Station type	Intermediate	Intermediate		
Station design	Feasibility study	Built (2002)		
Level	At-grade	At-grade / embankment		
Station access	Elevators Stairwells Provision for escalators Pedestrian overcrossing	Elevators Stairwells Escalator Passenger underpass	-4 escalators	USD - 1.2 Mil
Customer service	Ticketing office Ticket vending machine Information desk	Ticketing office Ticket vending machine Information desk		
Public facilities	Public restrooms Waiting areas	Public restrooms Waiting areas		
Commercial facilities	Concession areas	Concession areas		
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning supply		
Technical rooms	Included	Included		
Parking spaces [EA]	*(surface)* 1,600	*(surface)* 1,100	+500	USD + 2.2 Mil
Intermodal interchange	Regional bus station Taxi Bicycle storage racks	Regional bus station Taxi Bicycle storage racks Regional trains		
Platforms	2	3	-1	USD - 2.1 Mil
Through tracks	2	2		
Platform length [ft]	1,400	1,330	+70	USD + 1.1 Mil
Platform width [ft]	30	25	+5	

Station Name	Fresno		Montabaur ICE-Station	Adjustment to Benchmark	
Platform height [ft]	TBD		2 ft 6 in		
Platform canopy [ft]	990		660	+330	USD + 0.6 Mil
Allowance for seismic risks	Included		Included according to German conditions	+27%	USD + 7.6 Mil
Contingencies	21%	USD15 Mil	Included, station built		
Cost in year of construction (2002)			USD 28 Mil	USD + 8.2 Mil	
Escal.to 2017			USD +8 Mil	USD + 2.3 Mil	
Subtotal			USD 36 Mil	USD + 10.5 Mil	
Total Cost [2017]	USD 86 Mil		USD 47 Mil (rd)		

Table 5-65 - Adjustment from Montabaur Station to Fresno Station

Section 6: Poplar Avenue to Bakersfield

Bakersfield

Station Name	Bakersfield	Montabaur ICE-Station	Adjustment to Benchmark	
Station type	Intermediate	Intermediate		
Station design	Feasibility study	Built (2002)		
Level	Elevated	At-grade / embankment	Elevated	USD + 35.5Mil
Station access	Elevators Stairwells Provision for escalators Pedestrian overcrossing	Elevators Stairwells Escalator Passenger underpass	-4 escalators	USD - 1.2 Mil
Customer service	Ticketing office Ticket vending machine Information desk	Ticketing office Ticket vending machine Information desk		
Public facilities	Public restrooms Waiting areas	Public restrooms Waiting areas		
Commercial facilities	Concession areas	Concession areas		
Staff areas	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply	Station control room Police station Security services room Staff restrooms Staff mess & lockers Staff meeting room Storage room First aid room Garbage collection room Cleaning, supply		
Technical rooms	Included	Included		
Parking spaces [EA]	*(surface)* 900	*(surface)* 1,100	-200	USD - 1 Mil
Intermodal interchange	Regional bus station Taxi Bicycle storage racks	Regional bus station Taxi Bicycle storage racks Regional trains		
Platforms	2	3	-1	USD - 2.1 Mil
Through tracks	2	2		

Station Name	Bakersfield		Montabaur ICE-Station	Adjustment to Benchmark	
Platform length [ft]	1,400		1,330	+70	USD + 1.1 Mil
Platform width [ft]	30		25	+5	
Platform height [ft]	TBD		2 ft 6 in		
Platform canopy [ft]	1,400		660	+740	USD + 2.1 Mil
Allowance for seismic risks	Included		Included according to German conditions	+50%	USD + 14 Mil
Contingencies	21%	USD 28.6 Mil	Included, station built		
Cost in year of construction (2002)			USD 28 Mil	USD + 48.4 Mil	
Escal. to 2017			+USD 8 Mil	USD + 13.4 Mil	
Subtotal			USD 36 Mil	USD + 61.8 Mil	
Total Cost [2017]	USD 165 Mil		USD 98 Mil (rd)		

Table 5-66 – Adjustment from Montabaur Station to Bakersfield Station

5.4 SCC 30 - Support Facilities, Yard & Shops, Admin, etc.

5.4.1 CHSRA Cost Component

5.4.1.1 Qualitative description

The benchmark includes three different types of maintenance facilities:

- Heavy maintenance facilities for rolling stock (HMF)
- Light maintenance facilities for rolling stock (LMF)
- Maintenance of way facilities (MOWF)

To estimate the cost of maintenance facilities, ETO recommends that station locations, specifications, and service characteristics be considered, as well as the following construction components:

- Track length and type within the maintenance facilities
- Design and construction of maintenance sheds, workshops, and administration and other buildings
- Maintenance facility equipment, machinery, and plant
- Raw materials and finished goods required (Materials)
- Train control and communications systems within the depots
- Catenary/grid components

A detailed benchmark could not be calculated because the provided data is very generalized and impacted by the future rolling stock contractor. The ETO could not find detailed cost calculations for maintenance nor any assumptions CHSRA made that our team could compare with benchmarking data from Germany.

The following points form the basis for the benchmarking:

- For the Heavy Maintenance Facility (HMF) and Maintenance of Way Facility (MOWF), the provided lists of Unit Price Elements (UPE) in the HMF & MOWF UPE Report. The UPE include aggregated quantities by section and unit costs for various SCC sub-categories.
- For LMF, the Poplar to Bakersfield UPE report
- For MOWF, the Poplar to Bakersfield UPE report
- Cost calculations for specific construction elements according to the level of design maturity
- Drawings and plans according to the level of design maturity
- Workshops with CHSRA
- Other cost estimates provided (e.g. “Gilroy to Carlucci Rd. UPE” and “Poplar to Bakersfield UPE Report”) were not considered at the direction of CHSRA.

5.4.1.2 Quantitative estimation

For Heavy Maintenance Facilities (HMF), the following elements have been considered in the CHSRA estimate:

Description	Takeoff Quantity		Bid Total Cost in USD	Bid Unit Cost in USD
Clearing & grubbing allowance, Level 1	745,360.00	sq yd	536,659	0.7
Rough grading	745,360.00	sq yd	4,673,407	6.3
Finish grading	153,080.00	sq yd	1,138,915	7.4
Excavation w/haul	248,500.00	cu yd	2,678,830	10.8
Erosion control allowance	11,650.00	LF	44,503	3.8
Roadway drainage, allowance	8,500.00	LF	773,245	91.0
Storm water management pond	35,000.00	sq yd	1,114,750	31.9
Aggregate base (cu yd)	24,100.00	cu yd	770,477	32.0
Asphalt concrete paving	12,450.00	t	1,242,137	99.8
Misc. signage & striping, parking lot	650,000.00	sq ft	487,500	0.8
Cement concrete curb & gutter	25,000.00	LF	596,250	23.9
Cement concrete sidewalk, 4in	6,670.00	sq yd	294,681	44.2
Landscape irrigation allowance	170,000.00	sq ft	219,300	1.3
Landscaping allowance	170,000.00	sq ft	430,100	2.5
Site lighting allowance	650,000.00	sq ft	3,308,500	5.1
6 ft chain link fence	11,650.00	LF	458,311	39.3
Chain link gates, 12 ft opening	3.00	EA	5,085	1,695.0
Structural concrete, in place, retaining wall - complete	15,000.00	sq ft	873,600	58.2
Sub-ballast, place, spread & compact	8,000.00	cu yd	463,360	57.9
Utility piping, pressurized, 12 in to 24 in diameter	5,000.00	LF	1,023,950	204.8
Vehicle maintenance equipment allowance (heavy)	1.00	LS	10,437,000	10,437,000.0

Description	Takeoff Quantity		Bid Total Cost in USD	Bid Unit Cost in USD
Support & administration Building allowance (multi-floor)	283,800.00	sq ft	79,341,966	279.6
Maintenance building Allowance	101,900.00	sq ft	33,667,760	330.4
Wheel true building allowance	54,600.00	sq ft	16,651,908	305.0
Maintenance of way building allowance	40,050.00	sq ft	13,741,155	343.1
Car wash building allowance	58,200.00	sq ft	7,396,056	127.1
Paint & body shop building allowance	54,600.00	sq ft	16,305,198	298.6
Service & inspection building allowance	134,650.00	sq ft	56,465,478	419.4
Cement concrete pavement	14,450.00	sq yd	1,906,678	132.0
Heavy maintenance facility (HMF) - Total			257,046,758	

Table 5-67 - Heavy Maintenance Facility (HMF)

For the Light Maintenance Facilities (LMF), no detailed elements were considered in the CHSRA estimate. A total bid unit cost of USD 119,625,536 was considered.

Description	Bid Unit Cost
Light Maintenance Facility (LMF)	119,625,536

Table 5-68 - Light Maintenance Facility (LMF)

For the Maintenance of Way Facility (MOWF), the following elements were considered in the CHSRA. estimate:

Description	Takeoff Quantity		Bid Total Cost in USD	Bid Unit Cost in USD
Clearing & grubbing allowance, Level 1	121,000.00	sq yd	87,120	0.7
Rough grading	121,000.00	sq yd	758,670	6.3

Description	Takeoff Quantity		Bid Total Cost in USD	Bid Unit Cost in USD
Finish grading	45,820.00	sq yd	340,901	7.4
Excavation w/haul	40,335.00	cu yd	434,811	10.8
Erosion control allowance	1,890.00	LF	7,220	3.8
Roadway drainage, allowance	1,380.00	LF	125,539	91.0
Storm water management pond	5,680.00	sq yd	180,908	31.9
Aggregate base (cu yd)	3,910.00	cu yd	125,003	32.0
Asphalt concrete paving	2,020.00	t	201,535	99.8
Misc. signage & striping Parking lot	105,520.00	sq ft	79,140	0.8
Cement concrete curb & gutter	4,060.00	LF	96,831	23.9
Cement concrete sidewalk, 4 in	1,080.00	sq yd	47,714	44.2
Landscape irrigation allowance	27,600.00	sq ft	35,604	1.3
Landscaping allowance	27,600.00	sq ft	69,828	2.5
Site lighting allowance	105,520.00	sq ft	537,097	5.1
6 ft chain link fence	1,890.00	LF	74,353	39.3
Chain link gates, 12 ft opening	2.00	EA	3,390	1,695.0
Structural concrete, in place, retaining wall - complete	2,435.00	sq ft	141,814	58.2
Sub-ballast, place, spread & compact	1,300.00	cu yd	75,296	57.9
Utility piping, pressurized, 12 in to 24 in diameter	815.00	LF	166,904	204.8
Support & administration building allowance (multi-floor)	25,000.00	sq ft	6,989,250	279.6
Maintenance of way building allowance	7,500.00	sq ft	2,573,250	343.1
Cement concrete pavement	2,345.00	sq yd	309,423	132.0

Description	Takeoff Quantity		Bid Total Cost in USD	Bid Unit Cost in USD
Maintenance of Way Facility (MOWF)			13,461,600	

Table 5-69 - Maintenance of Way Facilities (MOWF)

5.4.1.3 Escalation of costs

Since costs were provided for the year 2017, no escalation of the provided costs was necessary.

5.4.2 DB Cost Component

5.4.2.1 Qualitative description

The new high-speed line VDE 8 does not include maintenance facilities. DB did not build any new depots or maintenance facilities in recent years, but, upgraded and modernized the existing facilities. Therefore, the benchmarking was based on DB internal data and data from potential contractors and manufacturers in Germany.

5.4.2.2 Quantitative estimation

Reference data for HMF, from potential contractors and manufactures in Germany, is summarized below. The cost estimate is based on 27 trainsets for the Valley to Valley Concept – Phase 1 with a total length of 660 ft each.

Table 5-70 shows the estimated total costs for DB's Benchmark Heavy Maintenance Facilities (HMF).

Cost element	Amount per train	Cost per unit in EUR	Price per train in USD	Number of trains/trainsets	Costs in USD
Total track for maintenance	200 m	600	146,502	54	7,911,122
Total track for stabling	400 m	600	293,005	27	7,911,122
Turnouts	6	90,000	659,260	27	17,800,024
Maintenance shed (building)	3,500 m^3	180	769,137	27	20,766,695
Office and administration	200 m^3	250	61,043	27	1,648,150
Maintenance equipment	42,729,825				

Cost element	Amount per train	Cost per unit in EUR	Price per train in USD	Number of trains/trainsets	Costs in USD
Washing plant	3,296,301				
Total costs	102,063,240				

* Note: Forex Rate is EUR 1.0000 = USD1.2208

Table 5-70 - Rolling stock facilities according to manufacturer's average cost estimate

Another cost estimation for Heavy Maintenance Facilities was determined in accordance with the "Price and Costs in the Railway Sector", a study conducted by the Federal Polytechnic School of Lausanne and the Intermodality of Transports and Planning Laboratory in Lausanne. This study provides a guideline for average railway infrastructure costs. The sample costs and cost indicators in this study were limited to railway equipment investments (infrastructure, fixed installations, and rolling stock) and to consumption of track energy. This cost was determined in U.S. Dollars as a percentage of the CAPEX.

Percentage of rain cost	0.08 %
Number of trainsets	27
Price per trainset	USD 52.000.000
Total costs	USD 112,320,000

Table - 5-71 - Average costs for Heavy Maintenance Facilities required

Source: trainsets according to the Study Federal Polytechnic School of Lausanne and the Intermodality of Transports and Planning Laboratory in Lausanne (HMF)

For Light Maintenance Facilities (LMF) the DB depot in Griesheim was used as a reference project. The depot contains the following facilities:

a) Inspection, corrective, and preventive light maintenance tracks
b) Maintenance workshops
c) Daily stabling and interior cleaning facilities
d) Daily outside cleaning of the fleet
e) Facility for storage and retrieval of maintenance parts

Figure 5-29 - LMF example - DB depot Griesheim - Source: DB Engineering & Consulting GmbH

	Description	Amount	Costs/ unit [EUR/unit]	Costs [EUR]	Total [USD]
2	Workshop/depots/Ttansfer stations				
2.1	Workshop (maintenance center)				
2.1.1	Civil works				6,592,602
	Excavation, foundation, floor slab	1	1,550,000	1,550,000	
	Building shell and roof	1	2,650,000	2,650,000	
	Interior fittings	1	1,200,000	1,200,000	
2.1.2	Technical equipment				8,814,553
	Air conditioning and climate control operation building	1	150,000	150,000	
	Mechanical climate control unit with cooling reclaiming	1	2,500,000	2,500,000	
	Gates	8	50,000	400,000	
	Water, sewage, sanitary	1	1,100,000	1,100,000	
	Building control	1	130,000	130,000	
	Fire alarm system	1	150,000	150,000	
	Telephone installation, network (without computers)	1	100,000	100,000	
	Security installations	1	100,000	100,000	
	Low voltage distribution	1	200,000	200,000	
	Low voltage installation, lighting	1	1,300,000	1,300,000	
	Compressed air system	1	70,000	70,000	
	Materials handling equipment	1	200,000	200,000	
	Cleaning machine for the workshop	1	70,000	70,000	
	Costs for architects and engineers (planning)	1	750,000	750,000	
2.1.3	Appurtenant structure				732,511
	Lighting, roads and ways	15	40,000	600,000	
2.2	Workshop equipment				32,540,500

	Description	Amount	Costs/ unit [EUR/unit]	Costs [EUR]	Total [USD]
2.2.4	Outdoor facilities				293,005
	Lighting of the tracks	1	170,000	170,000	
	Electric terminal boxes at the inspection track	10	5,000	50,000	
	Costs for architects and engineers (planning)	1	20,000	20,000	
2.x	Appurtenant structure (optional)				659,260
	Building structure	1	300,000	300,000	
	Cleaning area	1	240,000	240,000	
2.3	Depot layout				
2.3.1	Operation building				16,335,002
	Foundation	30	30,000	900,000	
	Building shell, one-storied	1	12,000,000	12,000,000	
	Water, sewage	8	10,000	80,000	
	Air conditioning	8	20,000	160,000	
	Low voltage distribution	8	30,000	240,000	
2.3.2	Depot’s outdoor facilities				3,455,012
	Underground work and concrete	47	50,000	2,350,000	
	Lighting or roads and ways	8	60,000	480,000	
2.3.3	Work stations				1,074,350
	Inspection pits	4	100,000	400,000	
	Tracks for inspection pits	4	120,000	480,000	
2.4	Depot equipment				
2.4.1	Operation building				2,038,823
	Measuring and monitoring equipment	18	75,000	1,350,000	
	Security installations	8	40,000	320,000	

	Description	Amount	Costs/ unit [EUR/unit]	Costs [EUR]	Total [USD]
	Total				72,535,617

Table 5-72 - DB Depot Griesheim – detailed cost estimate

The average costs for Light Maintenance Facilities (LMF) were determined in accordance with the “Price and costs in the railway sector”, a study conducted by The Federal Polytechnic School of Lausanne and the Intermodality of Transports and Planning Laboratory in Lausanne. This price was determined in U.S. Dollars.

Cost per train	USD 1,500,000
Number of trainsets	54
Total costs	81,000,000

Table 5-73 - Average costs for Light Maintenance Facilities (LMF) for 27 trainsets according to the study “Price and costs in the railway sector”

Costs of infrastructure maintenance facilities according to a previous DB project cost estimate:

Cost element	Unit	Amount	Price per unit
Main infrastructure maintenance depot in EUR (year 2017	EA	1	5,000,000
Inflation Factor*		1.19986	
Main infrastructure maintenance depot in USD (year 2017)	EA	1	6,000,000
Total costs in USD	6,000,000		

* Note: Forex Rate is EUR1.0000 = 1.19986

Table 5-74 - Costs of infrastructure maintenance facilities

5.4.2.3 Escalation of costs

The German manufacturer estimated its costs in 2017. The estimate of the maintenance facilities, according to the “Price and costs in the railway sector” study, is a cost quotation from the total price of the rolling stock and is not related to economic conditions or inflation. The price of the maintenance facilities in Griesheim was escalated to the year 2017.

5.5 SCC 40 - Site work, right of way, land, improvements

This section includes the following Standard Cost Categories (SCC) sub-categories:

- Demolition, clearing, site preparation (SCC 40.01)
- Site utilities, utility relocation (SCC 40.02)
- Hazardous materials, contaminated soil removal (SCC 40.03)
- Environmental mitigation (SCC 40.04)
- Site structures, retaining walls, sound walls (SCC 40.05)
- Highway/pedestrian overpass/grade separations (SCC 40.08)

Right of way and land acquisition are not included in the benchmarking.

5.5.1 CHSRA Cost Component

5.5.1.1 Qualitative description

The benchmarking is based on the provided lists of unit price elements (UPE). The UPEs include aggregated quantities by section and unit costs for various SCC sub-categories. UPEs are available for the following sections:

- 3 - Gilroy to Carlucci Road
- 4 - Carlucci Road to Madera Acres
- 6 - Poplar Avenue to Bakersfield

The benchmarking of costs for site work, right of way, land, and improvements, detailed in Chapter 6, is limited to the comparison of unit costs, because UPEs are not available for the entire Valley to Valley line. In addition, it is not possible at this design stage to find comparable elements for all given UPEs.

The available level of detail for the different UPE sub-categories varies substantially.

<u>Demolition, clearing, site preparation</u>

This cost category represents only a small portion of the overall costs. The UPE includes costs for the demolition of roads and railroad tracks. Costs depend on area or route miles.

Site utilities, utility relocation

UPE includes costs for the relocation of telecommunication lines, electric grid, and gas lines. Costs are calculated by length.

Hazardous materials, contaminated soil removal

Related to the available UPE for three sections, hazardous materials and contaminated soil removal represents only a very small portion of the overall costs. The category is represented by one single UPE and includes an allowance for the removal of contaminated material per route mile.

Environmental mitigation

UPE includes costs per route mile for an environmental mitigation allowance depending on the type of area affected.

Site structures, retaining walls, sound walls

UPE includes costs for relocations, retaining and sound walls, fencing, and other measures required for the construction site. Costs are calculated mostly by length.

Highway, pedestrian overpass/grade separations

UPE includes costs per route mile for roadway and pedestrian bridges, embankments and cuts. Costs are mostly given as a lump sum. In particular, the ETO reviewed the one detailed cost estimate.

Detailed information on design of “Road 26 Grade Separation” has been given.

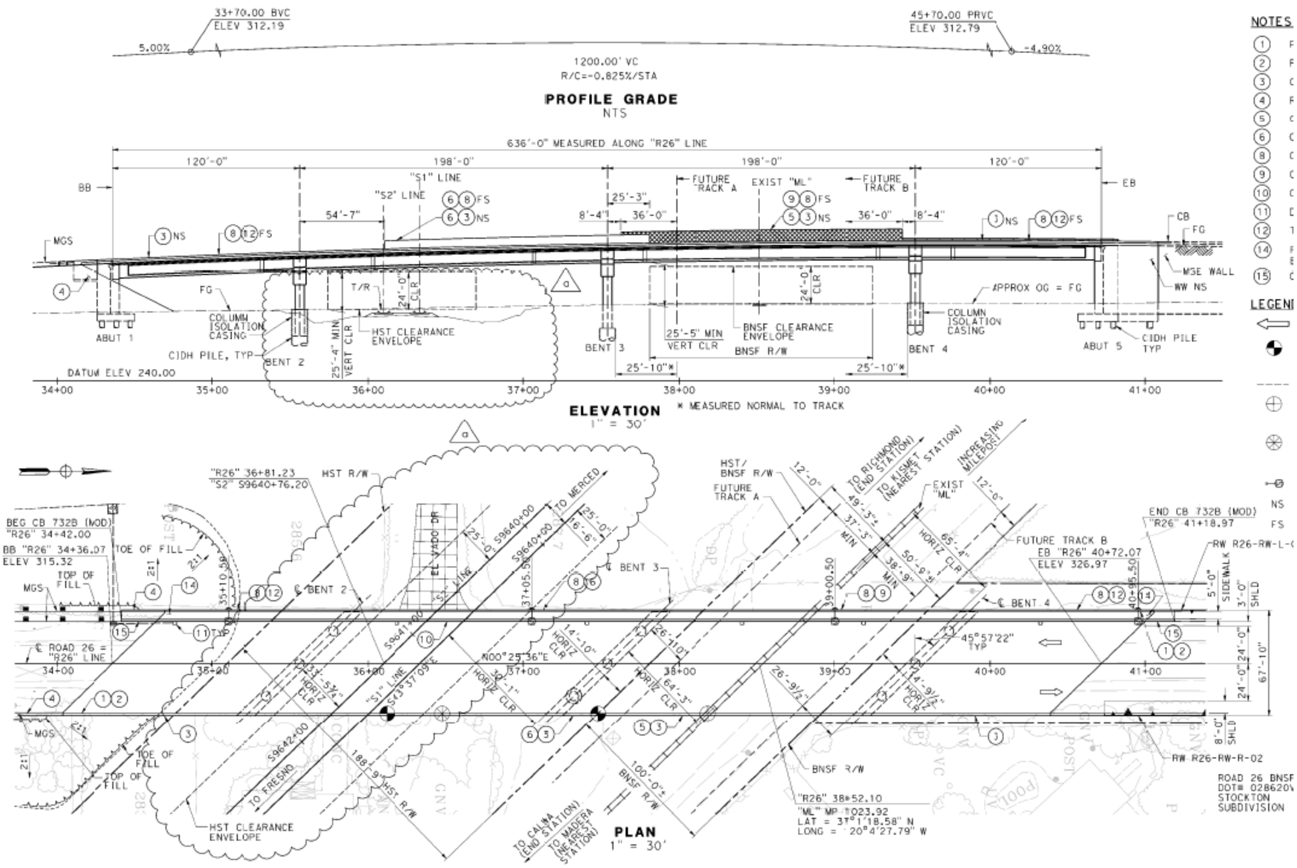


Figure 5-30 – Road 26, General Plan and Elevation of Overpass

Road 26 Overpasses data: Bridge Length = 636 ft = 194 m; Bridge Width = 67 ft – 10 in = 20,7 m; Spans = 120 ft / 198 ft / 198 ft / 120 ft = 36,6 m / 60,4 m / 60,4 m / 36,6 m

5.5.1.2 Quantitative estimation

The following UPEs are available for benchmarking:

Section 3	Gilroy to Carlucci Road	Original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
40.02.013	TelecommIFiber Optic UG, All Sizes	5,490.00	LF	299,040	54.47
40.02.014	TelecommIFiber Optic OH, All Sizes	2,100.00	LF	433,314	206.34
40.02.019	Electric OH, 51-114 kV	970.00	LF	91,694	94.53
40.02.021	Electric OH, 230 kV	1,340.00	LF	189,865	141.69
40.02.019	Electric OH, 51-114 kV	7,410.00	LF	700,467	94.53
40.02.022	Electric OH, unknown	8,950.00	LF	1,268,126	141.69
40.02.023	Electric & Telecomm OH on JP, 51-114 kV	2,300.00	LF	410,619	178.53
40.08.100.b	Rdwy Oxing HSR (Bloomfield Avenue): 2-Ln Rdw) < Over MF	1.00	EA	27,851,365	27,851,365.07
40.08.100.c	Rdwy Oxing HSR (Frazier Lake Road): 2-Ln Rdwy Over 2 Trks	1.00	EA	14,450,882	14,450,882.43
40.08.100d	Rdwy Oxing HSR (Henry Miller Road): 2-Ln Rdwy Over 2 Trks	1.00	EA	23,365,867	23,365,867.00
40.08.100e	Rdwy Oxing HSR (Mercey Springs Road): 2-Ln Rdwy Over 2 Trks	1.00	EA	14,589,997	14,589,997.00
40.08.100f	Rdwy Oxing HSR (Delta Road): 2 Ln Rdwy Over 2 Trks & 2 Ln Rdwy	1.00	EA	14,359,104	14,359,104.00
40.08.100g	Rdwy Oxing HSR (Turner Island Rd): 2 Ln Rdwy Over 2 Trks & 2 Ln Rdwy	1.00	EA	13,962,855	13,962,855.00
40.08.100j	Rdwy Oxing HSR (Carlucci Rd): 2 Ln Rdwy_ Over 2 Trks & 2 Ln Rdwy	1.00	EA	16,468,658	16,468,658.00

Table 5-75 – UPEs available for benchmarking - Gilroy to Carlucci Road

Section 4	Carlucci Road to Madera Acres (Central Valley Wye)	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
40.01.010	Demolition allowance, bridge	23,905.00	sq ft	413,962	17.32
40.01.050	Demolition allowance, building (one story)	470,648.00	sq ft	11,524,552	24.49
40.01.110	Demolition allowance, asphalt pavement	589,839.00	sq yd	3,855,378	6.54
40.01.110A	Demolition allowance, concrete pavement	101,238.00	sq yd	999,394	9.87
40.02.001	Utility relocation allowance, Level 1	183,294.00	LF	81,437,377	444.30
40.02.100	Relocate fiber optic line	9,000.00	LF	2,671,849	296.87
40.02.200	Relocate natural gas line (4 - 12in dia.) - standard complexity	12,400.00	LF	5,705,626	460.13
40.02.210	Protect in-place natural gas line (4 - 12in dia.)	400.00	LF	60,000	150.00
40.02.300	Relocate overhead electric (70-115KV) - standard complexity	10,900.00	LF	1,198,999	110.00
40.02.310	Relocate overhead electric (115-230KV) - high complexity	6,100.00	LF	3,598,997	590.00
40.04.500	Environmental mitigation	1.00	LS	0	0.01
40.05.012	Retaining wall - one wall (12 ft avg. height)	7,703.00	LF	16,405,358	2,129.74
40.05.020	Retaining wall - one wall (20 ft avg. height)	3,636.00	LF	9,529,503	2,620.88
40.05.030	Retaining wall - one wall (30 ft avg. height)	4,684.00	LF	18,216,771	3,889.15
40.05.320	Access restriction fencing	348,934.00	LF	44,630,773	127.91
40.06.010	Temp facilities and other indirect cost	1.00	LS	0	0.01
40.07.104	ROW	1.00	LS	74,755,200	74,755,200.00
40.08.010	Roadway excavation	1,173,468.00	cu yd	11,760,316	10.02
40.08.020	Roadway embankment	524,100.00	cu yd	15,805,771	30.16
40.08.110	Roadway structure: one span, one lane	1.00	EA	627,689	627,689.28
40.08.120	Roadway structure: one span, two lane	4.00	EA	4,360,751	1,090,187.86

Section 4	Carlucci Road to Madera Acres (Central Valley Wye)	Original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
40.08.310	Roadway structure: three span, main span <160 ft	6.00	EA	150,401,011	25,066,835.16
40.08.410	Roadway structure: four span, with pipe pile foundation	1.00	EA	18,894,224	18,894,223.72
40.08.510	Roadway structure: five-span	1.00	EA	20,947,988	20,947,987.78
40.08.920	Roadway structure: multiple-structure, five-span	1.00	EA	17,961,189	17,961,189.04
40.08.930	Roadway structure: multiple-structure, ten-span	1.00	EA	45,711,057	45,711,057.04

Table 5-76 - Carlucci Road to Madera Acres (Central Valley Wye)

Section 6	Poplar Avenue to Bakersfield	original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
40.01.010	Demolition allowance, bridge		sq ft		25
40.01.110	Demolition allowance, asphalt pavement	151,000.00	sq yd	4,735,619	31
40.01.140	Demolition allowance, concrete curb	20,900.00	LF	268,023	13
40.01.150	Demolition allowance, concrete sidewalk	10,000.00	sq yd	431,071	43
40.01.810	Demolition allowance, remove railroad track	4.79	RM	841,662	175,639
40.01.999	Maintenance of traffic	0.05	LS	313,819	
40.02.004	Utility relocation allowance, Level 4	17.71	RM	66,628,628	3,762,204
40.02.005	Utility relocation allowance, Level 5	5.42	RM	26,067,401	4,809,484
40.02.060	Major utility relocation, aerial transmission line	0.48	RM	233,317	490,162
40.02.999	Maintenance of traffic	5.00	LS	4,634,801	
40.03.105	Hazardous material removal allowance, medium	23.13	RM	9,548,883	412,925
40.04.100	Contractor environmental mitigation Allowance, urban at-grade new	1.20	RM	1,638,501	1,360,881

Section 6	Poplar Avenue to Bakersfield	original values			
UPE	**Description**	**Quantity / Unit**		**Grand Total in USD**	**Unit Price in USD**
40.04.115	Contractor environmental mitigation allowance, urban aerial	10.15	RM	2,033,296	200,400
40.04.125	Contractor environmental mitigation allowance, suburban at-grade	2.77	RM	3,144,288	1,137,175
40.04.130	Contractor environmental mitigation allowance, suburban aerial	0.09	RM	19,495	219,046
40.04.140	Contractor environmental mitigation allowance, rural at-grade	8.52	RM	11,753,538	1,379,523
40.04.145	Contractor environmental mitigation allowance, rural aerial	0.40	RM	95,176	236,756
40.04.150	Off-site mitigation property purchase urban		RM		133,305
40.04.155	Off-site mitigation property purchase suburban		RM		166,632
40.04.200	Retention basins	573,541.00	sq ft	6,295,141	11
40.05.006	Retaining wall - 1 wall (6 ft avg. height)	190.00	LF	279,030	1,469
40.05.012A	MSE wall - 1 wall (12 ft avg. height)	1,203.00	LF	804,702	669
40.05.020A	MSE wall - 1 wall (20 ft avg. height)	2,987.00	LF	3,543,525	1,186
40.05.030	Retaining wall - 1 wall (30 ft avg. height)	528.00	LF	2,704,571	5,122
40.05.030A	MSE wall - 1 wall (30 ft avg. height)	306.00	LF	610,522	1,995
40.05.040	Retaining wall - 1 wall (40 ft avg. height)	414.00	LF	1,943,131	4,694
40.05.120	Blast wall (at stations) - 1 wall (20 ft avg. height above platform)		LF		1,260
40.05.212	Sound wall - 1 wall (16 ft avg. height)	92,715.00	LF	35,702,542	385
40.05.400	Canal realignments (8 ft x 10 ft trench)		LF		952
40.05.401C	Canal realignments (20 ft x 10 ft trench)		LF		1,571
40.05.402	Canal realignments (45 ft x 10 ft trench)	4,830.00	LF	13,890,054	2,876
40.05.403	Canal realignments (65 ft x 10 ft trench)		LF		3,915
40.05.404	Canal realignments (115 ft x 10 ft trench)	6,550.00	LF	42,655,867	6,512
40.05.410	Hydraulic crossing 5 ft wide x 5 ft deep x 150 ft long RCBC	31.00	EA	2,792,721	90,088

Section 6	Poplar Avenue to Bakersfield	original values			
UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
40.05.411	Hydraulic crossing 10 ft wide x 5 ft deep x 150 ft long RCBC		EA		125,180
40.05.412	Hydraulic crossing 15 ft wide x 5 ft deep x 150 ft long RCBC		EA		160,264
40.05.413	Hydraulic crossing 10 ft wide x 10 ft deep x 150 ft long RCBC		EA		171,816
40.05.415	Hydraulic crossing 15 ft wide x 10 ft deep x 150 ft long RCBC		EA		239,770
40.05.999	Maintenance of traffic	0.05	LS	5,246,333	
40.08.346	Roadway Overcrossing HSR - 6 lane retained fill roadway over 4 tracks		EA		5,506,013
40.08.425A	Roadway Overcrossing HSR - SR204/F St Interchange	1.00	EA	50,142,027	50,142,027
40.08.425B	Roadway Overcrossing HSR - 7th standard interchange	1.00	EA	53,445,572	53,445,572
40.08.425C	Roadway Overcrossing HSR - Poplar Ave.	1.00	EA	14,823,365	14,823,365
40.08.425D	Roadway Overcrossing HSR - Riverside St	1.00	EA	13,004,570	13,004,570
40.08.432	Roadway Overcrossing HSR - 7th standard full reconstruction		EA		14,328,960
40.08.435A	Roadway Overcrossing HSR - pedestrian Overcrossing - Carrier Canal	1.00	EA	234,679	234,679
40.08.435B	Roadway Overcrossing HSR - pedestrian Overcrossing - F St	1.00	EA	707,392	707,392
40.08.440A	Roadway Overcrossing HSR - 2 lane - 34th St	1.00	EA	6,800,845	6,800,845
40.08.442	Roadway Overcrossing HSR - 2 lane roadway on embankment over 4 tracks		EA		14,823,365
40.08.999	Maintenance of traffic	0.05	LS	6,957,923	

Table 5-77 - Poplar Avenue to Bakersfield

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S04	40.01.010	Demolition allowance, bridge	23,905.00	sq ft	413,962	17.32
S06	40.01.010	Demolition allowance, bridge		sq ft		25
S04	40.01.050	Demolition allowance, building (1 Story)	470,648.00	sq ft	11,524,552	24.49
S04	40.01.110	Demolition allowance, asphalt pavement	589,839.00	sq yd	3,855,378	6.54
S06	40.01.110	Demolition allowance, asphalt pavement	151,000.00	sq yd	4,735,619	31
S04	40.01.110A	Demolition allowance, concrete pavement	101,238.00	sq yd	999,394	9.87
S06	40.01.140	Demolition allowance, concrete curb	20,900.00	LF	268,023	13
S06	40.01.150	Demolition allowance, concrete sidewalk	10,000.00	sq yd	431,071	43
S06	40.01.810	Demolition allowance, remove railroad track	4.79	RM	841,662	175,639
S06	40.01.999	Maintenance of traffic	0.05	LS	313,819	

Table 5-78 - Demolition, clearing, site preparation

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S04	40.02.001	Utility relocation allowance, Level 1	183,294.00	LF	81,437,377	444.30
S06	40.02.004	Utility relocation allowance, Level 4	17.71	RM	66,628,628	3,762,204
S06	40.02.005	Utility relocation allowance, Level 5	5.42	RM	26,067,401	4,809,484
S03	40.02.013	Telecomml fiber optic UG, all sizes	5,490.00	LF	299,040	54.47
S03	40.02.014	Telecomml fiber optic OH, all sizes	2,100.00	LF	433,314	206.34
S03	40.02.019	Electric OH, 51-114 kV	970.00	LF	91,694	94.53
S03	40.02.019	Electric OH, 51-114 kV	7,410.00	LF	700,467	94.53
S03	40.02.021	Electric OH, 230 kV	1,340.00	LF	189,865	141.69

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S03	40.02.022	Electric OH, unknown	8,950.00	LF	1,268,126	141.69
S03	40.02.023	Electric & telecomm OH on JP, 51-114 kV	2,300.00	LF	410,619	178.53
S06	40.02.060	Major utility relocation, aerial transmission line	0.48	RM	233,317	490,162
S04	40.02.100	Relocate fiber optic line	9,000.00	LF	2,671,849	296.87
S04	40.02.200	Relocate natural gas line (4 – 12 in dia.) - standard complexity	12,400.00	LF	5,705,626	460.13
S04	40.02.210	Protect in-place natural gas line (4 – 12 in dia.)	400.00	LF	60,000	150.00
S04	40.02.300	Relocate overhead electric (70-115 KV) - standard complexity	10,900.00	LF	1,198,999	110.00
S04	40.02.310	Relocate overhead electric (115-230KV) - high complexity	6,100.00	LF	3,598,997	590.00
S06	40.02.999	Maintenance of traffic	5.00	LS	4,634,801	

Table 5-79 - Site utilities, utility relocation

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S06	40.04.100	Contractor environmental Mitigation allowance, urban at-grade new	1.20	RM	1,638,501	1,360,881
S06	40.04.115	Contractor environmental Mitigation allowance, urban aerial	10.15	RM	2,033,296	200,400
S06	40.04.125	Contractor environmental mitigation allowance, suburban at-grade	2.77	RM	3,144,288	1,137,175
S06	40.04.130	Contractor environmental mitigation allowance, suburban aerial	0.09	RM	19,495	219,046
S06	40.04.140	Contractor environmental mitigation allowance, rural at-grade	8.52	RM	11,753,538	1,379,523
S06	40.04.145	Contractor environmental Mitigation allowance, rural aerial	0.40	RM	95,176	236,756
S06	40.04.150	Off-site mitigation property purchase urban		RM		133,305
S06	40.04.155	Off-site mitigation property purchase suburban		RM		166,632
S06	40.04.200	Retention basins	573,541.00	sq ft	6,295,141	11
S04	40.04.500	Environmental mitigation	1.00	LS	0	0.01

Table 5-80 - Environmental mitigation

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S06	40.05.006	Retaining wall - 1 wall (6 ft avg. height)	190.00	LF	279,030	1,469
S04	40.05.012	Retaining wall - 1 wall (12 ft avg. height)	7,703.00	LF	16,405,358	2,130
S06	40.05.012A	MSE wall - 1 wall (12 ft avg. height)	1,203.00	LF	804,702	669
S04	40.05.020	Retaining wall - 1 wall (20 ft avg. height)	3,636.00	LF	9,529,503	2,621
S06	40.05.020A	MSE wall - 1 wall (20 ft avg. height)	2,987.00	LF	3,543,525	1,186
S04	40.05.030	Retaining wall - 1 wall (30 ft avg. height)	4,684.00	LF	18,216,771	3,889
S06	40.05.030	Retaining wall - 1 wall (30 ft avg. height)	528.00	LF	2,704,571	5,122
S06	40.05.030A	MSE wall - 1 wall (30 ft avg. height)	306.00	LF	610,522	1,995
S06	40.05.040	Retaining wall - 1 wall (40 ft avg. height)	414.00	LF	1,943,131	4,694
S06	40.05.120	Blast wall (at stations) - 1 wall (20 ft avg. height above platform)		LF		1,260
S06	40.05.212	Sound wall - 1 wall (16 ft avg. height)	92,715.00	LF	35,702,542	385
S04	40.05.320	Access restriction fencing	348,934.00	LF	44,630,773	128
S06	40.05.400	canal realignments (8 ft x 10 ft Trench)		LF		952
S06	40.05.401C	Canal realignments (20 ft x 10 ft trench)		LF		1,571
S06	40.05.402	Canal realignments (45 ft x 10 ft trench)	4,830.00	LF	13,890,054	2,876
S06	40.05.403	Canal realignments (65 ft x 10 ft trench)		LF		3,915
S06	40.05.404	Canal realignments (115 ft x 10 ft trench)	6,550.00	LF	42,655,867	6,512
S06	40.05.410	Hydraulic crossing 5 ft wide x 5 ft deep x 150 ft long RCBC	31.00	EA	2,792,721	90,088
S06	40.05.411	Hydraulic crossing 10 ft wide x 5 ft deep x 150 ft long RCBC		EA		125,180
S06	40.05.412	Hydraulic crossing 15 ft wide x 5 ft deep x 150 ft long RCBC		EA		160,264

Section	UPE	Description	Quantity / Unit		Grand Total in USD	Unit Price in USD
S06	40.05.413	Hydraulic crossing 10 ft wide x 10 ft deep x 150 ft long RCBC		EA		171,816
S06	40.05.415	Hydraulic crossing 15 ft wide x 10 ft deep x 150 ft long RCBC		EA		239,770
S06	40.05.999	Maintenance of traffic	0.05	LS	5,246,333	
S04	40.06.010	Temp facilities and other indirect cost	1.00	LS	0	0.01
S04	40.07.104	ROW	1.00	LS	74,755,200	74,755,200

Table 5-81 - Site structures, retaining walls, sound walls

Scope	Description	Grand Total in USD
0320	Reinforcing Steel	3,331,817.00
0323	Post Tensioning Steel	625,000.00
0331	Substructure Concrete	1,153,770.00
0332	Superstructure Concrete	2,083,005.00
0341	Precast Concrete Girders	528,500.00
0905	Corrosion Protection	25,000.00
3111	Clear and Grub	81,574.00
3122	Rough Grading	551,972.00
3123	Structural Excavation	42,112.00
3124	Structural Backfill	209,261.00
3160	Multirotational Bearing Pads	43,320.00
3163	CIDH Piles	3,089,375.00
3212	Asphalt Paving	1,101,651.00
3231	Fencing	451,125.00
3235	Concrete Barrier	450,329.00
3340	Drainage	1,078,463.00
		27,083,997.00

Table 5-82 – Highway/pedestrian overpass/grade separations

5.5.1.3 Escalation of costs

The provided costs for Road 26 Grade Separation were normalized to USD per square foot of bridge deck for the given structure with its details. Benchmarking is done to DB's Costs Characteristics Catalogue for road overpasses.

Non-relevant components like soil import and utilities were excluded from the benchmark.

Scope	Description	Grand Total in USD	Share of total in %	bridge construction		embankment/ misc
				substructure	superstructure	
0320	Reinforcing Steel	3,331,817	12%	50%	50%	-
0323	Post Tensioning Steel	625,000	2%		100%	-
0331	Substructure Concrete	1,153,770	4%	100%		-
0332	Superstructure Concrete	2,083,005	8%		100%	-
0341	Precast Concrete Girders	528,500	2%		100%	-
0905	Corrosion Protection	25,000	0%	50%	50%	-
3111	Clear and Grub	81,574	0%	50%	50%	-
3122	Rough Grading	551,972	2%	100%		-
3123	Structural Excavation	42,112	0%	100%		-
3124	Structural Backfill	209,261	1%	100%		-
~~3125~~	~~Soil Import~~	~~3,069,117~~	~~11%~~	-	-	~~100%~~
3160	Multirotational Bearing Pads	43,320	0%	100%		-
3163	CIDH Piles	3,089,375	11%	100%		-
3212	Asphalt Paving	1,101,651	4%		100%	-
3231	Fencing	451,125	2%		100%	-
~~3232~~	~~MSE Walls~~	~~6,239,906~~	~~23%~~	-	-	~~100%~~
3235	Concrete Barrier	450,329	2%		100%	-
~~3301~~	~~Utilities~~	~~2,928,700~~	~~11%~~	-	-	~~100%~~
3340	Drainage	1,078,463	4%	50%	50%	-
		27,083,997		7,348,237	7,498,037	~~12,237,723~~
Area of bridgedeck: '0332.1740 'Cure Deck', A =		43,142 sq ft		27%	28%	~~45%~~
	27,083,997/43,142.00 =	627.79 USD/sq ft		170.33 USD/sq ft	173.80 USD/sq ft	~~283.66~~ USD/sq ft

Scope	Description	Grand Total in USD	Share of total in %	bridge construction		embankment/ misc
				substructure	superstructure	
				344.13 USD/sq ft		-

Table 5-83 - Road 26 Grade Separation, average bridge cost in USD per sq ft (w/o Soil Import, MSE Walls, Utilities)

5.5.2 DB Cost Component

5.5.2.1 Qualitative description

On basis of the given parameters of ‘Road 26 Grade Separation’ a comparable UPE-value will be assigned in DB’s Costs Characteristics Catalogue.

Figure 5-31 - VDE 8, Section Coburg North, 2012

Source: DB ProjektBau GmbH Regional Division South-east, Major Project VDE 8, Photo: Frank Kniestedt, DB AG

5.5.2.2 Quantitative estimate

DB Cost Estimation Catalogue (extract)				
	Description			UPE
3 35 1 0 0 0	Road Overpasses			
3 35 1 5 0 0		individual development factor f: f = 1.0 (three spans with high founded abutment) f = 2.0 (one span with standard abutment) i = nominalization factor (see chapter 5.5.2.3)		
3 35 1 5 1 0	span < 10 m		f x i x	2,920 EUR/m²
3 35 1 5 1 0	span 10 - 20 m		f x i x	2,510 EUR/m²
3 35 1 5 1 0	span 20 - 30 m		f x i x	2,150 EUR/m²
3 35 1 5 1 0	**span > 30 m**		**f x i x**	**1,870 EUR/m²**

Table 5-84 - Quantitative estimate

5.5.2.3 Escalation of costs

Unit costs for identified German or international benchmarking elements were transferred to a comparable level of detail and to Imperial units.

Nominalization was done on the basis of FXtop for the years 2016-2017 with i= 1.014.

On the basis of Table 5-84 - Quantitative estimate
on the number of bridge fields, an individual development factor of 1.0 is considered most suitable for comparison between CHSRA (four-field bridge) and DB (three-field bridge).

Bridge Span in m	Unit Cost in EUR/m²	Escalation to 2017 €/m²	Unit cost in USD/m²	Unit cost in USD/sq ft
Factor		**1.01360**	**1.19986**	**10.76392**
< 10	2920	2960	3551	330
10 - 20	2510	2544	3053	284
20 - 30	2150	2179	2615	243
> 30	1870	1895	2274	211

Table 5-85 - DB cost for road overpass – Escalation of cost

5.6 SCC 50 - Communication and Signaling

This section includes the following SCC sub-categories:

- Wayside signaling equipment (50.01)
- Signal power access and distribution (50.02)
- On-board signaling equipment (50.03)
- Traffic control and dispatching systems (50.04)
- Communications (50.05)
- Grade crossing protection (50.06)
- Hazard detectors: dragging equipment, high water, slide, etc. (50.07)
- Station train approach warning system (50.08)

5.6.1 CHSRA Cost Component

5.6.1.1 Qualitative description

The benchmarking is based on the provided list “2018 Baseline Estimate Optimization 7.1 (V2V)” section “2018 Baseline Budget”.

In addition, the submitted list, “Track and systems estimate - 09262017_with prices”, was analyzed and used for the benchmark report.

The documents include Unit Price Elements (UPE) with aggregated volumes, quantities, and unit costs for each section for various SCC sub-categories.

The UPE lists were not available for the entire Valley to Valley network (six sections).

UPEs for communications and signaling are available only for the following sections:

- 3 - Gilroy to Carlucci Road
- 4 - Carlucci Road to Madera Acres
- 6 - Poplar Avenue to Bakersfield

The UPE lists do not reflect all subsystems, i.e. it is not possible at this design stage to find comparable COM and SIG subsystems in the provided UPE lists. In addition, the available level of detail given in the provided information for the different UPE sub-categories varies substantially.

Refer to Appendix 2 “ETO_MGM_Capex Review Assumptions” for a list of all documents provided by CHSRA and used for the benchmark evaluation.

In the business plan, the SCC sub-categories 50.02, 50.03 and 50.08 are not considered as separate subsystems. DB specialists highlighted in the conference call on 25th August 2018 that single figures for SCC 50.02 (signal power) & SCC 50.03 (on-board units signal) could not be found in the provided data. CHSRA representatives noted that the cost for SCC 50.02 is included in SCC 50.01, and that costs for SCC 50.03 are counted in SCC 70 and should be considered in the same way by the ETO (see Appendix 2).

Furthermore, single figures for SCC 50.08 (station warning) are not available yet. CHSRA noted during the conference call on 25th August 2018 that the costs for SCC 50.08 are included in 50.07 and should be considered accordingly by ETO specialists (see Appendix 2 – Assumption List).

Caltrain will manage and technically upgrade Section 1 (San Francisco to San Jose) Caltrain. CHSRA will only fund the required modifications of the existing network to operate it later. In the business plan for 2018, no cost information on SCC 50.1 (train control) or SCC 50.4 (OCC) were provided and are considered to be included in the CHSRA funding.

Another discrepancy was ascertained in regards to different section boundaries and different section lengths, shown in BP 2018 and other provided documents. The differences between section boundaries not only led to shortening or extension of different sections, but also impacted the migration of stations between adjacent sections (see the differences in Sections 1, 2, 3, 4 and 6 in Table 5-86 - Differences between section lengths).

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total V2V
Section length by CHSRA BP 2018 (miles)	48	30	54	37	118	23	310
Section length, based on section boundaries, submitted by CHSRA 9th May 2018 (miles)	44	42	46	35	118	18	303

Table 5-86 - Differences between section lengths

On 9th May 2018, CHSRA provided the PDF file “Valley-to-Valley Section Boundaries (For Estimating Purposes Only)”, which defines the section boards to be used for the benchmark evaluation. This information supersedes the section boards defined in the BP 2018.

During the analysis of CHSRA-provided data, the ETO found a misalignment in the information. Therefore, in the Systems conference call on 25th June 2018, CHSRA instructed the ETO to use the “2018 Baseline Estimate Optimization 7.2.xlsx" file only as reference for the benchmark (see Appendix 2).

Basis for the CHSRA cost estimation by CHSRA

The “2018 Baseline Estimate Optimization 7.1 (V2V)”, section “2018 Baseline Budget” and “Track and systems estimate 09262017_with prices”, documents served as the source for the cost estimates. It is not possible to provide a detailed comparison of all SCCs listed in Business Plan 2018 / V2V sub-SCC at this time.

The highest level of detail regarding the costs estimated by CHSRA was found in the following file: “Track and systems estimate - 09262017_with prices”.

Costs were identified for Sections 2 to 6; for Section 1, the ETO specialists were only able to identify the estimated costs for sub-SCC 50.05 and 50.06 as partial costs for the Caltrain upgrade. CHSRA costs for sub – SCC 50.01, 50.02, 50.03, 50.04, 50.07, and 50.08 are not specified for this section. Caltrain upgrade costs are included in the same methodology as funded by CHSRA.

No.	Element	SCC	Unit	Price per Unit in USD	Remarks
POP50	Train control – route	50.01	USD / RM	537,507	HSH2 2012 converted
POP50	Train control – point end	50.01	USD / point end	873,539	HSH2 2012 converted
POP50	Signaling control system	50.04	pc	1,500,000	
POP50	OCC	50.04	pc	15,000,000	in Fresno
POP50	Equipment shelters “A”-sites	50.01	sq ft	0	in signaling rate
POP50	Equipment shelters “B”-sites	50.01	sq ft	0	in signaling rate
POP50	C-sites	50.01	sq ft	0	in signaling rate
POP50	D-sites	50.01	sq ft	0	in signaling rate
POP50	E-sites	50.01	sq ft	0	in signaling rate
POP50	Workforce protection system	50.01	p. rm	10,000	in right of way
POP50	Station control panels	50.04	pc	250,000	
POP50	Non-tunnel	50.05			UK GSMR average cost £250k per mile
POP50	Tunnel (includes leaky feeder and amplification for ATC, voice COM and first responder VF.)	50.05			Double allowed for in tunnels
POP50	Concentrator	50.05		250,000	Included in COM rate above
POP50	EACS central system	50.05		50,000	EACS workstations - 1 per 100 miles
POP50	PACIS control	50.05		50,000	CIS control cubicles - 1 in each station
POP50	CCTV control and viewing equipment	50.05		50,000	workstations in the OCC
POP50	IIMP	50.05		250,000	workstations in the OCC

POP50	PACIS screens and speakers	50.05		8,000	Screens and speakers in station
POP50	CCTV camera	50.05		5,000	8 per platform plus 10 per station - individual cameras
POP50	Stand-alone radio site (every 2.5 miles)	50.05		-	In communications rate
POP50	EACS	50.05		5,000	locked gates / access points, included in communications rate above

Table 5-87 - Identified CHSRA SCC 50 components

Table 5-88 shows an overview of the signaling cost elements (SCC 50.01 to SCC 50.08) of given section data by "2018 Baseline Estimate Optimization 7.1 (V2V)", section "2018 Baseline Budget" (it includes the COM-SCC 50.05 as well).

Sub-SCC		**Section 1**	**Section 2**	**Section 3**	**Section 4**	**Section 5**	**Section 6**	**Total**
50.01	AT Control	0	65,078,783	76,579,184	47,424,108	186,287,222	39,706,265	415,075,562
50.02	Signal Power	0	0	0	0	0	0	0
50.03	On Board units signal	0	0	0	0	0	0	0
50.04	OCC Basic Unit	0	2,149,786	1,283,411	365,951	26,956,863	364,561	31,120,572
50.05	COM	48,768,858	32,469,647	49,302,541	25,045,408	71,975,606	15,012,835	242,574,895
50.06	Grade crossings	16,438,816	10,767,000	0	0	0	0	27,205,816
50.07	Hazard systems	0	25,421,145	30,030,055	19,978,263	59,000,072	12,004,015	146,433,550
50.08	Station Train approach Warning	0	0	0	0	0	0	0
Total p. Section in USD		**65,207,673**	**135,886,360**	**157,195,192**	**92,813,731**	**344,219,762**	**67,087,677**	**862,410,396**
Total in USD							**862,410,396**	

Sub-SCC		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
50.01	AT Control	0	65,078,783	76,579,184	47,424,108	186,287,222	39,706,265	415,075,562
50.02	Signal Power	0	0	0	0	0	0	0
50.03	On Board units signal	0	0	0	0	0	0	0
Remark		Section 1 is not with all Sub-SCC complete part of BP 2018 / V2V						

Table 5-88 - CHSRA BP 2018 Costs - Signaling and Communications components (SCC 50) in USD

5.6.1.2 Quantitative estimation

For systems, CHSRA informed us that only a 15% design status should be developed before tendering. Therefore, for CHSRA projects only (as CHSRA explained during the systems conference call held 25-June-2018), in accordance with used planning rules at 15% project planning stage for systems, costs have been calculated using total costs of other, already realized projects in addition to the project length. The 15% project stage for systems therefore does not contain any detailed calculations.

The costs indicated for SCC 50 of the Baseline Estimate 2018 Optimization 7.1 (V2V) section “2018 Baseline Budget” are based only on the comparison with the total cost of comparable international projects in relation to the total length of the project section. The budget for signaling and communications was estimated using a parametric approach (cost per mile) only.

In consequence, the more detailed DB cost benchmarking for communications and signaling shown in Chapter 6 is limited in principal to comparing the “Total Costs” of the respective SCC sub-categories in the Business – Plan 2018 / V2V cost calculation. For more detail, please refer to Chapter 5.6.2.

During the cost benchmarking verification, ETO Specialists have neither audited nor confirmed the functionality and/or technical feasibility of the current project solutions, such as:

- Track layout related to ROW, traffic, and environmental impacts
- Section divisions to be reconstructed versus newly built
- Operational opportunities and capacity like the reachable average speed and travel time for HSR and Caltrain trains
- Concurrent operation of high-speed trains with Caltrain and Union Pacific on the same track
- Current at–grade solution of Sections 1 and 2 (San Francisco via San Jose to Gilroy) and the potentially required upgrade of 72 road crossings.

5.6.1.3 Escalation of costs

As already mentioned in chapter 5.6.1.1, the UPE lists do not reflect all subsystems, i.e. it is not possible at this stage to find comparable COM and SIG sub-systems. The list “Track and systems estimate - 09262017_with prices” does not allow an adjustment of values.

The requirements and functions, which are included in the additional document submitted by CHSRA, “TS01Specification 06-30-2017 Industry Draft Version”, made it possible to get a more detailed perception of the technical solutions for signaling and COM systems expected for use by CHSRA.

The ETO cost calculation for benchmark evaluation of SCC 50 and SCC 60 was executed on a schematic track layout of V2V, developed by DB, based on materials submitted by CHSRA (see Appendix 2 – Assumption List). The schematic track layout is divided into six sections and 24 sub-sections, showing such details as section lengths, allocation of stations, platforms, workshops etc. This allows a more detailed allocation and identification of elements on SCC 50. The schematic plan does not contain (because of the absence of existing information) the realization of Section 2 - San Jose to Gilroy - as an at-grade solution with three–track realignment (two tracks electrified for HSR and Caltrain plus one non-electrified track, for UPRR operations).

5.6.2 DB Cost Component

5.6.2.1 Qualitative description

Because their specific technical and cost structures differ, international projects for signaling systems cannot be compared on the basis of their total costs and total project section lengths. Unit costs for identified German or international benchmarking elements have been transferred to a comparable level of detail and to Imperial units.

Signaling and communication costs vary greatly according to:

- Number and layout of railway stations
- Use of different train control systems
- Different conditions of transition to other operators’ networks etc.

The V2V project alignment between San Francisco and Bakersfield was divided into 24 subsections with respect to their operational and technical signaling systems structure, summarized in a concept study. This detailed model was necessary to develop and calculate technically feasible signaling and COM systems, subsystems, and devices in accordance with the schematic track layout for the San Francisco – Bakersfield alignment. It was used to calculate benchmark costs to verify the provided file ”2018 Baseline Estimate Optimization 7.1 (V2V)” section “2018 Baseline Budget”, SCC 50 costs.

For the benchmark cost calculation, actual cost data for the following DB and international projects was used:

- VDE 8.2 High-Speed Line Project
- DB Project “Stuttgart 21”
- Other DB project costs from different actual German and international projects
- The “DB Cost Characteristic Catalogue”, DB Rulebook 808

It is important to note that the benchmark cost calculation does not include any additional local expense factors, e.g. caused by the Buy-America act requirements or any local taxes.

Benchmark costs were calculated for communication systems (SCC 50.05) and signaling system for SCCs 50.01, 50.02, 50.03, 50.04 and 50.06.

5.6.2.2 Quantitative estimation

The benchmark was performed for each sub SCC individually. SCC 50.02 was consolidated after benchmarking.

Wayside signaling equipment (SCC 50.01)

The wayside signaling equipment was calculated for the following elements:

1. Electronic interlocking (station Interlocking with user interface)
2. Electronic interlocking / open track section (satellites)
3. Switches (point machines and point control)
4. Routes to be set by interlocking
5. Track occupancy detection sections (track circuits, part detection)
6. Train control sections (track circuits, part train control)
7. Main aspect signals
8. Preliminary signals
9. Other signals / units
10. Radio Block Centers (RBC); the costs are included in European Train Control Systems (ETCS) sections
11. ETCS sections
12. ETCS transition section
13. Eurobalise
14. Dismantling of existing signaling units
15. Signaling cables on stations and open track sections
16. Cable crossings on open track sections
17. Cable crossings inside stations (additional to COM) for signaling purposes
18. Cable way inside stations (additional to COM) for signaling purposes
19. Additional costs for migration stages (if necessary)

The following benchmark cost elements were used:

No.	Part	Element	SCC	Remark	Unit	Price p. Unit in USD	Source

ATC 1	AT control	Electronic interlocking (station Interlocking with user interface)	50.01	Basic price unit incl. housing, feeding, core hard- and software etc.	EA	999,485	CCC
ATC1a	AT control	Electronic interlocking / open track section (satellite)	50.01	Basic price unit incl. housing, feeding, core hard- and software etc., to be operated from the adjacent station interlocking	EA	499,742	CCC
ATC 2	AT control	Switches, point machines & controller	50.01	Point machines & controller	EA	71,992	CCC
ATC 3	AT control	Routes to be set in interlocking	50.01		EA	86,390	CCC
ATC 4	AT control	Track occupancy detection sections - audio – frequency track circuit	50.01	Excl. ETCS L2, also with respect to higher costs of track chains compared to axle counters - part detection only	EA	17,818	CCC
ATC 5	AT control	Train control sections audio – frequency track circuit	50.01	Excl. ETC L2, also with respect to track chains compared to point – addicted control systems (a.ex. PZB 90), part frequency generation (train control) only	EA	35,636	CCC
ATC 6	AT control	Main aspect signals	50.01		EA	46,315	CCC
ATC 7	AT control	Preliminary signals	50,01		EA	37,196	CCC
ATC 8	AT control	Other signals / units	50.01	Frogs, etc.	EA	23,997	CCC
ETCS 1	ETCS L2	Radio block Centers	50.01	Included in ETSC L2 (excluding GSM-R)	EA	0	Different projects of DB Netz/DB KT (Medium),

ETCS 2	ETCS L2	ETCS sections	50.01	Including station track sections	per route mile	307,027	CCC
ETCS 3	ETCS L2	ETCS transition section	50.01	Additional costs to ETCS 2 for additional transition sections	EA	312,181	CCC
ETCS 4	ETCS L2	Balise	50.01		EA	3,000	CCC
DISM		Dismantling of existing signaling units	50.01	Dismantling of units without any temporary adaption	EA	18,883	CCC
Cable Sig	Cablework	Signaling cables on stations	50.01	Per interlocking, without cableway construction works	EA	590,096	act. Projects DB Netz
Cable Sig	Cableway	Cable crossings open track sections	50.01	Two crossing per route mile	per m	634	Stuttgart 21 (DB KT 2016) incl. Shafts
Cable Sig	Cableway	Cable crossings stations (additional to COM)	50.01	Five crossings per route mile	per m	815	CCC
Cable Sig	Cableway	Cable way stations (additional to COM)	50.01	Two cableways on both sides in addition to COM	per m	226	incl. Ducts and Shafts

Table 5-89 - DB cost for wayside signaling equipment

Signal power access and distribution (SCC 50.02)

The signal power access and distribution equipment is calculated for the following elements:

- Feeding of station interlockings
- Feeding of open track section interlockings
- Feeding of open track section interlockings in case of necessity with additional transformer station
- Feeding of OCC and Sub-OCC

The power supply and feeding network for stations and open track sections was not calculated on the signaling sub-SCC because of the multi-purpose nature of such a network. The calculation and benchmarking should be included in the power supply category (SCC 60).

The following benchmark costs were used:

No.	Part	Element	SCC	Unit	Price per Unit in USD	Source
SP 1	Signal power	Feeding of station interlockings	50.02	Flat basis	101,988	DB Netz
SP2	Signal power	Feeding of open track section interlockings	50.02	Flat basis	47,994	DB Netz
SP2a	Signal power	Feeding of open track section interlockings in case of necessity with additional transformer station	50.02	Flat basis	89,990	DB Netz
SP3	Signal power	Feeding of OCC and sub-OCC	50.02	Flat basis	203,976	DB Netz

Table 5-90 – DB cost for signal power access and distribution

The documents "2018 Baseline Estimate Optimization 7.1 (V2V)" section "2018 Baseline Budget" and "Track and systems estimate - 09262017_with prices" do not contain information for SCC 50.02.

On-Board Units – signaling part (SCC 50.03)

On–board units (signaling part) are priced for the following elements:

- On-board units for Caltrain / UPC RR (non-ETCS, class-B system)
- On-board units for high-speed trains (CHSRA), containing both ETCS and common systems

For SCC 50.03, it was difficult to give clear benchmark data because the costs of such systems depend on the level of system integration between signaling systems and rolling stock systems. It is also influenced by the number of systems to be delivered.

In fact, the number of systems currently projected for delivery to CHSRA is rather small, and the supplier of the rolling stock is unknown. Consequently, it is unknown if there will be additional costs for system development or integration.

The SCC 50.03 costs are based on cost assumptions known from the difference in price of multi-system locomotives, which will be equipped with different train control systems.

The named on–board units contain only the signaling part of the train control system, such as:

- The interface between rolling stock and track based train control system equipment
- The interface between rolling stock and radio–based train control system equipment,
- The interface between train control units (outside the train) and rolling stock control units (inside the train)

This pricing also does not contain any trainset cab radio units and interfaces, which are usually part of the operational radio system. These components are considered in COM – Benchmarking (SSC 50.05).

The following benchmark costs were used:

No.	Part	Element	SCC	Remark	Unit	Price per Unit in USD	Source
OBU 1	On-board units	On-board units for Caltrain / UPC RR (non-ETCS)	50.03	30 EA (Based on track chains)	EA	359,958	Assumption
OBU 2	On-board units	On-board units for high-speed trains (CHSRA)	50.03	30 EA on sections No. 1 to No. 6 (based both on track chains and ETCS)	EA	786,794	Assumption

Table 5-91 – DB cost for On-Board Units – Signaling part

The documents "2018 Baseline Estimate Optimization 7.1 (V2V)" section "2018 Baseline Budget" and "Track and systems estimate - 09262017_with prices" do not contain information for SCC 50.03.

<u>Traffic control and dispatching systems (SCC 50.04)</u>

Traffic control and dispatching system costs were calculated for the following elements:

- Partial costs of named interlocking to SUB OCC extension
- Percentage of named interlocking to OCC extension
- Dispositive systems on OCC
- SUB OCC basic unit
- OCC basic unit
- Installation and Integration of separate (see sub SCC 50.07) hazard warning systems into OCC traffic control system (only signaling part – automatic system reaction on hazard information)
- Installation and Integration of public address customer information system (PACIS) into OCC traffic control system, i.e. it provides traffic information from the OCC to PACIS (position of train, estimated times of arrivals and departures, etc.)

The following benchmark cost elements were used:

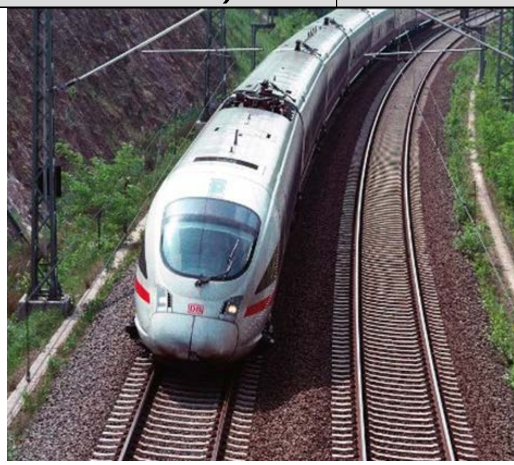
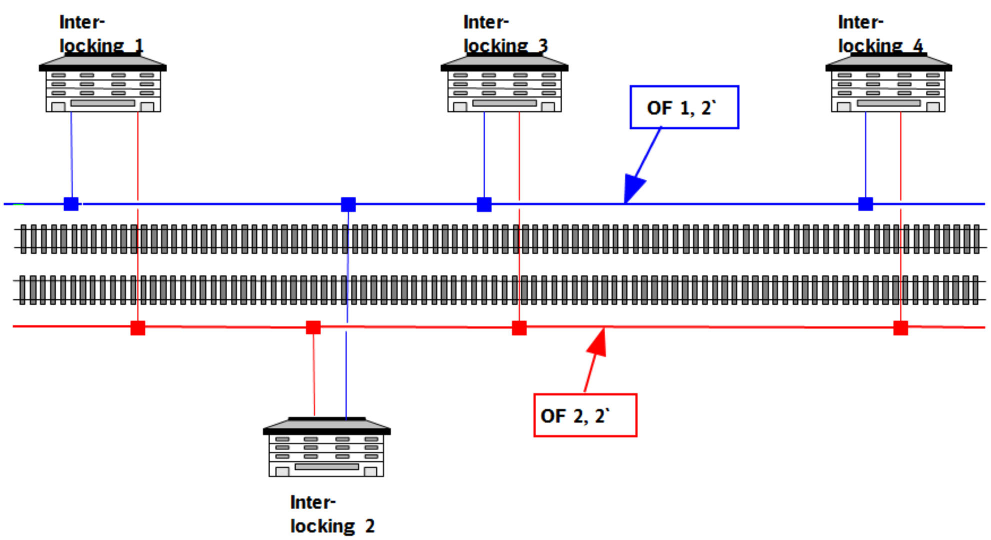
No.	Part	Element	SCC	Remark	Unit	Price p. Unit in USD	Source
OCC 1	Traffic control & dispatching systems	Partial costs of named interlocking to SUB OCC extension	50.04		Flat per interlocking	196,777	CCC
OCC 2	Traffic control & dispatching systems	Percentage of named interlocking to OCC extension	50.04		Flat per interlocking	89,990	DB Netz
OCC 3	Traffic control & dispatching systems	Dispositive systems on OCC	50.04	Comparable to ZN, ZL	Flat per interlocking	437,949	CCC
OCC 4	Traffic control & dispatching systems	SUB OCC basic unit	50.04	Basic price unit incl. housing, feeding, core Hard- and software etc.	EA	2,950,479	DB Netz
OCC 5	Traffic control & dispatching systems	OCC basic unit	50.04	Basic price unit incl. housing, feeding, Core Hard- and software etc.	EA	14,752,395	As given by CHSRA
OCC 6	Traffic control & dispatching systems	Implementation of hazard warning systems into OCC traffic control system	50.04	Source COM, effect = train stop or speed reduction by ATC system	EA	41,995	Comparable systems
OCC 7	Traffic control & dispatching systems	Implementation of passenger information systems into OCC traffic control system	50.04	Source COM, effect = warning by acoustic / visual systems, by interlocking	EA	29,997	Comparable systems (active train tracking)

Table 5-92 – DB cost for traffic control and dispatching systems

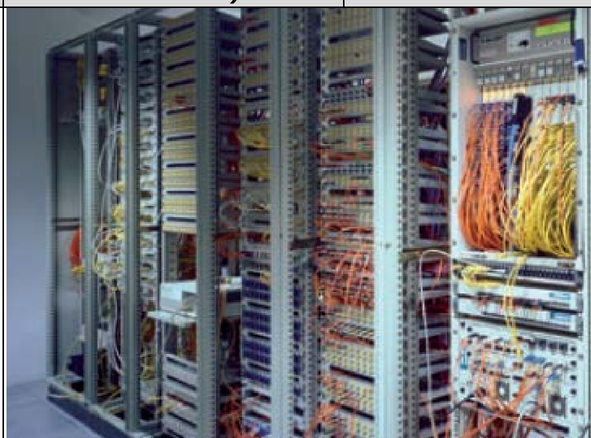
Communications (SCC 50.05)

For benchmarking purposes, the description of the following COM sub-systems deviates from the terminology used in the document "TS01 Specification 06-30-2017 INDUSTRY DRAFT Version". As currently understood, the following COM sub-systems are considered in SCC 50.05 and used for benchmarking:

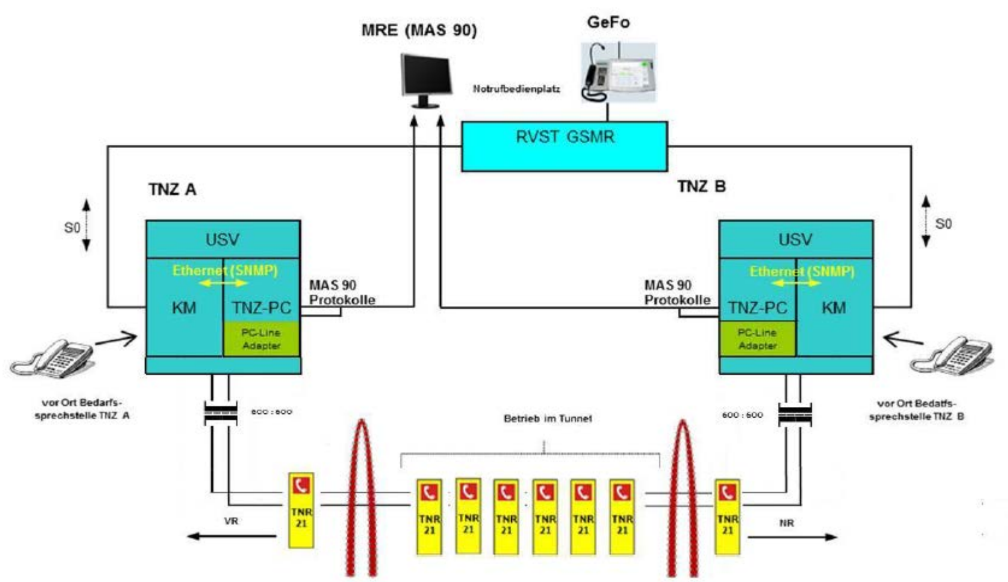
No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
1	Cable trough system	n/a	Part of communication network
1.1	Cable trough system (part of communication network)	DB AG benchmark value DB - Cost Characteristic Catalogue: USD 76,431.18 / km	Selected shafts, track crossings and grade crossings (for level crossings). Partly included in the SIG-COM costs; cable ducts - to be established on both sides of the tracks system-wide along at-grade sections, including all required shafts for track crossings / at- grade crossings (level crossings) that are part of the track & systems contractor package (COM)
1.2	Cable trough covers (part of communication network)	German projects / average price USD 47.99 / m	Within tunnels and elevated sections - part of the civil works (tunnel) contractor(s) package except the cable duct covers, which must be considered in the track & systems contractor package (part of COM)
	  **Cable trough for COM/ SIG** Source: DB E&C GmbH - source: DB E&C GmbH		

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
	 Source: DB AG		 Source: DB E&C GmbH
2	Optical fiber cable system OFC 72 ft / SM	Germany / Stuttgart 21 design phase USD 21.60 / m	Part of communication network
	 **Schematic COM-cable layout - Source: DB AG**		
3	Transmission system (backbone network) (part of communication cetwork) German and international projects / Mixed unit prices		

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
3.1	Ethernet/ TCP/IP Backbome network network management system	USD 179,979.22 / package price	Redundant system design central sites (ICC/ECC)
3.2	active: 10GB node	USD 179,979.22 / unit	Central sites (ICC/ECC)
3.3	active: 1GB node	USD 8,399,03 / unit	Every site including central sites, PoE
3.4	active: WLAN	USD 5,999.31 / unit	Per station, ICC/ECC, depot etc.
3.5	LAN switch	USD 5,399.38 / unit	
3.6	LAN router	USD 10,198.83 / unit	
3.7	Passive: inhouse network cables and outlets: station	USD 41,995.15 / LS	5 km CAT6 or OF fiber cable (5 EUR/m), ca 50 sockets (100 EUR/EA) + rack/ patchfields
3.8	Passive: inhouse network cables and outlets: ESTW/ shelter	USD 10,798.76 / LS	1 km CAT6 cable (5 EUR/m), ca 10 sockets (100 EUR/EA) + rack/ patchfields
3.9	Passive: inhouse network cables and outlets: station	USD 179,979.22 / LS	20 km CAT6 or OF fiber cable (5 EUR/m), ca 300 sockets (100 EUR/EA)+ rack/ patchfields
3.10	Racks, UPS	USD 399.03 / LS	In stations, COM-rooms
3.11	Racks, UPS	USD 23,997.23 / LS	In depot
3.12	Racks, UPS	USD 59,993.07 / LS	In ICC/ECC
3.13	COM room facilities	USD 4,799.45 / LS	Room furniture, cable supports etc.

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
	 source: DB AG rack equipment		 **Typical radio antenna mast**
4	Radio / Operations Radio System (ORS) Automatic Train Control Radio System (ATCRS);		
4.1	Train radio system (GSM-R)	DB AG Benchmark value DB - Cost Characteristic Catalogue: USD 190,777.98 / km	Only COM part
4.2	Tunnel radio Public Safety Trench and Tunnel Radio System (PSTTRS)	Germany / Stuttgart 21 design phase (2016)	
4.2.1	Repeater	USD 27,716.80 / unit	
4.2.2	Leaky cable	USD 47.99 / m	
4.2.3	Feeder cable	USD 9.60 / m	
4.2.4	Antenna	USD 959.89 / unit	
4.3	On board units	Cost estimation Germany USD 107,987.53 / train	2 cab units / voice call / per train Not part of track & systems contractors package (see Appendix 2 – Assumption List)
5	Telephone System (part of Telephone and Intercom Systems TIS)		

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
5.1	Operational & administrative telephone systems (VoIP)	Germany / Stuttgart 21 design phase (2016) Mixed unit prices	
5.1.1	Router	USD 23,997.23 / unit	Redundant / E1 interface provider: voice router, 19 in rack, UPS etc.
5.1.2	Server	USD 59,993.07 / unit	Redundant call manager: 19 in server, UPS
5.1.3	Management	USD 11,998.62 / LS	
5.1.4	Gateways	USD 3,599.58 / unit	
5.1.5	Phones	USD 599.93 / unit	IP Phones / PoE
5.2	Emergency call systems	Germany / Stuttgart 21 design phase (2016) Mixed unit prices	At-grade system and elevated sections system-wide
5.2.1	Central workplace	USD 17,997.92 / package price	ICC/ ECC
5.2.2	Phone unit / column	USD 3,239.63 / unit	Track site (at-grade, elevated)
5.3	Tunnel emergency call system	Germany / Stuttgart 21 design phase (2016) Mixed unit prices	Only in the section Gilroy to Carlucci (two tunnels)
5.3.1	Central unit / work station	USD 29,996.53 / package price	On both sides of the tunnel
5.3.2	Phone unit / columns	USD 3,239.63 / unit	

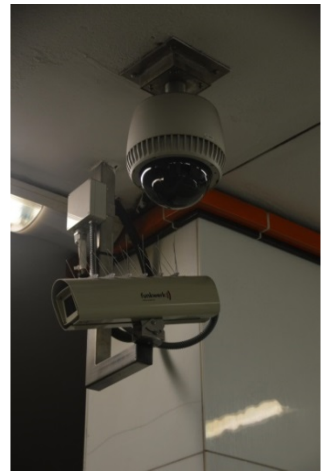
No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
	 **Tunnel emergency call system - principle system overview - Source: DB AG**		
6	Public Address Customer Information System (PACIS)		

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
6.1	Public address system	Germany / Stuttgart 21 design phase (2016) Mixed unit prices	Sections 1 has 24 existing Caltrain stations with warning system Section 2 will have 5 new Caltrain stations and 2 CHSR Stations. The system configuration is based on the maximal platform length (1.400 ft) The onboard PA system will be supplied by Trainset Supplier.
6.1.1	Local server with amplifier and loudspeakers, via LAN, 19 in rack	CHSRA station USD 65,992.38 / station Caltrain station USD 35,995.84 / station	1 speaker, 1 amplifier je platform; 40 loudspeakers per platform (CHSRA (platform length 1.400ft / 30 per platform edge)
6.1.2	PA central systems PA server	USD 59,993.07 / unit	ICC / ECC
6.1.3	PA central systems PA interface to signaling	USD 95,988.91 / unit	ICC / ECC
6.1.4	PA central systems PA man agent workstation	USD 59,993.07 / unit	ICC / ECC
6.1.5	PA workshops & depots	USD 59,993.07 / LS	
6.1.6	PA workshops & depots	USD 5,999.31 / LS	
6.2	Passenger information display system	German and international Projects Mixed unit prices	The trainset supplier will provide the onboard PIS system trainset. (see Appendix 2 – Assumption List)
6.2.1	Central units server, 19 in rack, UPS	USD 59,993.07 / LS	ICC / ECC
6.2.2	Central units interface to signaling	USD 119,986.15 / LS	ICC / ECC
6.2.3	Central units interface to customer (internet, GSM, mail, etc.)	USD 131,984.76 / LS	ICC / ECC
6.2.4	Central units per management work station	USD 59,993.07 / LS	ICC/ECC
6.2.5	PIS station train information display	USD 41,995.15 / unit	CHSRA platform edge 4 x / inside St. 4x Caltrain →platform 2 x / inside station 2x
6.2.6	PIS station	USD 11,998.61 / unit	Displays / boards on platforms with cable, mounting, PS, and grounding
6.2.7	PIS station terminals (service points)	USD 17,997.92 / unit	PC, monitor, printer

<table>
<tr><th>No.</th><th>COM Subsystem
(term used in CHSRA document)</th><th>Value for Benchmarking</th><th>Remarks</th></tr>
<tr><td></td><td colspan="3">

Train indication display and clock – typical platform arrangement
Source: DB E&C GmbH</td></tr>
<tr><td>7</td><td>Time distribution & clock system
(Network timing system)</td><td>Germany / Stuttgart 21 design phase
and international projects
Mixed unit prices</td><td></td></tr>
<tr><td>7.1</td><td>Central unit for COM
DCF receiver etc.
central clock, GPS based</td><td>USD 23,997.23 / LS</td><td>ICC / ECC</td></tr>
<tr><td>7.2</td><td>Central unit for SIG
DCF receiver etc.
central clock, GPS based</td><td>USD 17,997.92 / LS</td><td>ICC / ECC</td></tr>
<tr><td>7.3</td><td>NTP server</td><td>USD 11,998.61 / unit</td><td>ICC / ECC</td></tr>
<tr><td>7.5</td><td>Clocks</td><td>USD 239.97 / unit</td><td>30 x in ICC/ECC, ESTW etc.
Depots 20 x /
Building for technical equipment 3 x
Rooms for mechanical equipment in stations 5x</td></tr>
<tr><td>8</td><td colspan="3">Security management system
(part of Physical Security Information Management System – PSIMS)</td></tr>
</table>

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
8.1	Close Circuit Television (CCTV)	Germany / Stuttgart 21 design phase and international projects Mixed unit prices	Others will supply the CCTV system within stations (excluding platforms) (not part of track and systems contract) The rolling stock supplier will provide the onboard CCTV system in trainset.
8.1.1	Central system server, data storage	USD 119,986.15 / LS	ICC / ECC
8.1.2	Central system CCTV management workplace, monitor wall	USD 119,986.15 / LS	ICC / ECC
8.1.3	Central system Interface to third parties (security, police etc.)	USD 59,993.07 / unit	ICC / ECC
8.1.4	IP cameras platforms, tunnel cross passages, fences etc.	USD 2,999.65 / unit	CHSR station cameras 25 x (platform. edge including passenger/ freight elevator 6 x) Caltrain station cameras 15x (platform. edge including passenger/ freight elevator 4 x)
8.1.5	IP special cameras	USD 7,199.17 / unit	Tunnel access etc.
8.1.6	CCTV workstation (station buildings)	USD 29,996.54/ unit	CHSR local staff in station 1x CHSR depot 1x Tunnel control center 1x Caltrain local staff in station 1x

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
	  **Typical control center arrangement - Source: DB AG and Typical CCTV camera arrangement** Source: DB E&C GmbH		
8.2	Electronic Access Control Systems (EACS)	Germany / Stuttgart 21 design phase (2016) and international projects Mixed unit prices	
8.2.1	Central system server, data storage	USD 35,995.85 / unit	ICC / ECC
8.2.3	Access control / intrusion detection system	USD 7,199.17 / LS	TP; COM, slg-buildings
8.2.4	Access control / intrusion detection	USD 1,799.79 / LS	Tunnel cross passages (800 ft/ 243 m) / linked with OCC and tunnel control room
8.2.5	Access control / intrusion detection	USD 1199.86 / LS	three-mile interval on CCTV fences/ access/egress points / doors/ sensors, keys, cabling
8.2.6	Tunnel Access Control	USD 14,398.38/ LS	Laser scanner + mast / 1 x tunnel portal
8.3	Fire alarm / fire and smoke detection systems	Germany / Stuttgart 21 design phase (2016) and international projects Mixed unit prices	
8.3.1	Central system server, data storage	USD 119,986.15 / package price	ICC / ECC

No.	COM Subsystem *(term used in CHSRA document)*	Value for Benchmarking	Remarks
8.3.2	Fire alarm / detection system	USD 11,998.62 / package price	Small technical buildings TP; COM-buildings
8.3.3	Fire alarm / detection system	USD 63,592.66 / package price	Larger building for technical equipment / interlocking radio Building for signaling equipment 1x, depot building 1x
8.3.4	Fire alarm / detection system	USD 11,998.62/ package price	Tunnel cross passages
9	Level crossing monitoring and detection system	DB AG benchmark value Cost Characteristics Catalogue USD 101,988.23 / unit	Not part of COM/SIG (see Appendix 2 – Assumption List)
10	Integrated Information Management Platform (IIMP) Rail Infrastructure Information Management/ (RIIM)	Estimated price without reference USD 299,965.32 / package price	

Table 5-93 – DB cost for communications

Grade crossing protection (SCC 50.06)

Grade crossing protection systems and necessary road improvements were calculated for the following elements:

- Grade crossing signaling unit for two or more tracks
- Additional road signaling for up to four directions

Additional costs for road construction to configure the road to the changes of grade crossings (consequently, the additional costs for road construction and road signaling systems were based on volumetric assumptions for such work). Unit prices are based on realized DB at-grade crossing projects in Germany as well on the DB Cost Characteristic Catalogue.

These costs were not included in SCC 50.06, because CHSRA stated during the systems conference call on 25th June 2018 (MoM - Topic 6) that the estimated costs do not consider costs for road traffic modifications (civil and systems related). These costs were acccounted for in SCC 40, Civil Works.

The following benchmark cost elements were used:

No.	Part	Element	SCC	Remark	Unit	Price per unit	Source

						(USD)	
LC 1	Grade crossing	Grade crossing signaling unit two or more tracks	50.06	Incl. barriers, signals, control, switching, LC-containment, feeding etc.	EA	576,533	CCC (grade crossing unified by sections)
LC 5	Grade crossing	Additional road signaling in up to 4 directions	50.06		EA	0	DB Project LE - LBOR
LC 6	Grade crossing	Additional costs for road construction	50.06		EA	0	DB Project LE - LBOR

Table 5-94 – DB cost for grade crossing protection

For at-grade crossings, more detailed cost data is available from CHSRA. However, a final technical solution has not been found for the replacement of the existing 72 at-grade crossings in Sections 1 and 2. A more detailed analysis is therefore impossible.

During the systems conference call on 25th June 2018 (see MoM topic 8), CHSRA noted that costs for Train Control Systems (TCS) and for upgrading the signaling and communications systems at grade crossings are not considered in SCC 50. The costs were accounted for in SCC 40 (Site Work, Right of Way, Land, Improvements). In accordance, the benchmark price for one grade crossing in SCC 50.06 was reduced to USD 300,000. The remaining USD 354,499 should be considered in SCC 40, but could not be verified by the ETO.

Hazard detectors: dragging equipment, high water, slide, etc. (SCC 50.07)

Because available project data is lacking, no benchmarking could be performed for this sub-category.

Because of the absence of technical project data on SCC 50.07 from CHSRA, the BP 2018/V2V data from SCC 50.07 has been used without change. in accordance with the settings of Systems Conference Call 25-June-2018-06-25. In this case, therefore, the benchmark value is equal to the BP 2018/V2V – value.

Station train approach warning systems (SCC 50.08)

The costs for station train approach warning systems were not benchmarked in this chapter, because they were already accounted for in SCC 50.04 (Traffic control and dispatching systems).

Additional processing of supplied cost data, and its use for station train approach warning, was considered in the COM – systems (PACIS etc.).

The documents “2018 Baseline Estimate Optimization 7.1 (V2V)” section “2018 Baseline Budget” and “Track and systems estimate – 09262017 with prices” did not contain costs details for SCC 50.08.

During the systems conference call on 25th June 2018 DB noted that single cost data for SCC 50.08 (station warning) was not provided. CHSRA advised ETO to incorporate costs for SCC 50.08 in SCC 50.07. ETO could not verify or validate this information.

5.6.2.3 Escalation of costs

An adjustment of costs from ETO was necessary to allow benchmarking. Nevertheless, for signal and communication systems, it has been observed for some time that the advancement of systems / system components has led to comparatively high-quality equipment. These advanced systems have additional and more complex features, while prices have remained fairly constant or have fallen.

ETO used the following steps to escalate the costs for benchmarking:

1. Building a model of lines, stations, SIG, and COM units on all sections based on project documents submitted by CHSRA

2. Calculate all necessary SIG and COM costs based on information described in chapter 6.2.1. The ETO costs include design-related costs as part of the designer-builder scope, such as geodetic surveying, geologic and hydrologic investigations, planning, project audits, commissioning expenses, and fees (these are not included in SCC 80 Professional Services). All costs calculated by ETO for sub-SCC 50.01 to 50.05 are inflation adjusted (excluding SCC 50.07 and 50.08). For SCC 50.07 and 50.08, no inflation factor was applied per Systems Conference Call on 25th June 2018. In addition, costs for SCC 50.07 - Hazard systems are estimated with an additional 12% planning cost on contractor's service as, discussed and agreed during the Systems Conference Call. This adjustment is necessary because they are not included in SCC 80 Professional Services.

The adjusted ETO benchmarking cost is shown in Table 5-95. Sub-SCC costs for Section 1 were reduced in accordance with the cost division between the CHSRA and Caltrain.

Sub-SCC		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
50.01	AT Control	0	88,640,622	29,734,617	21,482,657	96,251,053	36,453,313	272,562,262
50.02	Signal Power	0	892,189	524,416	265,614	1,900,159	272,424	3,854,803
50.03	On Board units signal	0	5,109,658	5,929,129	4,511,294	15,209,506	2,320,094	33,079,681
50.04	OCC Basic Unit	0	7,871,721	3,617,794	1,514,678	24,630,009	5,158,376	42,792,577
50.05	COM	38,395,939	36,500,919	44,088,260	26,233,271	86,195,980	15,075,875	246,490,245
50.06	Grade crossings	26,179,968	20,943,975	0	0	0	0	47,123,944
50.07	Hazard systems (imported from BP 2018))	0	25,421,145	30,030,055	19,978,263	59,000,072	12,004,015	146,433,550
50.08	Station Train Approach Warning (already counted in chapter 50,4)	0	0	0	0	0	0	0
Total per Section USD		**64,575,908**	**185,380,229**	**113,924,271**	**73,985,778**	**283,186,779**	**71,284,097**	**792,337,062**
Total								**792,337,062**

Table 5-95 - Result ETO benchmark signaling and communications components for SCC 50 without Sub-SCC 50.01, 50.02, 50.03, 50.04 of Section 1 (to be funded by Caltrain) in USD

3. Adjustment of costs per Systems Conference Call on 25th June 2018 to allow benchmarking:

- Move ETO costs for sub-SCC 50.02 “Signal Power” to sub-SCC 50.01 “ATO”,
- Exclude costs for sub-SCC 50.03 “On Board Units” (already included in SCC 70 “Rolling Stock”) as shown in Table 5-96:

Sub - SCC	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total

50.03	On Board units signal	0	5,109,658	5,929,129	4,511,294	15,209,506	2,320,094	**33,079,681**
Total in USD								**33,079,681**

Table 5-96 - Value of Sub-Chapter 50.03, already allocated at SCC 70 "Rolling Stock" in USD

This results in the following adjusted ETO benchmarking costs for SCC 50:

Sub - SCC		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
50.01	AT Control	0	89,532,811	30,259,033	21,748,271	98,151,212	36,725,737	276,417,065
50.02	Signal Power	0	0	0	0	0	0	0
50.03	On Board units signal	0	0	0	0	0	0	0
50.04	OCC Basic Unit	0	7,871,721	3,617,794	1,514,678	24,630,009	5,158,376	42,792,577
50.05	COM	38,395,939	36,500,919	44,088,260	26,233,271	86,195,980	15,075,875	246,490,245
50.06	Grade crossings	26,179,968	20,943,975	0	0	0	0	47,123,944
50.07	Hazard systems	0	25,421,145	30,030,055	19,978,263	59,000,072	12,004,015	146,433,550
50.08	Station Train Approach Warning	0	0	0	0	0	0	0
Total per section in USD		**64,575,908**	**180,270,572**	**107,995,142**	**69,474,484**	**267,977,273**	**68,964,003**	**759,257,381**
Total in USD								**759,257,381**

Table 5-97 - Adjusted ETO benchmarking costs for SCC 50 - Signaling & Communications (aligned to BP 2018 Cost Structure) in USD

5.7 SCC 60 Traction Electrification Systems

This section includes the following SCC sub-categories:

- Traction power transmission HV (60.01)
- Traction power supply substations (60.02)
- Traction power distribution catenary (60.03)
- Traction power control (60.04)

5.7.1 CHSRA Cost Component

5.7.1.1 Qualitative description

The provided list “2018 Baseline Estimate Optimization 7.2 (V2V)” section “2018 Baseline Budget” forms the basis for this benchmarking.

The UPE lists were not available for the entire Valley to Valley line (6 sections). UPEs for Traction Electrification Systems (TES) are available for sections:

- 2 – San Jose to Gilroy
- 3 - Gilroy to Carlucci Road
- 4 - Carlucci Road to Madera Acres
- 5 – Madera Acres to Popular Ave.
- 6 - Poplar Avenue to Bakersfield F St. Station

The UPE-lists do not reflect all subsystems in Section 1 “San Francisco to San Jose”.

Refer to Appendix 2 “ETO_MGM_Capex Review Assumptions” for a complete list of documents submitted by CHSRA that were reviewed and used for benchmarking.

Another discrepancy was discovered regarding different section boundaries and different section lengths, shown in BP 2018 and other provided documents. The differences between section boundaries led not only to the shortening or extension of different sections, but also impacted the migration of stations between adjacent sections (see the differences for Sections 1, 2, 3 in the below table).

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total V2V
Section length by CHSRA BP 2018 (mile)	48	30	54	37	118	23	310
Section length, based on section boundaries, submitted by CHSRA 9th May 2018 (mile)	44	42	46	35	118	18	303

Table 5-98 - Differences between section lengths

On 9th May 2018, CHSRA provided the PDF file "Valley-to-Valley Section Boundaries - (For Estimating Purposes only)", which defines the section boards to be used for the benchmark evaluation. This information supersedes the section boards defined in the BP 2018.

5.7.1.2 Quantitative estimation

Therefore, the costs indicated in SCC 60 of the Baseline Estimate 2018 Optimization 7.2 (V2V) section "2018 Baseline Budget" are based only on the comparison with the total cost of comparable international projects in relation to the total length of the project section. The budget estimate for SCC 60 was done on a parametric (cost per mile) approach only.

In consequence, DB's benchmarking of costs for traction electrification systems will be in principal limited to the comparison of the "Total Costs" of the respective SCC sub-categories of the Business Plan 2018 / V2V cost calculation.

During the cost benchmarking verification, ETO Specialists have neither audited nor confirmed the functionality and/or technical feasibility of the current project solutions, such as:

- Track layout related to ROW, traffic, and environmental impacts
- Section divisions to be reconstructed versus newly built

The data from the Business Plan 2018 / V2V SCC 60 for Traction electrification systems is shown in Table 5-99.

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total 2 to 6
60.01	Traction power transmission: High voltage	n.a.	76,800,000	87,278,744	27,102,376	201,391,562	0	392,572,682
60.02	Traction power supply: Substations	n.a.	73,228,839	93,090,273	64,417,488	240,398,465	13,618,508	484,753,573
60.03	Traction power distribution: Catenary and third rail	n.a.	80,957,204	120,343,526	83,409,344	249,361,296	39,144,521	573,215,891
60.04	Traction power control	n.a.	484,161	560,079	479,063	1,591,538	0	3,114,841
Total per Section		n.a.	231,470,204	301,272,622	175,408,270	692,742,861	52,763,029	1,453,656,986
Total sec. 2 to 6			**1,453,656,986**					

Table 5-99 - SCC 60 - Traction electrification systems as provided in Business Plan 2018 / V2V

In the conference call on 25th June 2018 it was agreed to use low-speed-catenary in the maintenance sites.

The ETO Specialists could not verify the costs for section 1. In Section 6, costs for sub SCC 60.01 and 60.04 are estimated with USD 0. ETO Specialists were not able to verify the reason why these costs do not occur in Section 6.

5.7.1.3 Escalation of costs

As mentioned in chapter 5.6.1.1, the UPE lists do not reflect all subsystems, so it is not possible at this stage to find the comparable SCC 60. The submitted list “Track and Systems Estimate - 09262017_with prices” does not allow an adjustment of values. In addition, the provided requirements and functions, which are included in the document “TS01 Specification 06-30-2017 INDUSTRY DRAFT Version”, were accepted as-is and not adjusted further.

To undertake a reasonable benchmark cost calculation, allowing the use of DB cost components for SCC 60, ETO Specialists developed a schematic (track layout) based on documents submitted by CHSRA. Because a detailed site plan is not available, the developed schematic track layout does not yet include the realization of Section 2 - San Jose to Gilroy - as an at-grade solution and does not contain the three–track realignment (two tracks electrified for HSR and Caltrain plus one non-electrified track for UPRR operations). The cost calculation for benchmark evaluation of SCC 60 was executed based on the above named schematic situational plan (schematic track layout). Furthermore, the ETO reference project considers the catenary and traction power control systems as one cost unit. Therefore SCC 60.03 and SCC 60.04 are merged in the table below.

The adjusted CHSRA Business Plan Cost estimate looks as follows:

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total 2 to 6
60.01	Traction power transmission: High voltage	0	76,800,000	87,278,744	27,102,376	201,391,562	0	392,572,682
60.02	Traction power supply: Substations	0	73,228,839	93,090,273	64,417,488	240,398,465	13,618,508	484,753,573
60.03 + 60.04	Traction power distribution: Catenary and Traction power control	0	81,441,365	120,903,605	83,888,407	250,952,834	39,144,521	576,330,732
Total per Section		0	231,470,204	301,272,622	175,408,270	692,742,861	52,763,029	1,453,656,986
Total sec. 2 to 6							**1,453,656,986**	

Table 5-100 - Adjusted CHSRA Business Plan Cost estimation for SCC 60 in USD

5.7.2 DB Cost Component

5.7.2.1 Qualitative description

The specific technical and cost structure for different international TES projects cannot be compared on the basis of their total costs and total project section lengths. Unit costs for identified German or international benchmarking elements have been transferred to a comparable level of detail and to Imperial units.

Costs vary greatly according to:

- Number and layout of railway stations
- The amount of building phases
- Use of different pole and foundation systems because of local differences in available space for the TES infrastructure and types sub surface conditions

For the benchmark costs calculation, CCC and actual cost data for the following DB projects was used:

Sub-SCC 60.03 & 60.04:

- VDE 8.2 high-speed line project
- NBS Nuremberg – Ingolstadt (newly built HSR line including OCS installation)

Sub-SCC 60.02 because AT-TPS was used

- ABS 48 (upgrading of the line from Munich to Lindau)
- ABS Oldenburg – Wilhelmshaven (upgrading of the line)

It is important to note that the benchmark cost calculation does not include any additional local expense factors, e.g. caused by the Buy America Act requirements or any local taxes.

Benchmark costs were calculated for traction electrification systems for SCCs 60.02, 60.03 and 60.04.

5.7.2.2 Quantitative estimation

Each sub-SCC was benchmarked individually. SCC 60.03 and SCC 60.04 are given as one cost amount and listed in SCC 60.03.

Traction power transmission: High voltage (SCC 60.01)

The values for SCC 60.01 section 2 to 5 cannot be calculated because of missing information. The ETO Specialists were not able to list the approximate length of the interconnection between the next interconnection point and the public energy provider's grids for each Traction Power Supply (TPS) with 2x60MVA. Detailed information about the public energy provider's type and configuration of the 115kV/230kV grid is currently unavailable. The ETO Specialists were informed that the costs for SCC 60.01 must be calculated by the future public energy provider. The price for section 1 was set as a lump sum according to the values of sections 2 to 5. During site visits to section 1, it was noted that the technical conditions deviate from the other section. Section 1 is located in an urban area, which requires shorter interconnections between TPS and the public energy provider's grids.

Therefore, the ETO Specialists decided to use the values given in the Business Plan 2018 / V2V SCC 60.

Traction power supply: Substations (SCC 60.02)

The traction power supply equipment has been calculated for the following elements:

- TPS 2x 60 MVA transformer 115kV/230kV 60Hz --> 25kV 60Hz
- SWS 2x 20 MVA autotransformer 25kV 60Hz and phase break
- PS 1x 20 MVA autotransformer 25kV 60Hz

ETO calculates that for the reviewed sections to feed the 303 mi, the following are needed:

- 10 x TPS
- 10 x SWS
- 41 x PS

This configuration causes a price of around USD 2.1 Mil /mile

The following benchmark costs were used:

No.	Part	Element	SCC	Remarks	Unit	Price per Unit [Mil USD]	Source
1	TPS	TPS (2 x 60MVA for 115/230kV to 2x25kV)	60.02	converted	EA	43.2	Medium of DB Netz projects
2	SWS	SWS (2 x 20 MVA and phase break)	60.02	converted	EA	5	Medium of DB Netz projects
3	PS	PS (1 x 20 MVA)	60.02	converted	EA	3.6	Medium of DB Netz projects
4	Flat	Feeding of OCS	60.02	calculated	mi	2.1	Medium of DB Netz projects

Table 5-101 - DB cost for traction power supply: substations

The "2018 Baseline Estimate Optimization 7.2 (V2V)" section "2018 Baseline Budget", and the submitted list "Track and systems estimate - 09262017_with prices", do not contain any information concerning the sub– SCC 60.02.

The ETO Specialists converted the prices known through reference projects like NBS Nürnberg – Ingolstadt (new High-Speed Line), VDE 8 (New High-Speed Line), ABS 48 (upgraded High-Speed Line), and ABS Oldenburg – Wilhelmshaven (upgraded High-Speed Line), to prices for the required CHSRA configuration. ETO converted these costs because of different framework conditions.

The calculation has been detailed for each SCC sub-category.

Traction power distribution: Catenary and traction power control (SCC 60.03 & SCC 60.04)

HSR Overhead Catenary System (OCS) and Overhead Catenary System for Junctions

The benchmarked costs include costs per route mile for HSR OCS on the track at stations, bridges, and tunnels. Costs include HSR-catenary, poles, negative feeder, return current conductor, switches, and isolation and material transport.

Overhead Catenary System for Maintenance Sites (low speed)

The benchmarked costs include costs per Route Mile for low speed OCS (less than 80 miles per hour) on the tracks for:

- Brisbane LMF
- Fresno OCC
- Fresno HMF

Costs include low-speed-catenary, catenary for junctions, poles, negative feeder, return current conductor, switches, and isolation and material transport.

The following benchmark costs were used:

No.	Part	Element	SCC	Unit	Price per unit in USD	Source
1	OCS	HSR OCS	60.03/.04	mi	1.478.438	Converted value of CCC of DB
2	OCS	Low-speed OCS	60.03/.04	mi	641.356	Converted value of CCC of DB
3	OCS	OCS per junction	60.03/.04	Per junction	73.800	Converted value of CCC of DB

Table 5-102 – DB cost for Traction power distribution: Catenary and Traction power control

The “2018 Baseline Estimate Optimization 7.1 (V2V)” section “2018 Baseline Budget”, and the submitted list “Track and systems estimate - 09262017_with prices”, do not contain any information concerning the sub – SCC 60.03. The ETO could not identify the detailed cost information in the data provided by CHSRA.

Therefore, ETO converted the prices of the DB CCC to budget costs for the configuration CHSRA requires. The ETO has executed the calculation detailed for each SCC sub-category.

Benchmark cost estimate determined by ETO using the design basics given by CHSRA

The result of the ETO benchmark cost calculation for Sections 1 through 6 (San Francisco – Bakersfield) is shown in Table 5-103:

The ETO reference project is considering catenary and traction power control systems as one cost unit. Therefore SCC 60.03 and SCC 60.04 are merged in the table. ETO Specialists compared the sum from both SCCs.

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total 1 to 6
60.01	Traction power transmission: high voltage	30,000,000	76,800,000	87,278,744	27,102,376	201,391,562	0	422,572,682
60.02	Traction power supply: substations	91,474,589	87,316,653	95,632,525	72,763,877	245,318,215	37,421,423	629,927,282
60.03 + 60.04	Traction power distribution: catenary and traction power control	155,573,192	134,529,658	157,768,122	109,658,015	382,015,589	58,694,180	998,238,755
Total per section in USD		277,047,781	298,646,311	340,679,391	209,524,268	828,725,366	96,115,602	2,050,738,719
Total sec. 1 to 6 in USD			**2,050,738,719**					

Table 5-103 - ETO Benchmark costs for V2V SCC 60 - traction electrification systems in USD

5.7.2.3 Escalation of costs

The ETO costs are Inflation adjusted to year-end 2017. ETO did not consider costs for Section 1 for the reason given in chapter 5.7.1 the ETO do not consider. The result can be seen in Table 5-104 below:

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total 1 to 6
60.01	Traction power transmission: High voltage	0	76,800,000	87,278,744	27,102,376	201,391,562	0	392,572,682
60.02	Traction power supply: Substations	0	87,316,653	95,632,525	72,763,877	245,318,215	37,421,423	538,452,693
60.03 + 60.04	Traction power distribution: Catenary and Traction power control	0	134,529,658	157,768,122	109,658,015	382,015,589	58,694,180	842,665,563
Total per Section		0	298,646,311	340,679,391	209,524,268	828,725,366	96,115,602	1,773,690,938
Total for section 2 to 6			**1,773,690,938**					

Table 5-104 - Adjusted ETO Benchmark Costs - SCC 60 - Traction Electrification Systems in USD

5.8 SCC 70 - Vehicles

5.8.1 CHSRA Cost Component

5.8.1.1 Qualitative description

The benchmark is based essentially on following documents:

- SCHEDULE 1 PART A: AUTHORITY TIER III TRAINSETS PERFORMANCE SPECIFICATION REV.0, 04/13/2016
- 2018-02-21_EXH-TS-1-Track-Chart-Rev0.pdf
- Trainset Costs 040816_0.pdf

The train cost analysis contained in “Trainset Costs 040816_0.pdf” identified several recent highspeed train patterns used or under development/construction during the CHSRA first analysis phase.
A short, illustrated description of these trains can be found in Appendix 3.

5.8.1.2 Quantitative estimation

The CHSRA evaluation of price base information shows no need for deeper investigation by ETO. A direct comparison of the costs per train (considering the cumulative rate of inflation to year-end of 2017) shows the same deviations that CHSRA already estimated. The collected values that are publicly available match DB’s own negotiations/orders. The only variance applies to automatic train protection including automatic train control (ATP) and nonrecurring costs. currently these costs are not considered in the benchmark per trainset. Therefore, the vehicle benchmarking performed is primarily a qualitative suitability analysis, not a true cost benchmark. Chapters 5.8.2.1 and 8.8 explain this further.

The benchmark report only includes current developed train types. Train types under development are not further considered (e.g. Velaro Novo (Germany), TGV 2020 (France) and Avelia Liberty (France/USA) and are not taken into account at the moment.

5.8.1.3 Escalation of costs

Costs are not escalated.

5.8.2 DB Cost Component

5.8.2.1 Qualitative description

The analysis of trainset technical qualifications for the CHSRA project is based on the ETO train procurement staff’s existing expertise. The ETO benchmarking reference project is the Velaro D, DB series 407, which is also part of the CHSRA collection of identified trainsets. It is identified correctly and serves as the comparison and justification base for all other train types chosen by CHSRA in its exhaustive identification list “Trainset Costs 040816_0.pdf”.

The listed train types sold in Europe contain a remarkable, but widely varying, number of nonrecurring homologation and authorization costs (independent of the number of delivered or sold trains). Where it could be quantified, the ETO Specialist estimated the expected amount (refer to Chapter 5.8.2.3). Cost for authorization under US/California regulation was not further considered and estimated, as discussed and agreed with the CHSRA specialists.

The evaluation of availability, suitability, and price/cost focused on the main technical challenges driven by experience and does not claim to be exhaustive at this level. In particular, the estimated/known characteristics concerning the life cycle cost evaluation were not taken into consideration at this project stage. Necessary, but as yet undefined, modifications will influence the technical solution/choice of components, but until the CHSRA defines these needed modifications, their impact cannot be considered.

Additionally, the price/cost contribution depends on whether or not the rolling stock contractor's proposal includes a lifetime maintenance contract. Some potential rolling stock providers are offering trainsets with the corresponding maintenance. Consequently, their price seems higher than those from contractors who do not offer such "all-in-one" trainset packages. This would impact the budget for vehicles, too.

5.8.2.2 Quantitative estimation

The analysis of trainsets in regards to technical qualification is based on the DB procurement staff's existing expertise.

5.8.2.3 Escalation of costs

An inflation adjustment was done for all trainsets with the shown inflation factor.

The reference Indexes to define the inflation factor were chosen as follows:

- EUR (Euroland): EUCPI2005 – European Union from 31st January 1990
- CNY (Chinese Yuan Renminbi (RMB): YHCPI1994 – China from 31st January 1993
- JPY (Japanese Yen): JPCPI2010 – Japan from 31st January 1970
- KRW (South Korean Won): KRCPI1953 - South Korea from 31st January 1952

The exchange rate was chosen as follows:

Dollar in Euro:	0.819100 EUR/USD
Dollar in Yuan Renminbi:	6.507463 CNY/USD
Dollar in Yen:	112.574002 JPY/USD
Dollar in Korean Won:	1,066.964062 KRW/USD

Cost for all trainsets can be compared in the following tables. The shown prices contain only unmodified train types (not considering any necessary adjustments to fulfill CHSRA requested technical requirements) without any consideration of “Buy America” consequences.

Illustration			
Name	Alstom AGV	Alstom TGV Duplex	AnsaldoBreda V250**5
Number of Trainsets	25	30	12
Year of Procurement	2008	2012	2004
Contract Amount in the year of Procurement (original currency)	EUR 650,000,000	EUR 900,000,000	EUR 336,000,000
Inflation factor to 2017	1.1208	1.0344	1.2226
Adjusted Contract Amount to 2017 (original currency)	EUR 728,520,000	EUR 930,960,000	EUR 410,793,600
Adjusted Contract Amount to 2017 (in USD)	USD 889,415,212	USD 1,136,564,522	USD 501,518,252
Total Amount per Train sets (adjusted to 2017 in USD)	USD 35,576,608	USD 37,885,484	USD 41,793,187.64
Picture source	https://www.railway-technology.com/projects/alstom-agv-very-high-speed-trains-france/	Alaric Favier, own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19808904	Arnold de Vries https://commons.wikimedia.org/w/index.php?curid=8805902

Table 5-105 - Train comparison - Alstom AGV, Alstom TGV Duplex & AnsaldoBreda V250

Illustration			
Name	AnsaldoBreda/Bombardier Zefiro V300	Bombardier Zefiro 380	CSR CRH380A
Number of Trainsets	50	140	9
Year of Procurement	2010	2009	2012
Contract Amount in the year of Procurement (original currency)	EUR 1,540,000,000	CNY 27,400,000,000.00	CNY 1,300,000,000.00
Inflation factor to 2017	1.0865	1.2248	1.0991
Adjusted Contract Amount to 2017 (original currency)	EUR 1,673,210,000	CNY 33,559,520,000.00	CNY 1,428,830,000.00
Adjusted Contract Amount to 2017 (in USD)	USD 2,042,742,034	USD 5,157,081,953	USD 219,567,902
Total Amount per Trainsets (adjusted to 2017 in USD)	USD 40,854,841	USD 36,836,300	USD 24,396,434
Picture source	Netse Silva https://commons.wikimedia.org/w/index.php?curid=45679151	https://upload.wikimedia.org/wikipedia/commons/b/b2/	Jucember – Own work, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=17893723

Table 5-106 - Train comparison - AnsaldoBreda/Bombardier Zefiro V300, Bombardier Zefiro 380 & CSR CRH380A

Illustration			
Name	Japan Series E5	Japan Series N700A	Rotem KTX-II
Number of Train sets	5	36	10
Year of Procurement	2014	2013	2014
Contract Amount in the year of Procurement (original currency)	JPY 18,000,000,000	JPY 88,000,000,000	KRW 342,200,000,000
Inflation factor to 2017	1.0131	1.0372	1.0394
Adjusted Contract Amount to 2017 (original currency)	JPY 18,235,800,000	JPY 91,273,600,000	KRW 355,682,680,000
Adjusted Contract Amount to 2017 (in USD)	USD 161,989,444	USD 810,787,556	USD 333,359,569
Total Amount per Trainsets (adjusted to 2017 in USD)	USD 32,397,889	USD 22,521,877	USD 33,335,957
Picture source	https://upload.wikimedia.org/wikipedia/commons/7/74/E5_S11_Sendal_20090725.JPG	https://upload.wikimedia.org/wikipedia/commons/9/97/JRW_N700-7000series_S1.jpg	Minseong Kom – Own work CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37103539

Table 5-107 - Train comparison - Japan Series E5, Japan Series N700A & Rotem KTX-II

Illustration			
Name	Siemens Velaro CN	Siemens Velaro D	Siemens Velaro E
Number of Trainsets	140	15	26
Year of Procurement	2009	2008	2005
Contract Amount in the year of Procurement (original currency)	CNY 40,800,000,000.00	EUR 500,000,000	EUR 650,000,000
Inflation factor to 2017	1.2248	1.1208	1.196
Adjusted Contract Amount to 2017 (original currency)	CNY 49,971,840,000.00	EUR 560,400,000	EUR 777,400,000
Adjusted Contract Amount to 2017 (in USD)	USD 7,679,158,529	USD 684,165,548	USD 949,090,465
Total Amount per Trainsets (adjusted to 2017 in USD)	USD 54,851,132	USD 45,611,037	USD 36,503,479
Picture source	https://de.wikipedia.org/wiki/CRH3#/media/File:CRH3_in_Tianjin.JPG	DB AG	https://upload.wikimedia.org/wikipedia/commons/1/10/Renfe_clase_103.JPG

Table 5-108 - Train comparison - Siemens Velaro CN, Siemens Velaro D & Siemens Velaro E

Illustration			
Name	Siemens Velaro e320	Siemens Velaro TR	Talgo 350
Number of Trainsets	20	7	35
Year of Procurement	2010	2013	2011
Contract Amount in the year of Procurement (original currency)	EUR 600,000,000	EUR 285,000,000	EUR 1,600,000,000
Inflation factor to 2017	1.0865	1.0258	1.0574
Adjusted Contract Amount to 2017 (original currency)	EUR 651,900,000	EUR 292,353,000	EUR 1,691,840,000
Adjusted Contract Amount to 2017 (in USD)	USD 795,873,520	USD 356,919,790	USD 2,065,486,510
Total Amount per Trainsets (adjusted to 2017 in USD)	USD 39,793,676	USD 50,988,541	USD 59,013,900
Picture source	https://www.hochgeschwindigkeitszuege.com/england/fotos-england/eurostar-e320-langzug-01-fhd.jpg	By Mikhail krivyy – TrainPix, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=55022953	https://upload.wikimedia.org/wikipedia/commons/4/46/Talgo_350.jpg

Table 5-109 - Train comparison - Siemens Velaro e320, Siemens Velaro TR & Talgo 350

5.9 SCC 80 - Prof Services (associated to categories 10-60)

This section includes the following SCC sub-categories:

- 80.02 Preliminary engineering / project environmental
- 80.03 Final design
- 80.04 Project management for design and construction
- 80.05 Construction administration & management
- 80.06 Professional liability and other non-construction insurance
- 80.07 Legal; permits; review fees by other agencies, cities, etc.
- 80.08 Surveys, testing, investigation
- 80.09 Engineering inspection
- 80.10 Start up

The SCC80 costs are calculated as a percentage of the overall construction costs. Therefore, this section only gives values as percentages. To generate the absolute values of the professional service cost, the calculated overall construction costs must be multiplied by the values given in this section. SCC 80.01 was omitted per direction of CHSRA.

5.9.1 CHSRA Cost Component

5.9.1.1 Qualitative description

The document "SCC 80 Costs – TCRP 138 Calculator" provides the basis for this benchmark. The document shows default, adjusted, and assumed values for professional costs as percentages of construction costs.

It also shows the assumptions for the sub-category SCC 80.03 final design. The assumptions are based on experience values on prices for different infrastructure types: civil works, structures and tunnels. The overall values for the sub-category SCC 80.03 final design therefore consist of the different values per infrastructure type in different track sections.

<u>Preliminary Engineering / Project Environmental</u> (SCC 80.02)

In consultation with the CHSRA, SCC 80.02 includes a 30% design stage. This stage also includes the verification of alternatives and extensive resource checks (e.g. environmental study, groundwater study, vibration study, stakeholder study, etc.).

<u>Final design</u> (SCC 80.03)

The SCC 80.03 final design includes the design stages >30% and the approval planning.

<u>Project Management for design and construction</u> (SCC 80.04)

SCC 80.04 is to be considered as an overall program management containing costs which cannot be allocated to a specific project (e.g. interface management, safety management, final reporting, legal support, etc.). The project management for the specific projects will be the contractor's task.

Construction administration & management (SCC 80.05)

SCC 80.05 currently contains the costs of ongoing CHSRA projects (e.g. CP1 to CP4). These costs do not only relate to construction supervision; they also include project management costs for each defined project.

Professional liability and other non-construction insurance (SCC 80.06)

The costs for SCC 80.06 are fully burdened costs by the contractors or consultants. The costs are priced directly into the estimated unit prices. Therefore, CHSRA incurs no direct costs.

Legal; Permits; Review Fees by other agencies, cities, etc. (SCC 80.07)

SCC 80.07 includes infrastructure-related costs (e.g. land acquisition, redesign of infrastructure, etc.).

Surveys, testing, investigation (SCC 80.08)

Costs for the SCC 80.08 are considered either as burden costs by the contractor or as already calculated in SCC 80.05.

Engineering inspection (SCC 80.09)

Costs for SCC 80.09 are considered either as burden costs by the contractor or as already calculated in SCC 80.05.

Start up (SCC 80.10)

Costs in SCC 80.10 occur mainly for the ETO during the free trial run phase (12 months), when no revenue will be generated. These costs (ETO & energy costs) arise to verify and accept the network from different contractors (T&S, RST, station etc.).

5.9.1.2 Quantitative estimation

The SCC 80 - professional service costs are defined as shown in Table 5-110:

<table>
<tr><th>SCC</th><th>Default average Value [%]</th><th>Adjusted Value [%]</th><th>Assumed Value [%]</th></tr>
<tr><td>80.02</td><td>2</td><td>2.5</td><td>2.5</td></tr>
<tr><td>80.03</td><td>12</td><td>10</td><td>6.0</td></tr>
<tr><td>80.04</td><td rowspan="2">12.5</td><td rowspan="2">7.1</td><td>4.0</td></tr>
<tr><td>80.05</td><td>3.0</td></tr>
<tr><td>80.06</td><td>2</td><td>1.8</td><td>0.0</td></tr>
<tr><td>80.07</td><td rowspan="4">1</td><td rowspan="4">0.4</td><td>0.5</td></tr>
<tr><td>80.08</td><td>0.0</td></tr>
<tr><td>80.09</td><td>0.0</td></tr>
<tr><td>80.10</td><td>0.5</td></tr>
</table>

SCC	Default average Value [%]	Adjusted Value [%]	Assumed Value [%]
Total	29.5	21.8	16.5

Table 5-110 - Expected values by CHSRA

The value for SCC 80.03 - final design is based on the Table 5-111:

	Civil [miles]	Structure [miles]	Tunnel [miles]	Final Design [%]
San Francisco to San Jose	44			6.0
San Jose to Gilroy	5	28		8.5
Gilroy to Carlucci Rd	30	9	15	5.7
Carlucci to Madera Acres	34	1		6.1
Wye Leg 1	14	1		6.2
Merced to Wye Leg	7	1		6.4
Madera to Poplar Ave	113	6		6.2
Poplar Ave to Bakersfield	14	11		7.3
Bakersfield to Palmdale	54	10	11	6.0
Palmdale to Burbank	16	2	24	4.4
Burbank to Los Angeles	10			6.0

Table 5-111 - Expected values for SCC 80.03

5.9.1.3 Escalation of costs

Because of SCC 80's weighted approach regarding particular construction costs, the time-dependent adjustments are taken into account. No further nominalizations must be calculated.

5.9.2 DB Cost Component

5.9.2.1 Qualitative description

The data for the benchmark is taken partly from the HOAI (Honorarordnung für Architekten und Ingenieure/ the fee structure imposed on architects and engineers acting as public contractors). The HOAI is grouped in different service phases (Lph). Depending on the trades and relating sections of the HOAI, the HOAI defines specific percentages for the fee of each trade regarding the service phase and the overall construction costs as well as specifications like construction of a new line or modifying an existing line. This fee is defined as 100 percent of the engineering fees. Therefore, each Lph has its own percentage of how much the engineering can cost.

The HOAI also defines the scope of service for each trade and service phase.

To calculate the fees for the benchmark, ETO Specialists have made the following assumptions:

- High complexity in civil and systems works
- The complexity in the trades, signaling, communication, and traction power
- There are no additional costs regarding special services in addition to the scope of services in the HOAI
- There are no additional costs for modification of already existing lines
- There are no additional costs for special complexity in the engineering
- Engineering trades like geotechnical reports, environmental reports, noise and vibration reports, and costs for surveying work are not included

For the project management services, AHO book 9 is considered. It explains the different project management services and determines the fees for each service regarding the overall construction costs.

For the benchmark, the complexity of the project is assumed as high.

The HOAI and AHO together give a close summary of how the professional service costs relate to the overall construction costs that are estimated in DB reference projects.

In addition to the guidelines HOAI and AHO, the German government specifies a flat fee for planning expenses of 14% - 18% of the overall construction costs. That means that for each Euro of construction costs spent, a maximum 0.18 Euro in planning expenses can be charged. The German government's flat fee includes the engineering phases and the project management costs.

1.1.2.3 Quantitative estimation

Preliminary Engineering / Project Environmental (SCC 80.02)

For the sub-SCC 80.02, the following service phases of the HOAI are taken into account:

- Lph 0 feasibility study
- Lph 1 basic evaluation of the project
- Lph 2 preliminary planning
- Lph 3 conceptual design

	Total [%]
HOAI Lph 0	0.35
HOAI Lph 1	0.48
HOAI Lph 2	0.76
HOAI Lph 3	0.93
Total	2.52

Table 5-112 – HOAI service phases

The HOAI does not define resource studies as main services in the service phases. Therefore, an additional 0.18 percent was added for these services.

In this design stage the differences in the calculation of the costs for each trade are negligible. Therefore, no difference is taken into account and not displayed.

Final Design (SCC 80.03)

For the sub-SCC 80.03, the following service phases of the HOAI are taken into account:

- Lph 4 approval planning
- Lph 5 detailed design
- Lph 6 creation of the tender documents
- Lph 7 tendering
- Lph 8 support during the execution
- Lph 9 documentation

The HOAI defines different service costs for each trade. The following table shows the percentage for each trade regarding the sections.

Section	SCC10 [%]	SCC20 [%]	SCC30 [%]	SCC40 [%]	SCC50 [%]	SCC60 [%]	Total [%]
Section 1	5.50	5.70	4.50	5.20	7.65	7.25	5.967
Section 2	6.25	6.20	5.90	5.55	7.35	7.25	6.417
Section 3	5.00	4.45	5.10	5.65	6.30	7.05	5.592
Section 4	6.80	3.35	4.95	6.70	6.10	5.85	5.625
Section 5	5.50	6.05	5.70	4.95	5.30	6.05	5.592
Section 6	7.45	6.50	5.95	6.80	7.45	7.70	6.975

Table 5-113 - Cost percentages in the final design

The percentage values result from the complexity of the section per trade and the percentage of the construction cost for the trade and section. Taking the length of the different sections as weighting factor into account, the overall percentage of construction costs for the final design is 5.9 %.

Project management for design and construction (SCC 80.04)

For the sub-SCC 80.04, Book 9 of the AHO is taken into account. It defines the following project management services:

- Part A: Organization, information, coordination, and documentation
- Part B: Quality and quantity
- Part C: Cost and finance
- Part D: Scheduling, capacity, and logistics
- Part E: Managing contracts, and insurances

These project management phases are each included in the following service phases:

- Project start
- Planning
- Preparation for implementation
- Implementation
- Close out

In the project management sub-SCC, the costs for construction management, from the project management perspective, is included. It will not be calculated in sub-SCC 80.05.

Project management would be estimated at about 8.0 percent of the overall construction costs.

Construction administration & management (SCC 80.05)

For sub-SCC 80.05, construction supervision for the following trades is taken into account regarding the construction costs for the relevant trade:

- Civil engineering
- Track engineering
- Signaling
- Communication

Construction supervision handles a major portion of construction management. Minor construction management is included in the Sub-SCC 80.04 project management, and therefore can be neglected.

Each trade has a different percentage of the overall construction cost, resulting from the complexity of the trade and the availability of highly specialized professionals (e.g. the signaling and communication trade will be more expensive than the track and structure trade because of the lower availability of professional staff).

Section	SCC10 [%]	SCC20 [%]	SCC30 [%]	SCC40 [%]	SCC50 [%]	SCC60 [%]	Total [%]
Section 1	4	6	8	4	12	12	7.7

Table 5-114 - Construction management costs by trade

Following the listed facts, it can be assumed that the cost will add up to 7.7 percent of the overall construction costs.

Professional liability and other non-construction insurance (SCC 80.06)

For this benchmark, we have considered the insurance typical for German rail infrastructure projects. These costs average out at about two percent of the overall construction costs.

Legal; Permits; Review Fees by other agencies, cities, etc. (SCC 80.07)

The costs for Sub-SCC 80.07 contain the infrastructure-related costs.

Because we lack information on fees in the USA, the expected costs for Europe are taken into account. They add up to 0.25 percent of the overall construction costs.

Surveys, testing, investigation (SCC 80.08)

The Sub-SCC 80.08 includes the design review and the plan verification of the following trades:

- Civil engineering
- Track engineering
- Signaling
- Communication

The services of the engineers and architects who are authorized to sign building documents are taken into account, too. The different services add up to 2.1 percent.

Engineering inspection (SCC 80.09)

For sub-SCC 80.09, the engineering inspections of the following trades are taken into account regarding the construction costs for the relevant trade:

- Civil engineering
- Track engineering
- Signaling
- Communication

The different services add up to 1.5 percent.

Start up (SCC 80.10)

The startup costs allow for uncalculated effects during the startup phase of the track system, such as additional staff and smaller modifications to the infrastructure. The startup costs are estimated at about two percent of the overall construction costs.

Conclusion

SCC 80 Prof Services	Assumed Value by ETO [%]
80.02	2.7
80.03	5.9
80.04	8
80.05	7.7
80.06	2
80.07	0.25
80.08	2.1
80.09	1.5
80.10	2
Total	32,15

Table 5-115 - Assumed value by ETO

5.9.2.2 Escalation of costs

Because of SCC 80's weighted approach regarding the particular construction costs, time-dependent adjustments are taken into account. No further nominalizations must be calculated.

6 Benchmarking Results

6.1 Summary

SCC10:

Viaducts and bridges (SCC 10.01-10.03):

Two newly built bridges in Germany, which have a similar configuration to the CHSR bridges, were agreed upon with CHSRA and chosen by the ETO for benchmarking. In general, the ETO stated that because of deeper drilled shafts and piles, and stronger pier-to-aerial construction, costs are significantly higher than in the German benchmark projects. In addition, foundation costs deviate tremendously, because of higher earthquake-resistance in moderate to high seismic areas. Costs for substructures and superstructures remain within the same order of magnitude for both ETOs and CHSRA reference bridges.

In general, costs varied more strongly in Section 3, where higher seismic influences had to be incorporated, while less significant cost deviations were stated in Sections 4 and 6.

Earthworks & Drainage (SCC 10.04-10.06):

CHSRA's unit costs for cut and embankment lie in the range of DB's experience, wheras the costs for at-grade trackbed infill shows a significantly higher variation compared with DB's values.

Tunnel (SCC 10.07):

Pacheco Tunnel 2 was benchmarked to Finne Tunnel. For both total costs and costs per Route Mile, CHSRA tunnel costs were 125% higher than at Finne Tunnel.

Retaining Walls (SCC 10.08):

Considering cantilever retaining walls, the estimated costs for CHSRA only amount to 46% of DB's usual estimated costs in Germany. CHSRA costs for bored pile walls are substantially higher than those DB encounters in Germany.

Track (SCC 10.09, 10.10, 10.14):

CHSRA's costs for ballasted double-track are higher by 42% to 70%, depending on the ETO benchmarking basis. Estimates for direct track fixation were on a similar level for ETO and CHSRA facilities. For turnouts, the equivalent German facilities deviate by up to +281%. For ballasted track, ETO's estimated span ranges from 868-1,059 USD/yd, whereas the CHSRA estimate is 2,092 USD/yd (ca. +100-140%).

SCC 20:

Stations in Section 1 were not evaluated further, as agreed upon with CHSRA. The adjusted ETO reference stations in other sections were lower by +24% to +87% (mean: 61.2%, median: 63%) than CHSRA's estimated cost.

SCC30:

Benchmarking showed that CHSRA's estimate for HMF exceeds ETO's assumed costs by about 60%, for LMF by 35%. For MoW, no significant deviations could be stated. Since CHSRA provided limited data, benchmarking was done using lump-sums approach only.

SCC40:

For benchmarking of a grade separation, CHSRA provided detailed information for the project "Road 26". The comparison showed that CHSRA's estimated costs are 68% higher than the ETO's estimate. Taking into account the different production and labor costs between California and Germany, benchmarking indicates similar values for CHSRA and ETO. However, apart from the Road 26 grade separation, benchmarking for SCC 40 was impossible because data was missing.

SCC50:

Using a four-step analysis, the ETO built up a model to calculate all the required high-speed line signaling and communications equipment and rearranged them in a way that all data became compatible to the CHSRA structure. In accordance with CHSRA, some sub-SCCs were therefore partially integrated in other sub-SCCs. Eventually, the ETO identified a cost overestimation of about USD 128,677 million, which equals a percentage value of 84.20% in the benchmark.

SCC60:

The total cost difference over SCC 60 for Sections 2-6 is 19%. Other than what the title of the SCC implies, the ETO experts point out that a third rail will not be required. The verification of data from Section 1 was not possible; the section was thus excluded from the benchmarking result. For Section 6, ETO experts could not retrace the assumed value "0". The result of benchmarking shows that the values in the 2018 BP appear to be lower by about 305 million USD. In addition, 15 million USD should be incorporated for crossing power lines and other foreign supply facilities.

SCC70:

For benchmarking trains, the ETO used the price information for about 15 HSR trains provided by CHSRA. A detailed cost estimation was not possible. Functional requirements were compared at this point in time only.

SCC80:

Costs were calculated as a percentage of the overall construction costs. The outcome over all sub-SCCs showed an expected deviation of 3.05%, meaning that SCC80 costs are currently underestimated by CHSRA. It is important to mention that this number is displayed in [%] of [%] and consequently leads to respectively higher overall construction costs.

6.2 SCC 10 - Track Structures and Track

6.2.1 Global Benchmarking

Viaducts and bridges (SCC 10.01, 10.02, 10.03)

For comparison, all viaduct and bridge data was summarized and charted graphically. **Figure 6-1** shows total costs, whereas **Figure 6-2** and **Figure 6-3** show the foundation cost and superstructure cost separately to highlight the cost drivers.

Below, **Figure 6-1** graphically illustrates the cost of viaducts and bridges for Section 3 Gilroy to Carlucci Road, and DB's "VDE 8.2", with the average cost per mile varying by up to 85%.

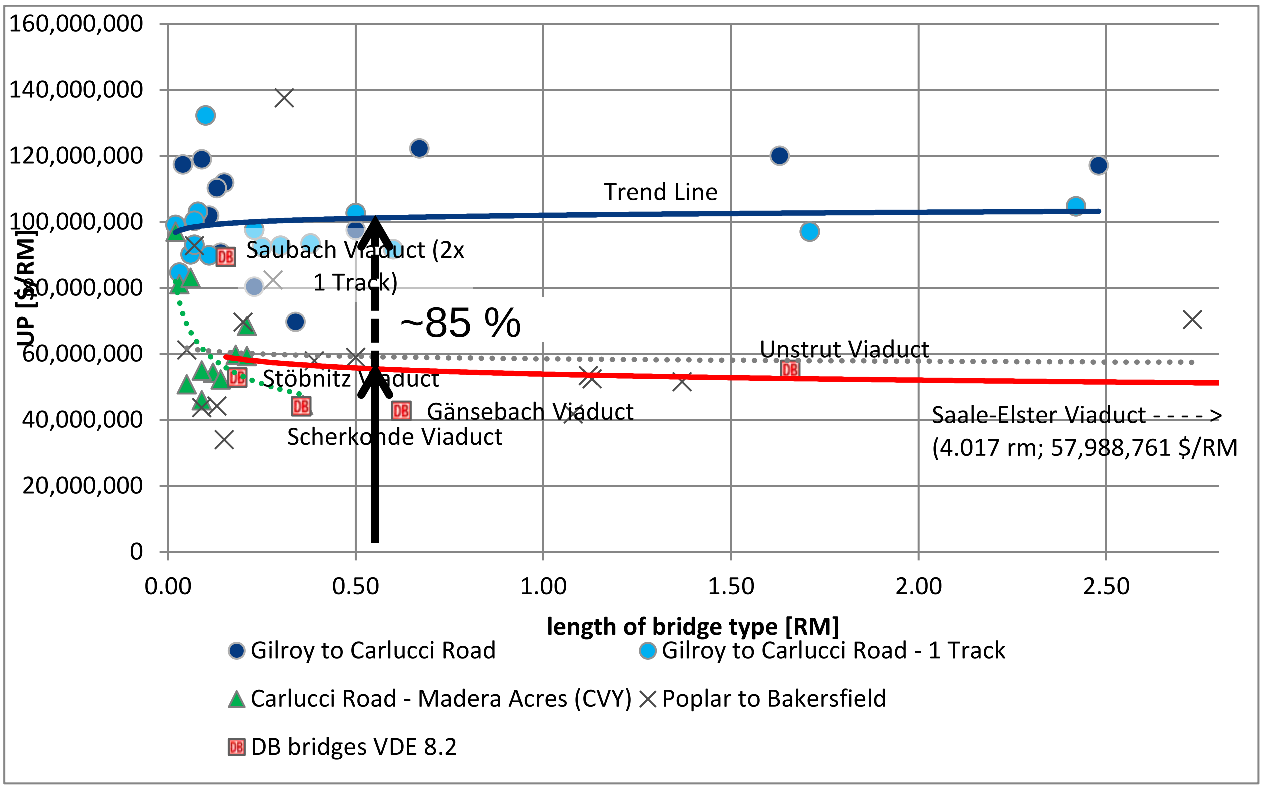


Figure 6-1– Cost comparison - Total costs of CHSRA viaducts and bridges versus DB viaducts and bridges

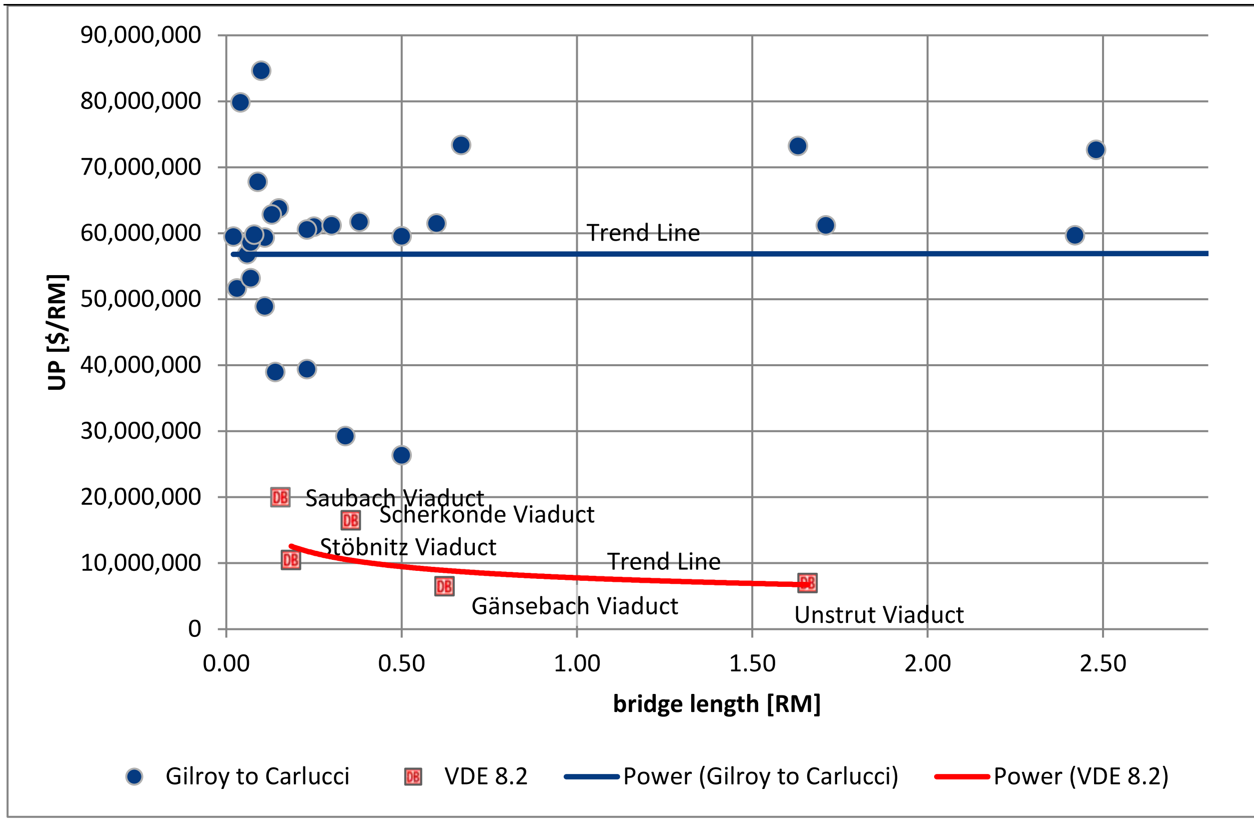


Figure 6-2 - Cost comparison - foundation costs of CHSRA viaducts and bridges versus DB viaducts and bridges

The cost of the foundations for CHSRA viaducts and bridges, in comparison to the DB viaducts, vary greatly, because of the increased depth of the drilled shafts for the pile foundations.

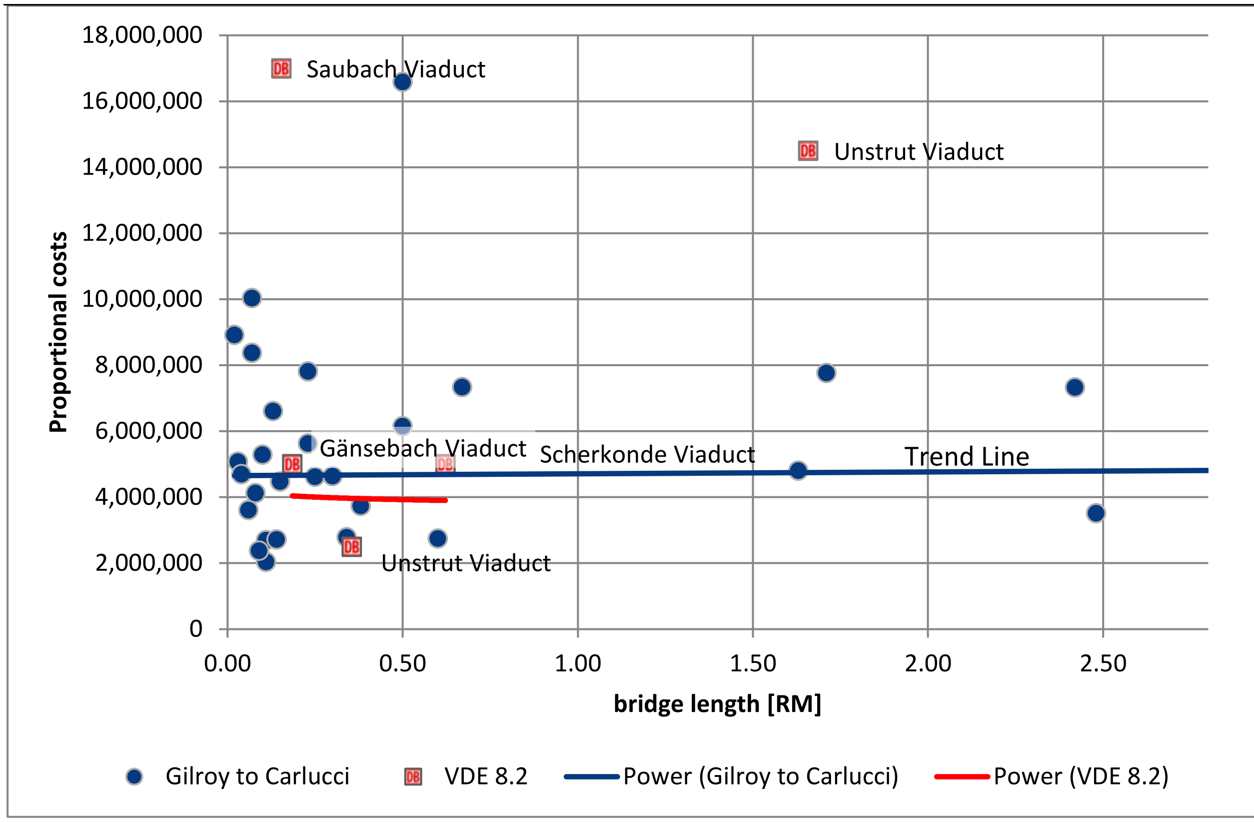


Figure 6-3 - Cost comparison - substructure costs per road mile (piers, abutments)

For substructure (Figure 6-3), the costs for the DB reference projects, Saubach viaduct and Unstrut viaduct, are much higher than the average proportional costs. The Saubach viaduct is located in a deep valley, which requires the construction of high piers (up to 120 ft) and one superstructure per track. Consequently, the number of piers is double compared to the other reference projects. The Unstrut viaduct is a flood bridge with unique topography and ground conditions. It is located in a potential flood zone with special environmental impact requirements. Complex construction methodologies were required for construction, which led to increased costs for building the substructure.

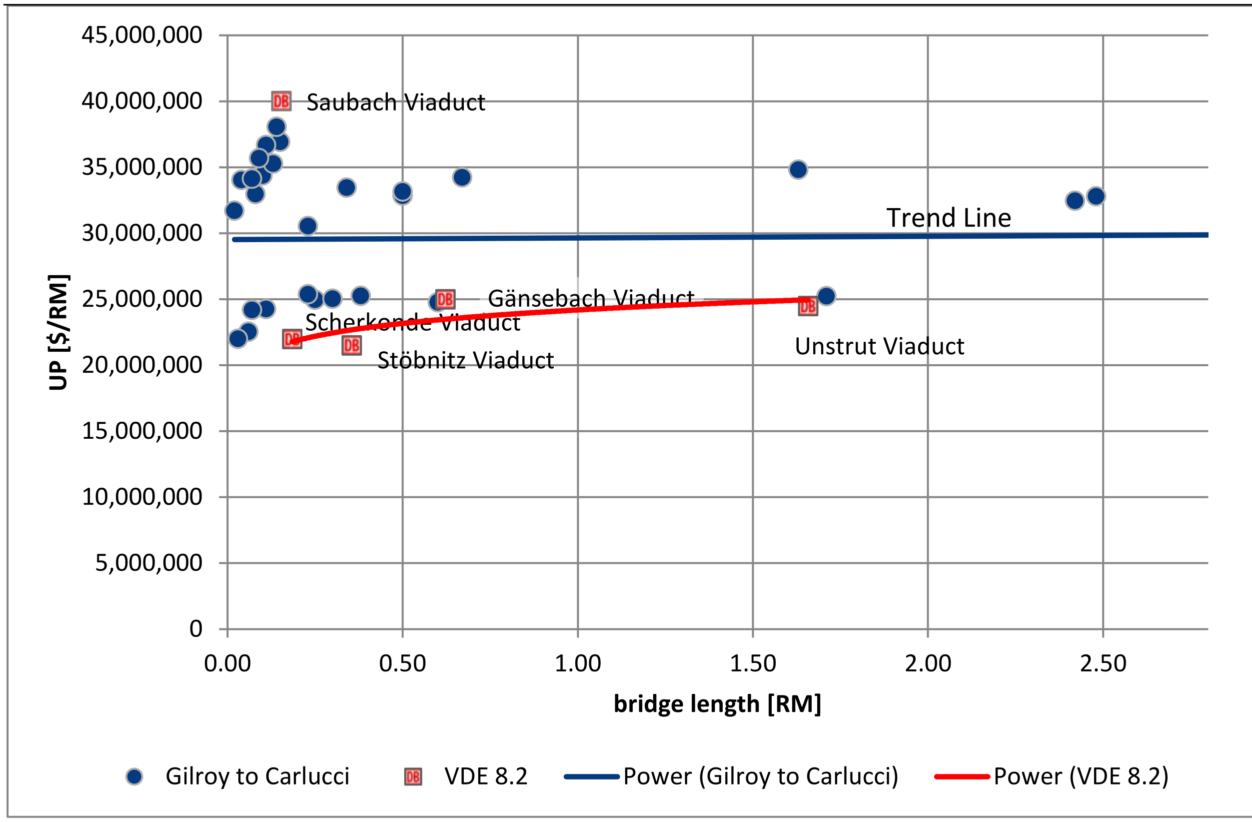


Figure 6-4 - Cost comparison - superstructure costs per road mile

The viaducts and bridges (CHSRA vs DB) used in the above comparison differ widely in structural design and bridge configuration. Therefore, it was deemed necessary to select two bridges for a more detailed assessment. The Gänsebach viaduct and Saubach viaduct were selected for benchmarking because they are the most similar in configuration (two-track or single-track), pier height, and span length.

The following tables show cost estimates of CHSRA structures compared to the selected DB reference bridges. CHSRA's chosen elevated structures are located in different seismicity zones. CHSRA defined high and moderate seismic zones in this context.

	Total cost per RM in USD	% of total	Total cost per RM in USD	% of total
Description	Elevated structure - two-Track (40 ft avg. pier ht, 150 ft span) high seismicity zone		Gänsebachtal Viaduct - two-track (50 ft avg. pier ht, 144 ft span)	
Reinforcing steel	4,142,771	4%	0	0%
Structural concrete, In-place, Aerial footing	17,083,736	15%	2,069,083	5%
Structural excavation	888,352	1%	319,262	1%

	Total cost per RM in USD	% of total	Total cost per RM in USD	% of total
Haul and dispose of excavated material	891,568	1%	686,291	2%
Structural backfill	234,320	0%	357,646	1%
Steel sheet piling, drive, extract and salvage	9,840,232	9%	904,168	2%
Drilled shaft, 120 in dia, un-cased in soft rock	30,750,720	27%	3,621,548	8%
Site demolition allowance	258,336	0%	319,262	1%
Site restoration allowance	30,528	0%	319,262	1%
Total Foundation	**64,120,563**	**56%**	**8,596,522**	**19%**
Reinforcing steel	4,142,771	4%	0	0%
Structural concrete, in-place, aerial pier	6,168,968	5%	5,778,089	13%
Multirotational bearing (1500 Kip)	425,776	0%	1,358,446	3%
Total Substructure	**10,737,515**	**9%**	**7,136,535**	**16%**
Reinforcing steel	4,142,771	4%	0	0%
Structural concrete, in-Place, Parapet wall	709,632	1%	2,289,666	5%
Structural concrete, in-place, OCS pole base	44,944	0%	703,229	2%
Precast segmental box girder, double (10.5 ft depth)	31,933,440	28%	21,683,980	48%
Service/safety \walkway	1,419,264	1%	1,726,815	4%
Metal pipe & cable railing	354,816	0%	319,262	1%
Corrosion control, aerial	29,568	0%	319,262	1%
Walkway lighting, allowance	354,816	0%	563,290	1%
Trackway drainage allowance, aerial	402,128	0%	922,678	2%
Cable duct, aerial guideway	437,608	0%	651,902	1%
Total Superstructure	**39,828,987**	**35%**	**29,180,084**	**65%**
TOTAL	**114,687,065**	**100%**	**44,913,141**	**100%**

Table 6-1 - Benchmarking of CHSRA's elevated two-track structure in high seismicity zone with DB's reference viaduct Gänsebachtal (two-Track)

Table 6-1 compares the total cost per RM for the three main bridge components of a two-track structure in a high seismic zone. It can be seen that the foundation costs are 750% higher for CHSRA projects. The costs for sub and superstructure show the same order of magnitude compared to DB's benchmarking projects.

	Total cost per RM in USD	% of Total	Total Cost per RM in USD	% of Total
Description	Wasco viaduct - two-track (40 ft avg. pier ht, 150 ft span) moderate seismicity zone		Gänsebachtal Viaduct - two-track (50 ft avg. pier ht, 144 ft span)	
Reinforcing steel	3,880,293	6%	0	0%
Bridge foundation	18,708,443	29%	6,243,611	14%
Structural excavation	50,887	0%	973,626	2%
Structural backfill	34,594	0%	644,982	1%
Total Foundation	**22,674,217**	**36%**	**7,862,219**	**18%**
Reinforcing steel	3,880,293	6%	0	0%
Substructure	2,912,380	5%	6,065,424	14%
Multirotational bearing (1500 Kip)	1,690,005	3%	1,645,781	4%
Total Substructure	**8,482,678**	**13%**	**7,711,205**	**17%**
Reinforcing steel	3,880,293	6%	0	0%
Falsework	4,074,236	6%	0	0%
Cast-in-place box girder	8,591,405	14%	21,882,483	49%
Precast beams	9,249,372	15%	0	0%
Bridge barrier	2,513,507	4%	2,577,002	6%
Expansion joint assemblies	487,715	1%	695,430	2%
Approach slabs	24,408	0%	606,597	1%
Equipment support	3,609,736	6%	3,578,202	8%
Total Superstructure	**32,430,672**	**51%**	**29,339,714**	**65%**
TOTAL:	**63,587,567**	**100%**	**44,913,138**	**100%**

Table 6-2 - Benchmarking of CHSRA's two-track viaduct in moderate seismicity zone with DB's reference viaduct Gänsebachtal (two-track)

Table 6-2 compares the total cost per RM of the three main bridge components for a two-track structure in a moderate seismic zone. It can be seen that the foundation costs are 288% higher for CHSRA projects. The costs for sub and superstructure show the same order of magnitude.

	Total cost per RM in USD	% of Total	Total cost per RM in USD	% of Total
Description	Elevated structure - one track (60 ft avg. pier ht, 120 ft span)		Saubachtal Viaduct - one track (60 ft avg. pier ht, 135 ft avg. span)	
Reinforcing steel	3,769,500	4%	0	0%
Structural concrete, in-place, aerial footing	12,841,900	13%	3,085,598	6%
Structural excavation	673,500	1%	1,120,116	2%
Haul and dispose of excavated material	671,100	1%	757,376	2%
Structural backfill	181,550	0%	892,461	2%
Steel sheet piling, drive, extract and salvage	8,253,950	8%	1,698,944	3%
Drilled shaft, 120 in dia, un-cased in soft rock	28,537,600	29%	1,331,884	3%
Site demolition allowance	194,200	0%	1,168,035	2%
Site restoration allowance	22,800	0%	652,114	1%
Total Foundation	**55,146,100**	**56%**	**10,706,528**	**22%**
Reinforcing steel	3,769,500	4%	0	0%
Structural concrete, in=place, aerial pier	7,306,700	7%	3,291,613	7%
Multirotational Bearing (1500 Kip)	395,100	0%	1,410,517	3%
Total Substructure	**11,471,300**	**12%**	**4,702,130**	**9%**
Reinforcing steel	3,769,500	4%	0	0%
Structural concrete, in-place, parapet wall	658,550	1%	3,483,030	7%
Structural concrete, in-place, OCS pole base	20,850	0%	652,114	1%
Precast segmental box girder, double (10.5 ft depth)	26,342,400	27%	24,046,476	48%
Service/safety walkway	658,550	1%	1,353,462	3%
Metal pipe & cable railing	329,300	0%	703,861	1%
Corrosion Control, Aerial	27,450	0%	652,114	1%
Walkway lighting, allowance	164,650	0%	1,107,548	2%
Trackway drainage allowance, aerial	373,200	0%	1,605,244	3%
Cable duct, aerial guideway	203,050	0%	703,861	1%
Total Superstructure	**32,547,500**	**33%**	**34,307,710**	**69%**
TOTAL:	**99,164,900**	**100%**	**49,716,368**	**100%**

Table 6-3 - Benchmarking of CHSRA's one-track elevated structure with DB's reference, one-track viaduct Saubachtal

Table 6-3 compares the total cost per RM for the three main bridge components of a one-track structure. It can be seen that the foundation costs are 515% higher for CHSRA projects. The costs for sub and superstructure show the same order of magnitude.

Benchmarking results show significant deviations in the foundation costs depending on the seismicity zone in which the bridge is located. It should also be noted that the required pile lengths were estimated for CHSRA projects, because geotechnical information required for the design was not available.

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

Table 6-4 compares the escalated cost for earthwork from the CCC with CHSRA's aggregated UPEs:

	DB CCC min	DB CCC max	CHSRA
Year	2017	2017	2017
	USD/cu yd	USD/cu yd	USD/cu yd
Topsoil	included	included	3.36
Cut	13.02	22.78	10.72
Embankment	13.02	26.04	15.68
Sub-ballast	n/a	n/a	47.04

Table 6-4 - Benchmarking of earthwork and drainage

CHSRA's unit costs for cut and embankment lie between the lower and upper values of the CCC. There is no equivalent unit cost in the earthwork section of the CCC for subballast.

Table 6-5 compares the escalated cost for at-grade trackbed infill from the CCC with CHSRA's aggregated UPEs. Compared with the CCC, the CHSRA values show a much wider range:

	CCC min	CCC max	CHSRA min	CHSRA max	CHSRA weighted average
Year	2017	2017	2017	2017	2017
	USD/cu yd	USD/cu yd	USD/cu yd	USD/cu yd	USD/cu yd
At-grade trackbed infill	18.60	31.61	14.29	97.16	51.31

Table 6-5 - Benchmarking of at-grade trackbed infill

Tunnels (SCC 10.07)

Table 6-6 compares the escalated CHSRA total costs of the Pacheco Tunnel 2 to the escalated total costs of the DB reference project "Finne tunnel":

	CHSRA costs (Pacheco Pass tunnel No.2 single-track twin tunnel)		ETO costs (Finne tunnel)	
Description	**Total cost in USD**	**% of Total**	**Total cost in USD**	**% of Total**
Total Site work allowances	**52,390,498**	**2%**	**29,652,369**	**3%**
Site development	1,866,238	0%	9,333,573	1 %
Portal development	50,524,260	2%	20,318,795	2 %
Total Single-track tunnel	**2,186,903,110**	**89%**	**970,971,662**	**89%**
Procurement & mob-demob	312,076,959	13%	242,080,169	22%
Starter tunnels	2,746,000	0%	258,660	0%
PCC segment procurement	889,722,330	36%	302,657,912	28%
Tbm Mining	390,084,621	16%	251,377,917	23%
Mucking operation	56,316,737	2%	131,364,802	12%
Cleanup tunnel	8,659,549	0%	0	0%
Invert concrete	42,289,046	2%	37,156,818	3%
Walkway & bench concrete	88,442,153	4%	6,075,384	1%
Saturday maintenance shift	6,535,709	0%	0	0%
Support	390,030,007	16%	0	0%
Total Cross passages	**220,877,670**	**9%**	**91,671,317**	**8%**
Remove portion of PCC	20,571,585	0%	0	0%
F&I crown bars	21,290,766	0%	0	0%
X-passage excavation	51,265,934	0%	75,319,722	7%
X-passage concrete	101,185,804	0%	10,984,801	1%
F&I rebar	22,238,951	0%	0	0%
F&I waterproofing	4,324,630	0%	5,366,794	0%
Total:	**2,460,171,278**	**100%**	**1,092,295,348**	**100%**

Table 6-6 - Benchmarking of total tunnel costs

Table 6-7 compares the escalated CHSRA costs per RM of the Pacheco Tunnel 2 and the escalated costs per RM of the DB reference project “Finne tunnel”:

	CHSRA costs (Pacheco Pass tunnel No.2 single-track twin tunnel)		ETO costs (Finne tunnel)	
Description	**Total cost in USD/RM**	**% of total**	**Total cost in USD/RM**	**% of Total**
Total Site work allowances	**3,849,412**	**2%**	**2,178,719**	**3%**
Site development	137,123	0%	685,788	1%
Portal development	3,712,290	2%	1,492,931	2%
Total Single-track tunnel	**160,683,550**	**89%**	**71,342,517**	**89%**
Procurement & mob-demob	22,929,975	13%	17,786,934	22%
Starter tunnels	201,763	0%	19,005	0%
PCC segment procurement	65,372,691	36%	22,237,907	28%
TBM mining	28,661,618	16%	18,470,089	23%
Mucking operation	4,137,894	2%	9,652,079	12%
Clean up tunnel	636,264	0%	0	0%
Invert concrete	3,107,204	2%	2,730,112	3%
Walkway & bench concrete	6,498,321	4%	446,391	1%
Saturday maintenance shift	480,214	0%	0	0%
Support	28,657,605	16%	0	0%
Total Cross passages	**16,229,072**	**9%**	**6,735,585**	**8%**
Remove portion of PCC	1,511,505	0%	0	0%
F&I crown bars	1,564,347	0%	0	0%
X-passage excavation	3,766,784	0%	5,534,146	7%
X-passage concrete	7,434,666	0%	807,112	1%
F&I rebar	1,634,015	0%	0	0%
F&I waterproofing	317,754	0%	394,327	0%
Total:	**180,762,034**	**100%**	**80,256,822**	**100%**

Table 6-7 - Benchmarking of tunnel costs per RM

Retaining Walls (SCC 10.08)

UPEs for CHSRA include the wall construction as well as the corresponding earthwork (fill and cut). The benchmark values from DB's CCC, however, do not include earthwork. Hence, the comparability of the UPEs and the CCC is limited.

Table 6-8 shows the cost (minimum, maximum, average) comparison for both a cantilever wall (DB) and a retained fill (CHSRA). Considering the minimum and maximum costs for retaining walls, the calculated average costs show a significant cost difference. The estimated costs from CHSRA are only 46% of DB's usual estimated costs in Germany.

	DB CCC	CHSRA
	Cantilever retaining wall	Retained fill
Year	2017	2017
	USD/sq yd	USD/sq yd
Minimum	1,566	483
Maximum	2,662	1,452
Weighted Average	2,114	967.5

Table 6-8 - Benchmarking of cantilever retaining walls (DB) with retained fill (CHSRA)

Table 6-9 shows the cost (minimum, maximum, average) comparison for both a bored pile wall (DB) and a retained cut (CHSRA). Considering the minimum and maximum costs for bored pile walls, the calculated average costs differ a significantly. The estimated costs from CHSRA are substantially higher than those from DB in Germany.

	DB CCC	CHSR
	Bored pile wall	Retained cut
Year	2017	2017
	USD/sq yd	USD/sq yd
Minimum	885	4,099
Maximum	1,062	5,949
Average	973.5	5,024

Table 6-9 - Benchmarking of bored pile walls (DB) with retained cut (CHSRA)

<u>Track (SCC 10.09, 10.10, 10.14)</u>

Unit costs for track were benchmarked on a high level using cost per mile for a two track line (Table 6-10). Further on, unit costs for specific turnouts were compared (Table 6-11**)**. Finally, detailed unit cost for a section ballasted track from CHSRA and DB were benchmarked (Table 6-12, Table 6-13).

Unit cost for a two track line	DB CCC	VDE 8.2	UIC/SBB	CHSRA
Year	2017	2017	2017	2017
Ballasted track - USD/mi	1,859,384	2,219,412	1,845,191	3,157,581
Direct fixation - USD/mi	3,836,203	3,733,329		3,806,184

Table 6-10 - Benchmarking high-level on costs for track

UPEs for track with direct fixation are in line with comparable DB values. However, CHSRA's unit cost for ballasted track is substantially higher than those from DB.

UPE	Branch speed	Unit	Unit cost CHSRA in USD	Equivalent turnout DB	Branch speed	Unit Cost DB CCC in USD
Ballasted turnout	25	mph	324,880	EW -190-1:9	25	101,551
Ballasted turnout	60	mph	441,732	EW -1200-1:18,5	62	206,751
Ballasted crossover	80	mph	1,270,080	EW -2500-1:26,5	81	389,177
Ballasted crossover	110	mph	1,530,234	EW -10000/4000-1:39	99	401,339
Ballasted turnout	150	mph	2,003,175	n/a		
Direct fixation turnout	80	mph	703,175	EW -2500-1:26,5	81	447,100
Direct fixation turnout	110	mph	989,369	EW -10000/4000-1:39	99	485,450

Table 6-11 - Benchmarking turnouts

Turnouts for CHSRA are estimated to show more than double the cost compared to DB turnouts.

Specific unit cost	Unit	Unit cost DB min	Unit Cost DB max	Unit cost CHSRA
Subballast, place, spread & compact	USD/cu yd	26.14	31.37	47.04
Ballast, place, spread & compact	USD/cu yd	33.47	36.60	58.24
Unload track material & distribute	USD/tf	3.34	4.17	7.84
Electric (flash butt) welding	USD/EA	246.21	273.57	504.00
Install rail on ties, 141 RE	USD/tf	43.36	50.45	145.60
Align & tamp	USD/tf	6.25	8.34	31.36
Rail grinding	USD/tf	3.75	4.59	3.36
Concrete cross ties	USD/EA	68.39	95.75	127.68

Table 6-12 - Detailed benchmarking ballasted track – specific unit cost

Unit costs per yard of two-track line	Unit cost DB min in USD/yd	Unit cost DB max in USD/yd	Unit cost CHSRA in USD/yd
Sub-ballast, place, spread & compact	120.82	144.98	217.37
Ballast, place, spread & compact	164.69	180.13	286.61
Unload track material & distribute	20.02	25.02	47.05
Electric (flash butt) welding	36.94	41.04	75.62
Install rail on ties, 141 RE	260.22	302.75	873.80
Align & tamp	37.53	50.04	188.20
Rail grinding	22.52	27.52	20.16
concrete cross ties	205.22	287.31	383.13
10.09.120 Total ballasted track - two-Track	867.95	1,058.80	2,091.95

Table 6-13 - Detailed benchmarking ballasted track - USD/yd

The comparison of detailed unit costs for ballasted track shows the same results as the high-level benchmarking.

6.3 SCC 20 – Stations, Terminals, and Intermodal

6.3.1 Global Benchmarking

Comparison by section

Section 1: San Francisco to San Jose

Station name	CHSRA station cost [USD Mil 2017]	DB benchmark cost [USD Mil 2017]	Deviation benchmark (CHSRA vs DB)
Transbay Transit Center	550	Not considered	n/a
4th & King	42	Not considered	n/a

Table 6-14 - Stations benchmarking results – Section 1

The stations in Section 1 are not further evaluated, because the Transbay Transit Center (TTC) is not part of the Valley to Valley scope and the 4th & King Station is to be seen only as an allowance. Refer to Chapters 5.3.1.2 and 5.3.2.3 for details.

Section 2: San Jose to Gilroy

Station name	CHSRA station cost [USD Mil 2017]	DB benchmark cost [USD Mil 2017]	Deviation benchmark (CHSRA vs DB)
San Jose Diridon	61	49	+24%
Allowance for Caltrain stations (5x)	121	Not considered	n/a
Gilroy	61	40	+56%

Table 6-15 - Stations benchmarking results – Section 2

An allowance was made for the five Caltrain stations; therefore, they are not further evaluated in this assessment.

Both the San Jose and the Gilroy station deviate from their DB benchmark stations by +24% and +56%, respectively.

Section 5: Madera Acres to Poplar Avenue

Station name	CHSRA station cost [USD Mil 2017]	DB benchmark cost [USD Mil 2017]	Deviation benchmark (CHSRA vs DB)
Madera Acres	30	Not considered	n/a
Fresno	86	47	+87%
Fresno, DB Cost Calculation)	86	49	+76%

Table 6-16 - Stations benchmarking results – Section 5

Although the cost calculation deviates from the benchmark, it still corresponds more closely to the benchmark than the Business Plan cost and can therefore be seen as both validation of the benchmark and confirmation of Montabaur Station as an appropriate benchmark.

Section 6: Poplar Avenue to Bakersfield

Station name	CHSRA station cost [USD Mil 2017]	DB benchmark cost [USD Mil 2017]	Deviation benchmark (CHSRA vs DB)
Poplar Avenue	31	Not considered	n/a
Bakersfield	165	98	+63%
Bakersfield F Street	47	Not considered	n/a

Table 6-17 - Stations benchmarking results – Section 6

The Bakersfield station shows large deviations, exceeding its benchmark by 63%. To adjust the benchmark station such that costs for the elevated platform were included, ETO used the UPE that CHSRA provided for an elevated structure with four tracks (SCC 10.01.255A). This includes all relevant contingencies for seismic and geological risks.

6.4 SCC 30 - Support Facilities, Yard & Shops, Admin, etc.

6.4.1 Global Benchmarking

Heavy Maintenance Facilities (HMF)

As can be seen in Table 6-18 - Benchmarking of cost for Heavy Maintenance Facilities in USD (HMF), estimated DB costs for HMFs based on German manufacturers' information and the European study of railway systems are both in the order of approximately USD100 mil In comparison, the estimated CHSRA costs are approximately 150% higher than the benchmarking costs.

Construction elements correspond with specific DB price elements, resulting in a detailed table of sums to make up the main construction cost. Adding to this are costs for technical installations, heating, electric, ventilation, etc. These costs are included via price elements estimated based on the building's surface area.

CHSRA-heavy maintenance facilities (section 5)	Benchmarking German manufacturer for heavy maintenance facilities	Benchmarking of heavy maintenance facilities according to the "Price and costs in the railway sector" study	Deviation to the manufacturers' estimation	Deviation to the European "Price and costs in the railway sector" study
257,046,758	102,063,240	112,320,000	60%	56%

Table 6-18 - Benchmarking of cost for Heavy Maintenance Facilities in USD (HMF)

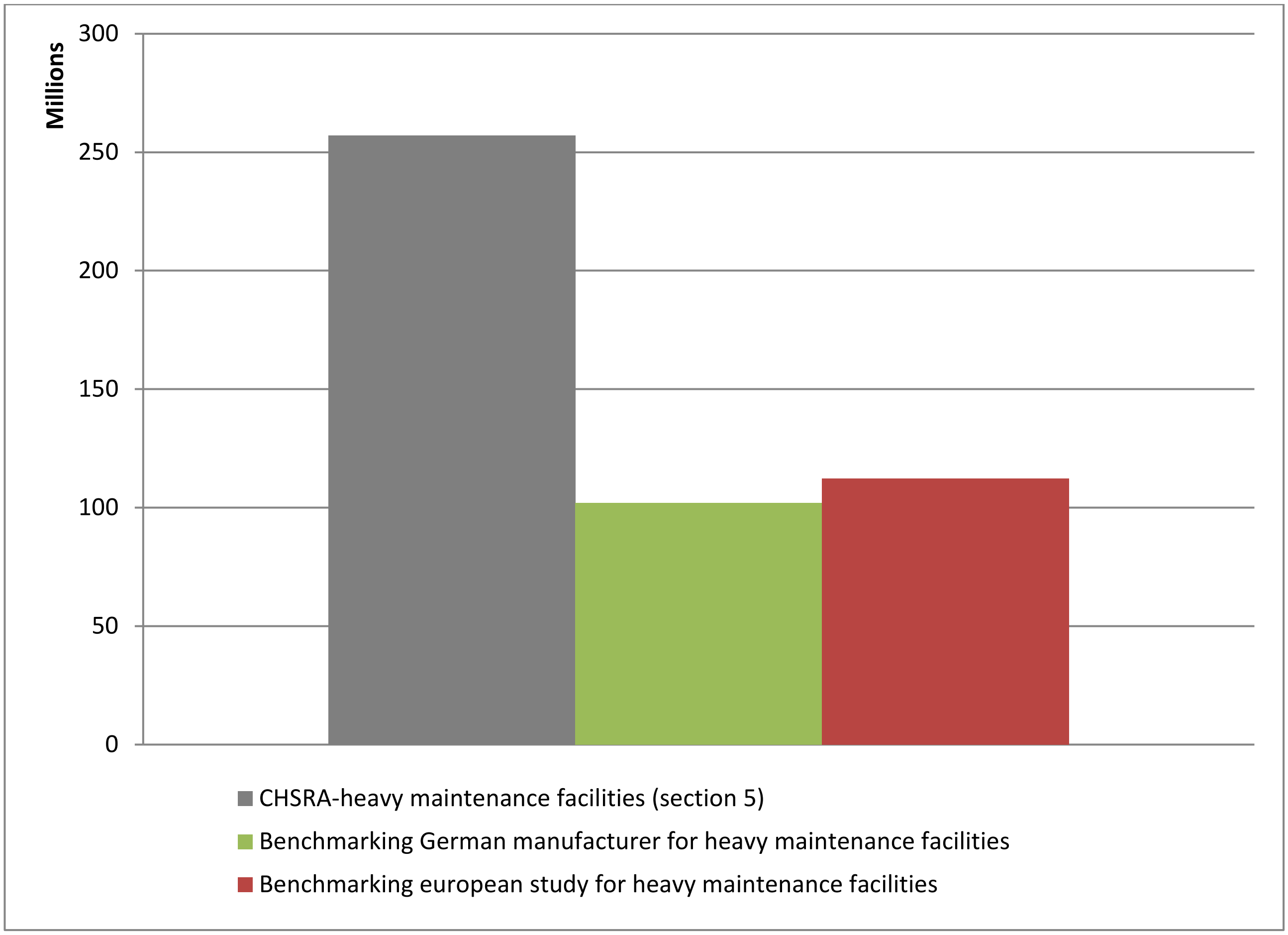


Figure 6-5 - Benchmarking of cost for Heavy Maintenance Facilities in USD (HMF)

<u>Light Maintenance Facilities (LMF)</u>

Similarly, the estimated costs for LMFs, based on the depot of Griesheim and according to the European study, are about equal. By comparison, the CHSRA Business Plan costs and the estimated DB reference costs vary by approximately 50%.

Light maintenance facilities in section 6 (Poplar Avenue to Bakersfield)	Benchmarking depot Griesheim	Benchmarking Previous DB project estimations	Deviation to the European "Price and costs in the railway sector" study	Deviation to Griesheim
119,625,536	72,535,616.59	81,000,000	39%	32%

Table 6-19 - Benchmarking of cost for Light Maintenance Facilities in USD (LMF)

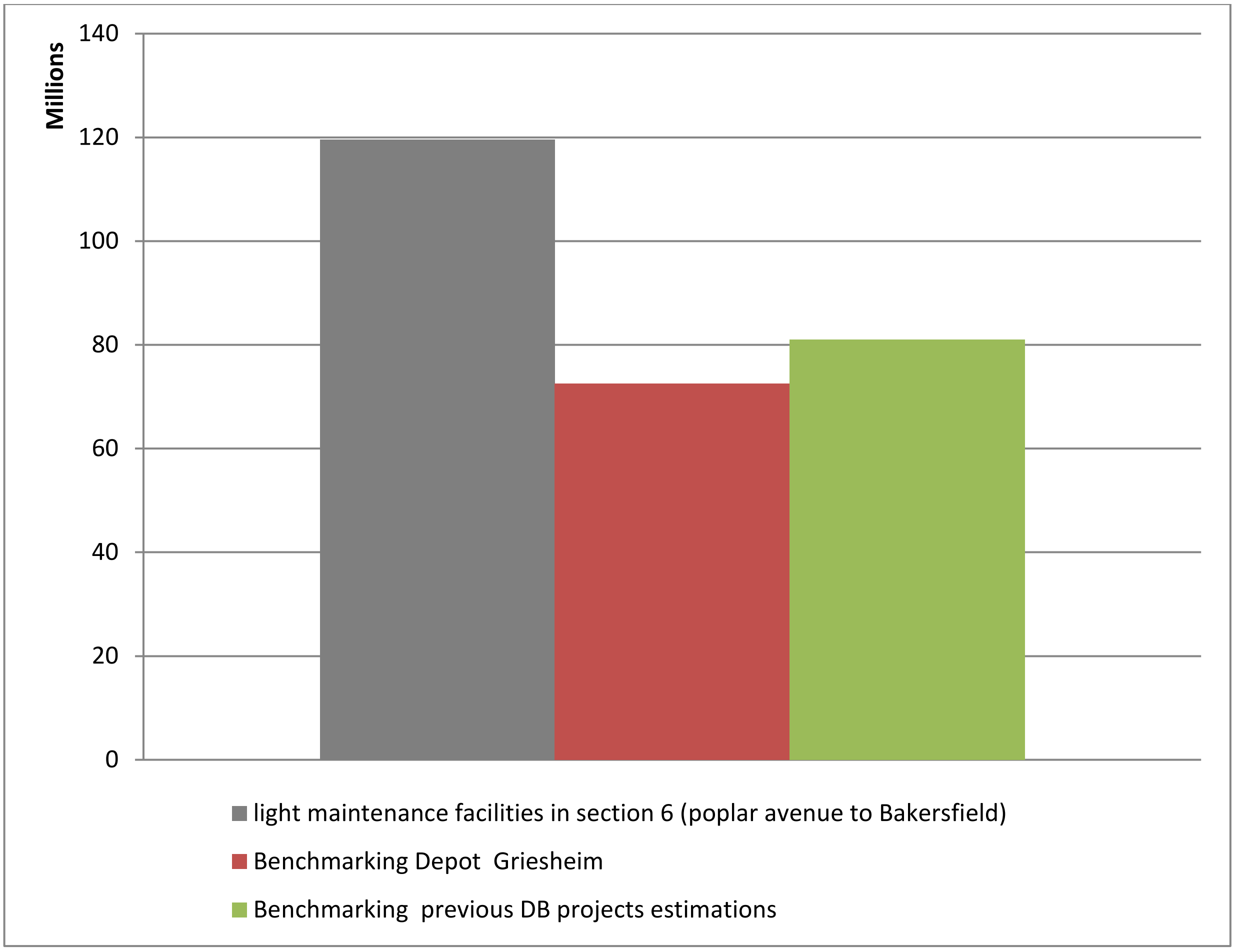


Figure 6-6 - Benchmarking of cost for Light Maintenance Facilities in USD (LMF)

Maintenance of the Way Facilities (MOWF)

The CHSRA and ETO benchmarked costs for MOWFs are similar, as seen in Figure 6-6. CHSRA's estimated costs are on the same level as the benchmarking costs provided by the manufacturers.

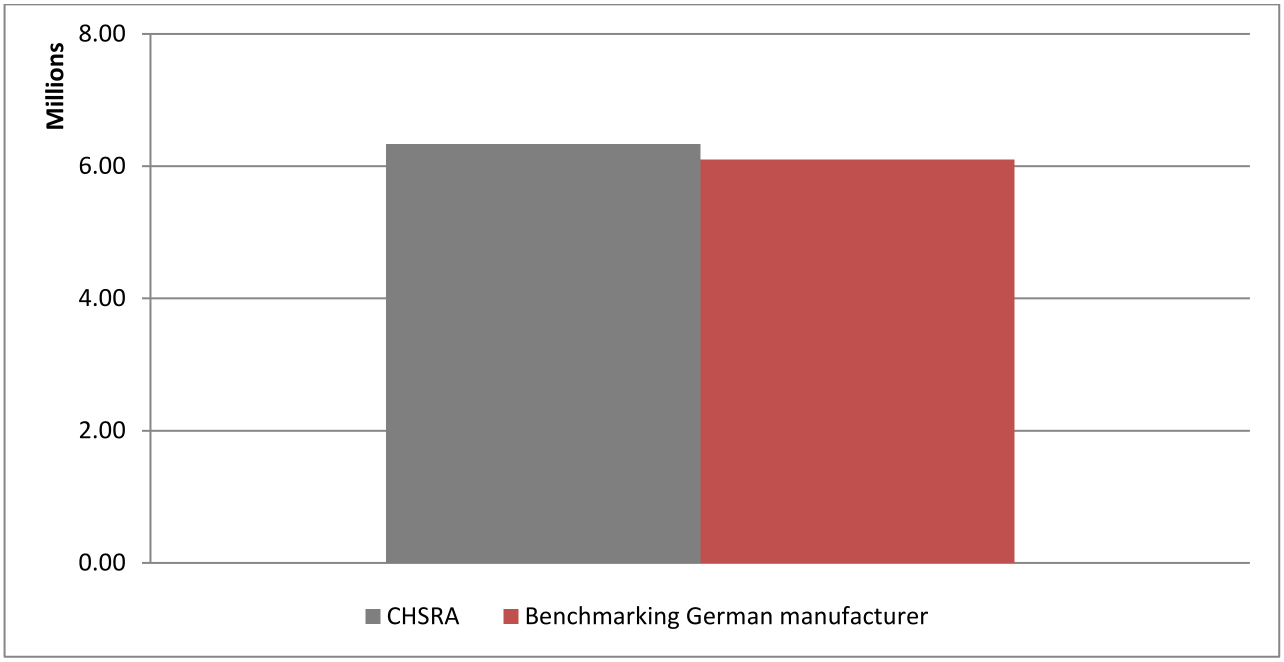


Figure 6-7 Benchmarking of cost for Maintenance of Way Facilities in USD (MoWF)

6.5 SCC 40 - Site Work, Right of Way, Land, Improvements

6.5.1 Global Benchmarking

With the exception of one structure from sub-component “Highway, Pedestrian Overpass, Grade Separations,” The ETO could not fully verify the UPE data for site work and ROW, and so could not identify comparable unit costs in DB’s cost catalogue.

Highway, Pedestrian Overpass, Grade Separations

Table 6-20 compares unit costs for bridges from the CCC and a selected example from the CHSRA (Road 26 Grade Separation).

Unit cost DB from CCC in USD/sq ft	Unit cost CHSRA for Road 26 Grade Separation in USD/sq ft
211	344

Table 6-20 – Benchmarking of cost for Highway/pedestrian overpass/grade separations

Cost Comparison of ‘Road 26 Grade Separation’ and DB’s CCC shows a deviation of 61 %.

6.6 SCC 50 - Communications and Signaling

6.6.1 Global Benchmarking

Comparing Table 5-88 - CHSRA BP 2018 Costs - Signaling and Communications components (SCC 50) in USD with Table 5-97 - Adjusted ETO benchmarking costs for SCC 50 - Signaling & Communications (aligned to BP 2018 Cost Structure) in USD, the results of the benchmark look as follows (Table 6-21):

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
50	AT control	0	-24,454,029	46,320,151	25,675,838	88,136,010	2,980,528	138,658,497
50	Signal power	0	0	0	0	0	0	0
50	On board units signal	0	0	0	0	0	0	0
50	OCC basic Unit	0	-5,721,935	-2,334,383	-1,148,727	2,326,854	-4,793,814	-11,672,005
50.1	COM	10,372,918	-4,031,272	5,214,281	-1,187,863	-14,220,375	-63,040	-3,915,350
50.1	Grade crossings	-9,741,153	-10,176,975	0	0	0	0	-19,918,128
50.1	Hazard systems	0	-0	0	-0	-0	0	0
50.1	Station train approach warning	0	0	0	0	0	0	0
Total per Section		**631,766**	**-44,384,211**	**49,200,050**	**23,339,248**	**76,242,489**	**-1,876,326**	**103,153,015**
Total		**103,153,015**						

Table 6-21 - Benchmark Result - SCC 50 – Signaling & Communications (in USD)

The CHSRA cost estimation is USD 103,153,015 higher than the ETO estimated figures.

6.7 SCC 60 -Traction electrification systems

6.7.1 Global benchmarking

Comparing Table 5-99 - SCC 60 - Traction electrification systems as provided in Business Plan 2018 / V2V with Table 5-103 - ETO Benchmark costs for V2V SCC 60 - traction electrification systems in USD, the results of the benchmark look as follows (Table 6-22):

Sub - Chapter		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total 1 to 6
60.01	Traction power transmission: high voltage	0	0	0	0	0	0	0
60.02	Traction power supply: Substations	0	14,087,814	-2,542,252	-8,346,390	-4,919,750	-23,802,915	-53,699,120
60.03 + 60.04	Traction power distribution: catenary and traction power control	0	53,088,293	36,864,517	25,769,608	-131,062,755	-19,549,659	-266,334,831
Total per section			67,176,107	39,406,769	34,115,998	-135,982,505	-43,352,573	-320,033,952
Total for section 2 to 6			**-320,033,952**					

Table 6-22 - Benchmark Result SCC 60 - Traction Electrification Systems in USD

Since the BP 2018 cost structure for Section 1 was not yet detailed, it was omitted from the benchmark. For sub-chapter 60.01, the costs were taken as provided by CHSRA, Because of pending information from PG&E, the energy provider.

The CHSRA Cost estimation is USD -320,033,952 lower than the ETO estimated figures for the V2V.

6.8 SCC 70 – Vehicles

6.8.1 Global Benchmarking

Benchmarking results are provided in the following tables.

Illustration			
Name	**Alstom AGV**	**Alstom TGV Duplex**	**AnsaldoBreda V250**
TSI conformity (base design capability)	yes	yes (with modifications)	yes (with modifications)
UIC guidelines compatibility	yes (with modifications)	yes (with modifications)	yes (with modifications)
Suitable for CHSRA	yes	yes	no
Engineering comment	very unique design no product line follow-up cancelled by the supplier	Double deck, three catenary systems available	max speed 250/150 km/h
Design capable with 220 mph (360 km/h)	yes	yes	no
Estimated degree of design modification for CHSRA	medium	medium	high
Supplier's high -speed experience references	high	high	low
Number of Train sets	25	30	12
Year of Procurement	2008	2012	2004
Contract Amount (original)	EUR 650,000,000	EUR 900,000,000	EUR 336,000,000
Adjusted Contract Amount to 2017 (in USD)	USD 889,415,212	USD 1,136,564,522	USD 501,518,252
Total Amount per Train sets (adjusted to 2017 in USD)	USD 35,576,608	USD 37,885,484	USD 41,793,187.64
Picture source	https://www.railway-technology.com/projects/alstom-agv-very-high-speed-trains-france/	Alaric Favier, own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19808904	Arnold de Vries https://commons.wikimedia.org/w/index.php?curid=8805902

Table 6-23 – Benchmarking results for Alstom AGV, Alstom TGV Duplex, & AnsaldoBreda V250

Illustration			
Name	AnsaldoBreda/Bombardier Zefiro V300	Bombardier Zefiro 380	CSR CRH380A
TSI conformity (base design capability)	yes	Yes (with modifications)	no
UIC guidelines compatibility	yes (with modifications)	no	no
Suitable for CHSRA	yes	unknown	unknown
Engineering comment	poor quality record of supplier	wide loading gauge	wide loading gauge
Design capable with 220 mph (360 km/h)	(yes)	yes	yes
Estimated degree of design modification for CHSRA	medium	high	high, non TSI
Supplier's high- speed experience references	low	medium	high, not international
Number of Train sets	50	140	9
Year of Procurement	2010	2009	2012
Contract Amount (original)	EUR 1,540,000,000	CNY 27,400,000,000	CNY 1,300,000,000
Adjusted Contract Amount to 2017 (in USD)	USD 2,042,742,034	USD 5,157,081,953	USD 219,567,902
Total Amount per Train sets (adjusted to 2017 in USD)	USD 40,854,841	USD 36,836,300	USD 24,396,434
Picture source	Netse Silva https://commons.wikimedia.org/w/index.php?curid=45679151	https://upload.wikimedia.org/wikipedia/commons/b/b2/	Jucember – Own work, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=17893723

Table 6-24 - Benchmarking results for AnsaldoBreda/Bombardier Zefiro V300, Bombardier Zefiro 380, & CSR CRH380A

Illustration			
Name	**Japan Series E5**	**Japan Series N700A**	**Rotem KTX-II**
TSI conformity (base design capability)	no	no	no
UIC guidelines compatibility	no	no	yes (with modifications)
Suitable for CHSRA	unknown	unknown	yes
Engineering comment	wide loading gauge, double deck	wide loading gauge	modified TGV replica
Design capable with 220 mph (360 km/h)	yes (with modifications)	yes (with modifications)	no
Estimated degree of design modification for CHSRA	high, non TSI	high, non TSI	high, non TSI
Supplier's high -speed experience references	high, not international	high, not international	unknown
Number of Train sets	5	36	10
Year of Procurement	2014	2013	2014
Contract Amount (original)	JPY 18,000,000,000	JPY 88,000,000,000	KRW 342,200,000,000
Adjusted Contract Amount to 2017 (in USD)	USD 161,989,444	USD 810,787,556	USD 333,359,569
Total Amount per Train sets (adjusted to 2017 in USD)	USD 32,397,889	USD 22,521,877	USD 33,335,957
Picture source	https://upload.wikimedia.org/wikipedia/commons/7/74/E5_S11_Sendal_20090725.JPG	https://upload.wikimedia.org/wikipedia/commons/9/97/JRW_N700-7000series_S1.jpg	Minseong Kom – Own work CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37103539

Table 6-25 - Benchmarking results for Japan Series E5, Japan Series N700A, & Rotem KTX-II

Illustration			
Name	**Siemens Velaro CN**	**Siemens Velaro D**	**Siemens Velaro E**
TSI conformity (base design capability)	yes (with modifications)	yes	no
UIC guidelines compatibility	no	yes	yes
Suitable for CHSRA	unknown	yes	yes
Engineering comment	wide loading gauge	four catenary systems	two catenary systems
Design capable with 220 mph (360 km/h)	yes (with modifications)	yes (with modifications)	yes
Estimated degree of design modification for CHSRA	high, non TSI	medium	high, non TSI
Supplier's high -speed experience references	high	high	high
Number of Train sets	140	15	26
Year of Procurement	2009	2008	2005
Contract Amount (original)	CNY 40,800,000,000	EUR 500,000,000	EUR 650,000,000
Adjusted Contract Amount to 2017 (in USD)	USD 7,679,158,529	USD 684,165,548	USD 949,090,465
Total Amount per Train sets (adjusted to 2017 in USD)	USD 54,851,132	USD 45,611,037	USD 36,503,479
Picture source	https://de.wikipedia.org/wiki/CRH3#/media/File:CRH3_in_Tianjin.JPG	DB AG	https://upload.wikimedia.org/wikipedia/commons/1/10/Renfe_clase_103.JPG

Table 6-26 - Benchmarking results for Siemens Velaro CN, Siemens Velaro D, & Siemens Velaro E

Illustration			
Name	**Siemens Velaro e320**	**Siemens Velaro TR**	**Talgo 350**
TSI conformity (base design capability)	yes	yes	yes (with modifications)
UIC guidelines compatibility	yes	yes	yes (with modifications)
Suitable for CHSRA	yes (with modifications)	yes	yes
Engineering comment	400m trainset	nearly identical with VelaroD	very unique design; expensive maintenance facilities and spare parts
Design capable with 220 mph (360 km/h)	yes (with modifications)	yes (with modifications)	yes
Estimated degree of design modification for CHSRA	medium	medium	medium
Supplier's high -speed experience references	high	high	special customized solutions worldwide
Number of Train sets	20	7	35
Year of Procurement	2010	2013	2011
Contract Amount (original)	EUR 600,000,000	EUR 285,000,000	EUR 1,600,000,000
Adjusted Contract Amount to 2017 (in USD)	USD 795,873,520	USD 356,919,790	USD 2,065,486,510
Total Amount per Train sets (adjusted to 2017 in USD)	USD 39,793,676	USD 50,988,541	USD 59,013,900
Picture source	https://www.hochgeschwindigkeitszuege.com/england/fotos-england/eurostar-e320-langzug-01-fhd.jpg	By Mikhail krivyy – TrainPix, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=55022953	https://upload.wikimedia.org/wikipedia/commons/4/46/Talgo_350.jpg

Table 6-27 - Benchmarking results for Siemens Velaro e320, Siemens Velaro TR, & Talgo 350

6.9 SCC 80 - Professional Services (associated with categories 10-60)

6.9.1 Global Benchmarking

The costs of SCC 80 were calculated as a percentage of the overall construction costs. Therefore, this section shows values in percentages, not in USD. Deviations are shown as percentage-of-percentage values. To convert the deviations into USD, multiply the overall construction costs by the percentage of overall construction costs given in the tables below.

Preliminary Engineering / Project Environmental (SCC 80.02)

The preliminary engineering phase for HOAI adds up to 2.2 percent of the overall construction costs. Considering the environmental resource studies, which add 0.5 percentage points, the overall costs add up to 2.7 percent of the construction costs.

Final Design (SCC 80.03)

ETO estimated the cost for final design at 5.9 percent of the overall construction cost. An additional 1% was added for project management services by the contractor during final design (e.g. risk studies, project management, stakeholder studies, etc.). Therefore, these costs are added to the final design and not the project management SCC, resulting in 6.9% of the overall construction costs for the final design.

Project Management for Design and Construction (SCC 80.04)

In accordance with CHSRA, the cost for SCC 80.04 Project Management for Design and Construction were considered as program management costs, which cannot be allocated to a single project. Therefore, the assumed costs in the benchmark (8% in total) were reduced by 3.5% to 4.5% in total.

Construction Administration & Management (SCC 80.05)

SCC 80.05 only contains costs associated with ongoing CHSRA projects (CP1 to CP4). For future projects, the benchmarking value was reduced by 3.0% of the overall construction costs. This results in 4.7% of the overall construction costs.

Professional liability and other non-construction insurance (SCC 80.06)

Insurances are included in the contractor’s pricing. Therefore, the 2.0% for SCC 80.06 is not included.

Legal; permits; review fees by other agencies, cities, etc. (SCC 80.07)

The benchmark assumes 0.25% for SCC 80.07.

Surveys, testing, investigation (SCC 80.08)

CHSRA is treating these costs as covered by the contractors. Furthermore, the costs are part of SCC 80.05.

Engineering inspection (SCC 80.09)

CHSRA is treating these costs as covered by the contractors. Furthermore, the costs are part of SCC 80.05.

Startup (SCC 80.10)

SCC 80.10 considered the start-up costs, including Test & Commissioning, at 0.5 percent.

Benchmarking results are provided in the following table.

SCC 80 prof services	CHSRA assumed value [%]	ETO benchmark value [%]	Deviation benchmark (CHSRA vs DB) [%]
80.02	2.5	2.7	-0.2
80.03	6	6.9	-0.9
80.04	4	4.5	-0.5
80.05	3	4.7	-1.7
80.06	0	0	0
80.07	0.5	0.25	0.25
80.08	0	0	0
80.09	0	0	0
80.10	0.5	0.5	0
Total	**16.5**	**19.55**	**-3.05**

Table 6-28 – SCC 80 benchmark results

7 Deviations Analysis

7.1 Summary

Based on the outcomes described in the previous chapter, the analysis of the benchmarking results provides a more detailed view:

SCC 10:

Viaducts and bridges (SCC 10.01-10.03): The significant cost deviations are caused by the necessity to design earthquake-resistant structures. The benchmark projects from Germany do not consider those risks, since seismic activity is virtually negligible there. However, the increase of costs does not exclusively result from seismic-resistant design, but also from a lack of geotechnical information. Knowing the specific ground conditions would enable CHSRA and the ETO to plan viaduct and bridges more dependent on the actual requirements.

Earthwork and drainage (SCC 10.04-10.06): CHSRA unit costs lie within an acceptable range of accuracy. However, also here, ETO could not consider important information such as load, soil conditions, and transport distances in the benchmark because respective data was not at hand.

Tunnels (SCC 10.07): Equally to bridges, seismic-resistant design and unclear geotechnical information, with their inherent current budget reserves, are the main cost drivers. Further, labor-related costs and different market prices could be identified as reasons for the cost deviation.

Retaining walls (SCC 10.08): CHSRA's unit costs vary greatly by almost a factor of 10 between the lowest and the highest values.

Track (SCC 10.09, 10.10 and 10.14): The comparison of the overall cost per track mile shows that the estimates for ballasted track lie above the benchmark. The biggest deviations result from the sub-components "Install Rail on Ties, 141 RE" (including the cost of steel) and "Align & Tamp". Concerning the track with direct fixation, all sources show almost identical costs.

SCC 20:

Apart from geological information, which would be valuable here as well, specific station functions and the operational requirements are yet to define. Detailed benchmarking is only possible with data that is more precise.

SCC30:

The ETO could not verify and allocate the provided data with regard to specific cost drivers. Consequently, benchmarking was limited to lump-sums here.

The Valley to Valley concept includes a total of 14 stations, five of which are Caltrain stations. Temporary stations, and stations for which only an allowance is included in the baseline costs, have not been further evaluated, as instructed by CHSRA. ETO focused on the San Jose, Gilroy, Fresno, and Bakersfield stations for benchmarking only.

The benchmarking has shown that the provided Business Plan costs deviate from their respective benchmarks by +24 to +87%. While the stations' very early desing stage may account for a majority of the deviations, further significant factors are likely to include the unspecific design manual for individual station functions and operational requirements and the geological conditions, since no geological investigation was provided.

With station designs, more specific design requirements, unit costs, and operational requirements in hand, the overall Business Plan costs can be further validated in the next phase.

SCC40:

The benchmark could only be carried out for the Road 26 Grade Separation. Here, ETO assumes the same cost drivers as for viaducts and bridges.

SCC50:

SIG and COM facilities calculated as benchmarks are lower than the values contained in the CHSRA calculations. However, the benchmark may still underestimate the actual costs, since the treatment of grade crossings in Section 1 and Section 2 is still undetermined. Additional effects, such as road alignment adaptions, could still not be integrated into the calculation yet because respective data were not available.

As result of the identified deviations between ETO benchmarking and CHSRA Business Plan 2018 / V2V cost data, the following can be stated:

1. The calculated ETO benchmark costs for SCC 50 are only 88% of the estimated costs given in CHSRA Business Plan 2018 / V2V Costs for SCC 50.
2. The benchmarked costs could potentially increase by approximately 30%, because of unknown conditions, such as:
    - Operational conflicts at the level crossings in Sections 1 and 2
    - Design modification of Section 2 from elevated to at-grade
    - Relocation of Bakersfield Station to section 6

The ETO benchmark for SCC 50 does not contain any contingency.

SCC60:

The ETO overall cost estimate for SCC 60 (considering Section 2 to Section 6 only) is 22% higher than the reference cost estimate of CHSRA. Nevertheless, the CHSRA's cost assumption for SCC 60 appears realistic with regard to the technical solution in the BP 2018. ETO highlights that a possible cost increase may occur, because the planning of powerlines and catenary systems has not reached an advanced level yet.

The ETO wants to point out that costs for SCC 60.01 and 60.04 in Section 6 (Poplar Avenue to Bakersfield) could not be verified. Therefore, costs in section 6 for SCC 60.01 were set to USD 0 under the assumption that no interconnection is needed (TPS is not required).

In addtion, the ETO could not verify why SCC 60.04 in Section 6 was assigned a value of USD 0. The Bakersfield station will require a traction power control (SCADA system). Therefore, the ETO considered the costs as such.

SCC70:

Given the wide range of costs for trains (see chapter 7.8) it becomes apparent that detailed technical prerequisites must be defined in order to further improve benchmark assessments. A reliable estimation was almost impossible at this time. It is also necessary to include future developments of trainsets that will be available by the time of the CHSRA inauguration. Apart from those circumstances, import policies will also play a role in the trainset purchase decision.

SCC80:

The allocations for professional services have the same order of magnitude. The accumulated deviations for all professional services account for a total of 3.5 percent and 15.6 percent relative to the ETO benchmark values, which can be attributed to different contractual parameters in the respective countries (e.g. ROW, legal parameters, permitting, labor laws, etc.).

7.2 SCC 10 - Track structures and track

7.2.1 Qualitative deviation analysis

Viaducts and bridges (SCC 10.01, 10.02, 10.03)

Seismic conditions were identified as the main driver for the higher costs, which require the structures to be designed and built accordingly. Sections 4 and 6 are located in a moderate seismic zone, and therefore have less stringent design requirements.

The seismic design requires deeper piles, and the pier-to-aerial structure connections must be stronger than is customary on DB reference projects, because of the lack of seismic activity in that region. Section 7.2 presents a deviations analysis.

As has been shown, the costs drivers for CHSRA projects are the foundations, which are significantly more expensive than those of DB's reference projects:

1. The significant costs deviations are caused by the necessity to design earthquake-resistant structures. In case of earthquakes, pile caps and the underground piles encounter high internal forces caused by ground shaking. Therefore, these structural parts of the viaducts must be designed more robustly to withstand larger movements. Subsequently, they require more materials (e.g. concrete and rebar) in comparison to the DB reference projects. Figure 7-1 highlights the critical structural parts of the viaduct.

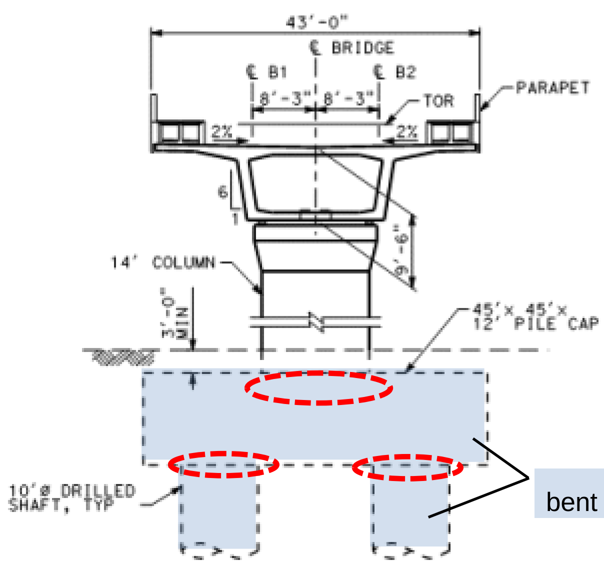


Figure 7-1 - HST standard two-track aerial viaduct - typical section with substructure in high seismic zones

2. In high seismic zones, in which CHSRA viaducts and bridges are located, bent construction is the standard solution for foundations. In zones with lower seismicity, mono-piles are preferred. Pile depth and diameter are much larger than those used on DB's reference projects. In

addition, special earthquake-related design details are required, e.g. isolation casings and bents for reducing shear forces.

3.

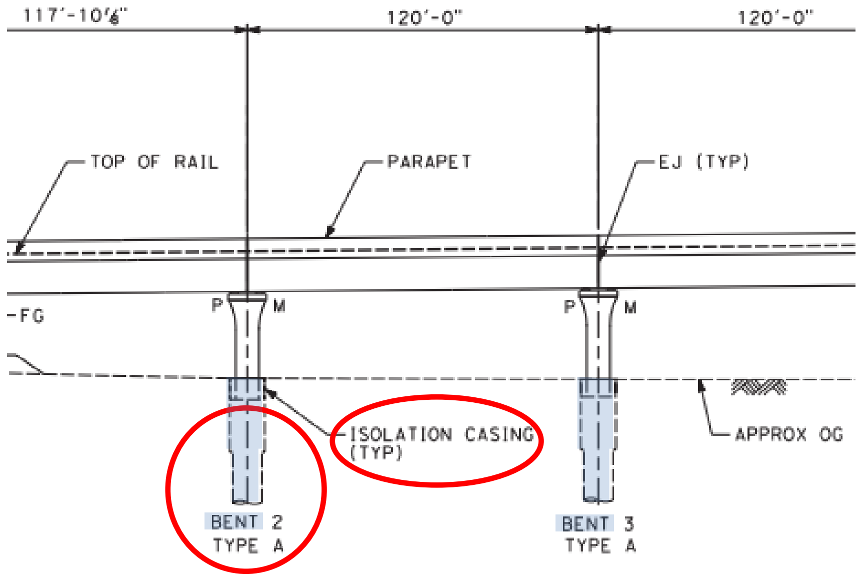


Figure 7-2 – High-speed rail standard aerial viaduct longitudinal section showing typical situation of isolation casings and bents

Design details for earthquake resistant structures, as shown in Figure 7-2, are necessary in every bridge axis at CHSRA elevated structures. In contrast, this is not required for DB structures.

Figure 7-3 - Isolation casings at mono-pile heads as built [picture taken at site visit on 08/02/2018]

"Foundations: *Foundations consist of large-diameter pile groups with pile caps. The piles are 10 sq. ft. cast-in-drilled-hole (CIDH) reinforced concrete piles in groups of four piles per column. Pile caps consist of 45 sq. ft. cast-in-place reinforced concrete pile caps with a depth of 12 ft. for simply supported spans up to 130 ft. in length. For spans greater than 130 ft. in length, larger pile caps and piles are required, and are determined on an individual basis according to the span configuration. The piles and pile caps are larger than indicated in Technical Memorandum (TM) 200.11 due to larger operating basis earthquake loads compared to TM 200.11." (extract from: San Jose to Merced Project Section: San Jose to Central Valley Wye Advance Planning Study Technical Report–DRAFT PEPD Page | 5-1)"*

Earthwork and drainage (SCC 10.04, 10.05, 10.06)

The available data for benchmarking earthwork was limited to a comparison of unit cost only. For the same reason, drainage was not included in the benchmarking.

CHSRA unit costs for embankment earthwork and cuts on a cubic yard basis lie in the range between the upper and lower cost of the CCC.

Unit costs for earthwork for embankments and cuts are prevailing depending on load and settlement specifications, soil conditions on site, and transport distances. No corresponding information is currently available from CHSRA, so no further in-depth benchmarking was performed.

The unit costs for at-grade trackbed infill vary widely, between 14.29 USD/cu yd and 97.16 USD/cu yd, with an average of 51.31 USD/cu yd. Compared with the CCC, the CHSRA values show a much wider range. The lower limit lies 23% under the minimum cost of the CCC. The maximum costs are around three times higher than the CCC. Based on the available information, we could not identify any specific reasons for the wide range of unit costs. Cost differences may be influenced by the attributes of the soil to be replaced and transported.

Tunnels (SCC 10.07)

There are significant deviations between the estimated CHSRA tunnel costs and the escalated cost of the Finne Tunnel. Escalated CHSRA costs of the Pacheco Tunnel 2 are 125% higher than the escalated costs of the DB reference “Finne Tunnel”. Possible reasons for this great difference were identified in chapter 7.2.2. Therefore, the CHSRA costs of the Pacheco Tunnels seem too high. Probably some costs are based on higher risk contingencies because of uncertainties at this point in the design stage. Possible causes of these deviations are:

- The Pacheco Tunnel is located in a highly active seismic zone. This seismic loading must be considered in the structural analysis of the tunnel lining and potentially increases the thickness of the lining and the amount of reinforcement.
- The segmental lining must resist a maximum hydrostatic head of up to 1,000 feet. Both segments and gaskets must resist this water pressure to make the lining waterproof.
- Different material market prices in the United States and Germany
- Labor related cost
- High indirect cost
- Profit and risk markup (15% of total construction costs or 50% of the expected labor costs)
- Low level of design, with a lot of uncertainties remaining
- No tunnel-specific geotechnical investigations have been performed, therefore, additional budget was allocated for risk mitigation measures associated with these unverified ground conditions

Retaining walls (SCC 10.08)

The available data limited the benchmarking of retaining walls to a comparison of unit cost only. Further on, UPEs for CHSRA include the wall construction as well as the corresponding earthwork (fill and cut). The benchmark values from DB’s CCC do not include earthwork. Hence, the comparability of the UPEs and the CCC is limited.

CHSRA unit costs for retaining walls vary by almost a factor of 10 between the lowest and highest cost. Costs for retained fill are lower than DB’s cost for cantilever retaining walls. On the other hand, the unit costs for retained cut exceed by far DB’s corresponding values for bored pile walls.

Track (SCC 10.09, 10.10, 10.14)

The comparison of the overall cost per track mile shows that the estimates for ballasted track lie 70% above the costs of the CCC and are 42% higher than track cost for VDE 8.2. For track with direct fixation all three sources show almost identical cost.

For this reason, unit costs for ballasted track have undergone a more detailed analysis. A section of 12.89 miles of double track was split into eight sub-components. The sub-components were compared with corresponding costs from DB reference projects. The biggest deviations result from the sub-components “Install Rail on Ties, 141 RE” (including the cost of steel) and “Align & Tamp”.

The costs for the “Install Rail on Ties, 141 RE” are 189% to 236% higher than the latest values from DB data. The price of steel, transport costs, and personnel and equipment cost for mounting should influence this cost. Since this sub-component is responsible for around 30% of the overall cost of ballasted track, an even more detailed cost breakdown is recommended to identify specific cost drivers.

The CHSRA cost for turnouts exceeds the DB reference values by between 57% and 281%. The costs appear to be very high, even under the assumption that a portion of these assets could be imported. ETO could not verify the cause.

7.2.2 Quantitative estimation of deviations

Viaducts and bridges (SCC 10.01, 10.02, 10.03)

Further analysis proves that mono-piles make up to 46% of total costs.

Description	Takeoff quantity		Unit Cost in USD		Total Cost in USD	% of total cost
Gilroy to Carlucci Road						
Elevated structure - one track (20 ft avg. pier ht) - 110 ft spacing	0.11	RM				
Structural concrete, in place, aerial footing	1,996.80	cu yd	436.80	per cu yd	872,202	9%
Drilled shaft, 120 in dia, un-cased in soft rock	1,560.00	vlf	2,912.00	pervlf	4,542,720	45%
10.01.122 Elevated structure - one track (20 ft avg. pier ht) - 110 ft spacing	0.11	RM	89,926,000	per RM	9,891,860	
Elevated structure - one track (30 ft avg. pier ht) - 110 ft spacing	0.06	RM				
Structural concrete, in place, aerial footing	1,075.20	cu yd	436.80	per cu yd	469,647	8%
Drilled shaft, 120’’ in dia, un-cased in soft rock	840.00	vlf	2,912.00	per vlf	2,446,080	44%
10.01.123 Elevated structure - one track (30 ft avg. pier ht) - 110 ft spacing	0.06	RM	90,241,033	per RM	5,414,462	
Elevated Structure - 1 Track (40 ft Avg. Pier Ht)	0.25	RM				
Structural concrete, in place, aerial footing	4,517.24	cu yd	436.80	per cu yd	1,973,129	9%

Description	Takeoff quantity		Unit Cost in USD		Total Cost in USD	% of total cost
Drilled shaft, 120 in dia, un-cased in soft rock	3,529.09	vlf	2,912.00	pervl f	10,276,713	45%
10.01.124 Elevated structure - one track (40 ft avg. pier ht)	0.25	RM	92,471,208	per RM	23,117,802	
Elevated structure - one track (50 ft avg. pier ht) - 110 ft spacing	0.03	RM				
Structural concrete, in place, aerial footing	488,.3	cu yd	436.80	per cu yd	213,476	8%
Drilled shaft, 120 in dia, un-cased in soft rock	381.82	vlf	2,912.00	per vlf	1,111,854	42%
10.01.125 Elevated structure - one track (50 ft avg. pier ht) - 110 ft spacing	0.03	RM	84,706,233	per RM	2,541,187	
Elevated structure - one track (50 ft avg. pier ht) - 110 ft spacing	1.71	RM				
Structural concrete, in place, aerial footing	31,446.11	cu yd	436.80	per cu yd	13,735,660	8%
Drilled shaft, 120 in dia, un-cased in soft rock	24,567.27	vlf	2,912.00	per vlf	71,539,899	43%
10.01.125 elevated structure - one track (50 ft avg. pier ht) - 110 ft spacing	1.71	RM	97,124,664		166,083,17 6	
Elevated structure - one track (70 ft avg. pier ht) - 110 ft spacing	0.07	RM				
Structural concrete, in place, aerial footing	1,214,84	cu yd	436.80	per cu yd	530,640	8%
Drilled shaft, 120 in dia, un-cased in soft rock	949.09	vlf	2,912.00	per vlf	2,763,753	43%
10.01.127 Elevated Structure - one track (70 ft Avg. Pier Ht) - 110 ft Spacing	0.07	RM	93,081,357	per RM	6,515,695	
Elevated Structure - two track (20 ft Avg. Pier Ht)	0.04	RM				
Structural Concrete, In Place, Aerial Footing	1,636,36	cu yd	436.80	per cu yd	714,764	16%
Drilled Shaft, 120 in Dia, un-cased in soft rock	545.46	vlf	2,912.00	per vlf	1,588,365	36%
10.01.222 Elevated Structure - two track (20 ft Avg. Pier Ht)	0.04	RM	117,445,20 0	per RM	4,697,808	

Description	Takeoff quantity		Unit Cost in USD		Total Cost in USD	% of total cost
Elevated Structure - 2 Track (30 ft Avg. Pier Ht) – 110 ft Spacing	0.10	RM				
Structural Concrete, In Place, Aerial Footing	4,500.00	cu yd	436.80	per cu yd	1,965,600	15%
Drilled Shaft, 120 in Dia, un-cased in soft rock	1,500.00	vlf	2,912.00	per vlf	4,368,000	33%
10.01.223a Elevated structure - two track (30 ft Avg. pier ht) - 110 ft spacing	0.10	RM	132,272,290	per RM	13,227,229	
Elevated structure - one track (20 ft avg. pier ht) - 110 ft spacing	0.60	RM				
Structural concrete, in place, aerial footing	11,115.06	cu yd	436.80	per cu yd	4,855,056	9%
Drilled shaft, 120 in dia, un-cased in soft rock	8,683.64	vlf	2,912.00	per vlf	25,286,748	46%
10.01.122 Elevated structure - one track (20 ft avg. pier ht) - 110 ft spacing	0.60	RM	91,770,635	per RM	55,062,381	
Elevated structure - one track (30 ft avg. pier ht) - 110 ft spacing	0.38	RM				
Structural concrete, in place, aerial footing	7,058.62	cu yd	436.80	per cu yd	3,083,204	9%
Drilled shaft, 120 in dia, un-cased in soft rock	5,514.55	vlf	2,912.00	per vlf	16,058,355	45%
10.01.123 Elevated structure - one track (30 ft avg. pier ht) - 110 ft spacing	0.38	RM	93,541,016	per RM	35,545,586	

Table 7-1 - Share of drilled shafts to total costs of structure

A detailed analysis of the total costs for elevated structures in the Gilroy to Carlucci Road section shows that foundations make up a large share of the structure cost compared to ETO reference projects.

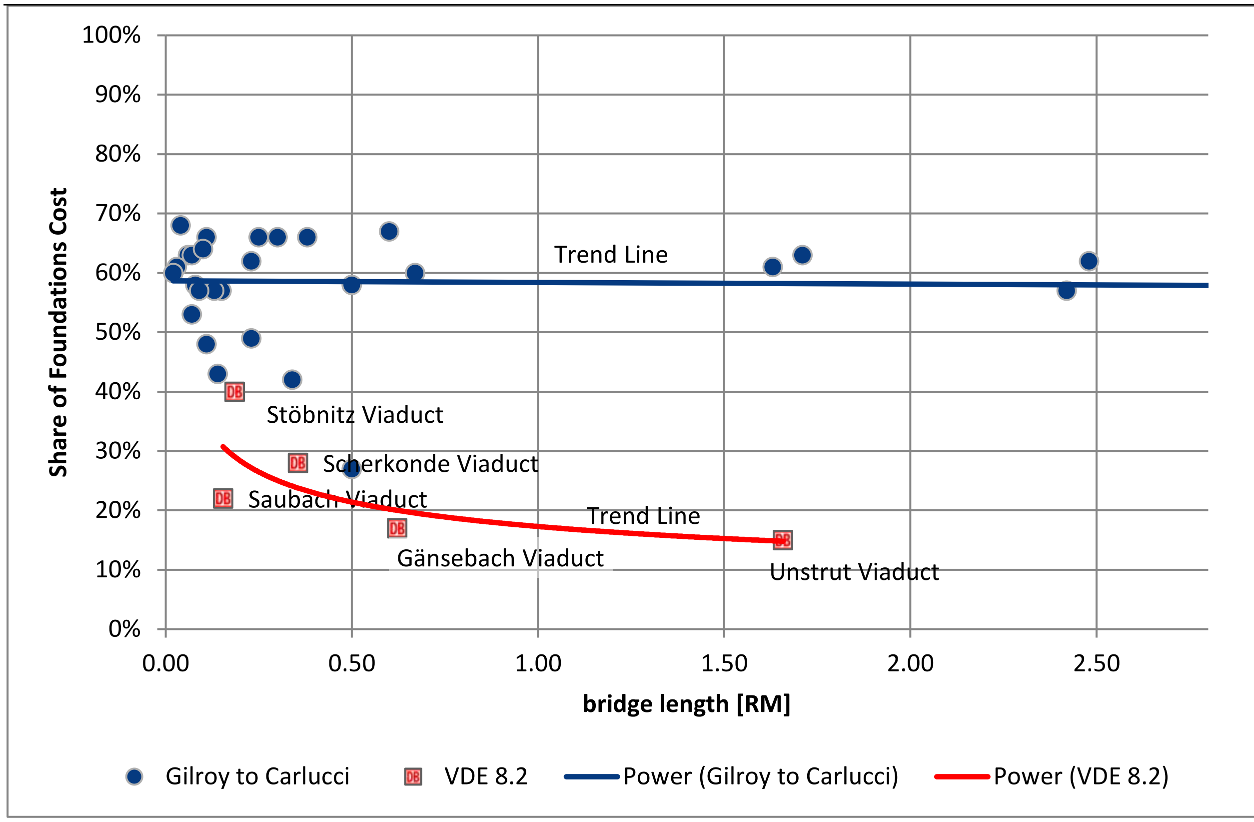


Figure 7-4 – Ratio of bridge length (RM) to share of foundations cost

Earthwork and drainage

Conversion to Imperiai Units	CCC min	CCC max	CHSRA	Deviation from CCC min (%)	Deviation from CCC max (%)
Year	2017	2017	2017		
	USD/cu yd	USD/cu yd	USD/cu yd		
Topsoil	included	included	3.36		
Cut	13.02	22.78	10.72	-18	-53
Embankment	13.02	26.04	15.68	20	20
Subballast	n/a	n/a	47.04		

Table 7-2 - Unit cost deviations for earthwork and drainage (SCC 10.04, 10.05, 10.06)

CHSRA unit costs for embankment earthwork and cuts on a cubic yard basis lie in the range between the upper and lower cost of the CCC.

	CCC min	CCC max	CHSRA min	CHSRA max	CHSRA weighted average
Year	2017	2017	2017	2017	2017
	USD/cu yd	USD/cu yd	USD/cu yd	USD/cu yd	USD/cu yd
At-grade trackbed infill	18.60	31.61	14.29	97.16	51.31
Deviation to CCC (%)			to CCC min	to CCC max	
			-23	207	

Table 7-3 - Unit cost deviations for at-grade trackbed infill

The CHSRA unit costs for at-grade trackbed infill vary widely.

<u>Tunnels</u> (SCC 10.07)
The quantitative estimates of the tunnel cost deviations are:

	CHSRA Costs	ETO Costs		
Description	**Total cost per RM in USD**	**Total cost per RM in USD**	**Delta (cost) per RM in USD**	**Delta (%)**
Site work allowances	3,849,412	2,178,719	1,670,693	77%
Site development	137,123	685,788	(548,665)	
Portal development	3,712,290	1,492,931	2,219,358	
Single track tunnel	160,683,550	71,342,517	89,341,032	125%
Procurement & mob-demob	22,929,975	17,786,934	5,143,041	
Starter tunnels	201,763	19,005	182,758	
Pcc segment procurement	65,372,691	22,237,907	43,134,785	
TBM mining	28,661,618	18,470,089	10,191,529	
Mucking operation	4,137,894	9,652,079	(5,514,186)	
Cleanup tunnel	636,264	-	636,264	
Invert concrete	3,107,204	2,730,112	377,092	
Walkway & bench concrete	6,498,321	446,391	6,051,930	
Saturday maintenance shift	480,214		480,214	
Support	28,657,605		28,657,605	
Cross passages	16,229,072	6,735,585	9,493,487	141%

	CHSRA Costs	ETO Costs		
Description	**Total cost per RM in USD**	**Total cost per RM in USD**	**Delta (cost) per RM in USD**	**Delta (%)**
Remove portion of Pcc	1,511,505		1,511,505	
F&I crown bars	1,564,347		1,564,347	
X-passage excavation	3,766,784	5,534,146	(1,767,361)	
X-passage concrete	7,434,666	807,112	6,627,554	
F&I rebar	1,634,015	-	1,634,015	
F&I waterproofing	317,754	394,327	(76,573)	
Total:	180,762,034	80,256,822	100,505,212	125%

Table 7-4 - Deviations of tunnel costs CHSRA/escalated costs Finne Tunnel

Retaining walls (SCC 10.08)

Table 7-5 and Table 7-6 show the quantitative estimates of the cost deviations for retaining walls:

	CCC	CHSRA	Deviation from unit cost CCC
	Cantilever retaining wall	**Retained fill**	
Year	2017	2017	
	USD/sq yd	USD/sq yd	%
Minimum	1,566	483	-69
Maximum	2,662	1,452	-45

Table 7-5 – Deviation of cost for cantilever retaining walls / retained fill

	CCC	CHSRA	Deviation from unit cost CCC
	Bored pile wall	**Retained cut**	
Year	2017	2017	
	USD/sq yd	USD/sq yd	%
Minimum	885	4,099	363
Maximum	1,062	5,949	460

Table 7-6 - Deviation of cost for bored pile walls / retained cut

UPEs for CHSRA include wall construction as well as the corresponding earthwork (fill and cut). The benchmark values from DB's CCC do not include earthwork. Hence, the comparability of the UPEs and the CCC is limited.

Track (SCC 10.09, 10.10, 10.14)

The following tables provide the deviations of cost between CHSRA and DB concerning high-level unit cost for track, cost for turnouts, and detailed cost for ballasted track.

	CCC	VDE 8.2	UIC/SBB	CHSRA	Deviation from CCC (%)	Deviation from VDE 8.2 (%)
Year	2017	2017	2017	2017		
Ballasted track - USD/mi	1,859,384	2,219,412	1,845,191	3,157,581	70	42
Direct fixation - USD/mi	3,836,203	3,733,329	n/a	3,806,184	-1	2

Table 7-7 – Deviation of high level unit costs for track

	Branch speed in mph	Unit cost CHSRA in USD	Equivalent turnout DB	Branch speed in mph	Unit cost DB CCC in USD	Deviatio n from DB (%)
Ballasted turnout	25	324,880	EW -190-1:9	25	101,551	220
Ballasted turnout	60	441,732	EW -1200-1:18,5	62	206,751	114
Ballasted crossover	80	1,270,080	EW -2500-1:26,5	81	389,177	226
Ballasted crossover	110	1,530,234	EW -10000/4000-1:39	99	401,339	281
Ballasted turnout	150	2,003,175	NA			
Direct fixation turnout	80	703,175	EW -2500-1:26,5	81	447,100	57
Direct fixation turnout	110	989,369	EW -10000/4000-1:39	99	485,450	104

Table 7-8 – Deviation of costs for turnouts

Specific unit cost	Unit	Unit cost DB minimum	Unit cost DB maximum	Unit cost CHSRA	Deviation from unit cost DB min in %	Deviation from unit cost DB max in %
Subballast, place, spread & compact	USD/cu yd	26.14	31.37	47.04	80	50
Ballast, place, spread & compact	USD/cu yd	33.47	36.60	58.24	74	59
Unload track material & distribute	USD/tf	3.34	4.17	7.84	135	88
Electric (flash butt) welding	USD/EA	246.21	273.57	504.00	105	84
Install rail on ties, 141 RE	USD/tf	43.36	50.45	145.60	236	189
Align & tamp	USD/tf	6.25	8.34	31.36	401	276
Rail grinding	USD/tf	3.75	4.59	3.36	-10	-27
Concrete cross ties	USD/EA	68.39	95.75	127.68	87	33

Table 7-9 - Deviation of detailed cost for ballasted track – specific unit cost

Unit costs per yard of two-track line	Unit cost DB minimum in USD/yd	Unit cost DB maximum in USD/yd	Unit cost CHSRA in USD/yd	Deviation from unit cost DB min in %	Deviation from unit cost DB max in %
Subballast, place, spread & compact	120.82	144.98	217.37	80	50
Ballast, place, spread & compact	164.69	180.13	286.61	74	59
Unload track material & distribute	20.02	25.02	47.05	135	88
Electric (flash butt) welding	36.94	41.04	75.62	105	84
Install rail on ties, 141 RE	260.22	302.75	873.80	236	189
Align & tamp	37.53	50.04	188.20	401	276
Rail grinding	22.52	27.52	20.16	-10	-27
concrete cross ties	205.22	287.31	383.13	87	33
10.09.120 bTotal ballasted track - two-Track	867.95	1,058.80	2,091.95	141	98

Table 7-10 - Deviation of detailed cost for ballasted track - USD/yd

7.3 SCC 20 - Stations terminals and intermodal

7.3.1 Qualitative deviation analysis

The stations are generally at an Estimate Class 5 design stage (0% to 2% maturity level). Therefore, the benchmarking was done by comparing functions and facilities, with major cost deviations to be expected during this early design stage. Following the direct comparison of functions, facilities, and cost for individual stations, the deviations are as follows:

Overall comparison

The overall cost comparison shows major deviations between the estimated costs for the stations and their respective benchmarks.

Potential factors for the deviation may include:

- Early design stage and unfinished designs
  - No design was provided for several stations. Assumptions were made for each missing station design, resulting in deviations from the respective benchmarks.
  - CHSRA's proposed design stage for the stations is Estimate Class 3. With no design provided for several stations, the design stage is, in fact, equivalent to an Estimate Class 5, resulting in greater cost deviations, because of higher contingencies.
  - Cost deviations may be reduced by ensuring a more detailed design from an early planning stage with increased levels of detail as the design progresses.
- Unspecific design manual for individual station functions and operational requirements
  - In generating a generic station at an early design stage, it is possible to provide more specific design details and thereby provide more reliable costs.
- Geological conditions for the building foundation
  - Because geological investigations were not provided for the station locations, geological conditions were not considered in the benchmarking and may account for part of the deviation (risk contingencies)
  - The costs allocated to geological conditions are not yet included in the benchmark costs. ETO could not verify the specific amount for this allowance in the Business Plan, which is required for the allowance to be included in the benchmark.
- Seismic risks
  - The provided allowance factor for seismic risks included in the adjustments is presumed to be in accordance with seismic conditions of coastal regions in the Peninsula area.
- Stakeholders' interests
  - With the affected stakeholders as yet unknown, the respective costs contributing to the deviation cannot be quantified.

- Buy America policy
  - With railway infrastructure projects of a certain size (>5.5Mil EUR) in Germany being required to have a Europe-wide bidding process, a larger pool of competitors usually results in lower costs, as opposed to limiting the competition to local bidders only.
  - Even when allowing international competitors, costs may increase when bidders are forced to source their materials and products only from the US market. This Buy America policy is a recent development, so the amount of increase in cost cannot be quantified as yet.
- Other contingencies
  - Unallocated contingencies may be included in the station costs and will be determined by CHSRA.

The allowances for five (5) Caltrain stations (USD 121 Mil), Madera Acres Temporary Station (USD 30 Mil) and 4th & King Station (USD 45 Mil), are seen as given costs and are not further evaluated.

7.3.2 Quantitative estimation of deviations

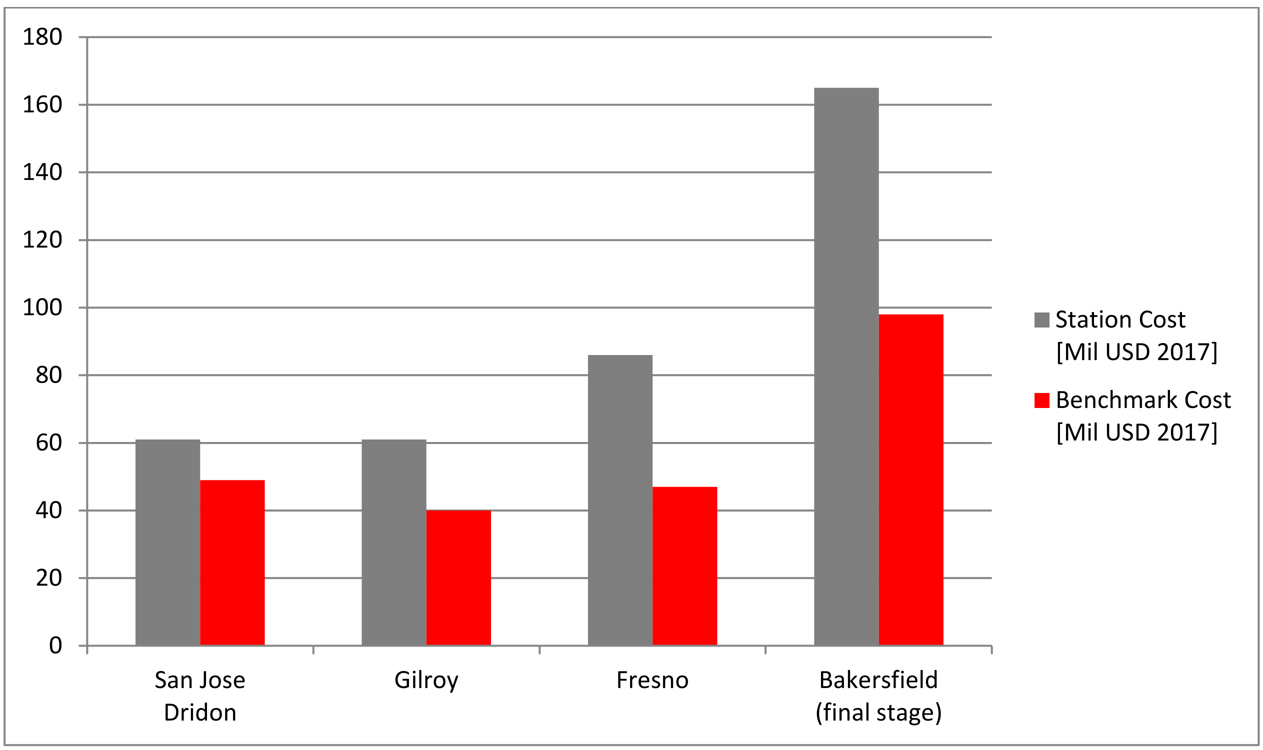


Figure 7-5 - Station cost to benchmark cost comparison

The difference in the number of tracks and surface parking spaces accounts for the individual deviations from the given costs by CHSRA. San Jose shows the lowest deviation of all stations evaluated, because it is the station with the most tracks and platforms.

When more detailed information is available, the deviations from the benchmark station costs may decrease.

7.4 SCC 30 - Support facilities, yard & shops, admin, etc.

7.4.1 Qualitative deviation analysis

The deviations in estimated costs for HMF and LMF are significant. A thorough deviation analysis was not possible because the available data was limited. Specific cost units or components have been calculated on a lump sum basis only. A deeper deviation analysis can be performed as soon as additional information becomes available. The cost estimate for CHSRA MOW facilities is close to the DB reference projects and deviates only minimally in cost.

7.4.2 Quantitative estimate of deviations

Not applicable.

7.5 SCC 40 - Site work, right of way, land, improvements

7.5.1 Qualitative deviation analysis

Highway/pedestrian overpass/grade separations

The structure for 'Road 26 Grade Separation' was benchmarked with comparable cost from the CCC.

7.5.2 Quantitative deviation estimate

Highway/pedestrian overpass/grade separations

In comparison of costs per square foot of bridge deck between CHSRA and DB, the deviation is about 61%. ETO assumes the same reasons for the cost differences as for elevated structures and bridges.

Unit cost DB from CCC in USD/sq ft	Unit cost CHSRA for Road 26 Grade Separation in USD/sq ft	Deviation of unit cost for Road 26 Grade Separation in %
211	344	61

Table 7-11 - Deviation of cost for highway/pedestrian overpass/grade separations

7.6 SCC 50 - Communication and signaling

7.6.1 Qualitative deviation analysis

Causes for deviations are potentially as follows:

- The Unit Price Elements (UPE) lists were not available for the entire Valley to Valley network (please refer to Chapter 5.6.1.1).
- The UPE lists do not reflect all subsystems, i.e. it is not possible to find the comparable COM and SIG subsystems in the given UPE lists at this stage of work.
- The available level of detail for the different UPE subcategories varies substantially.
- High level cost comparison with international projects with similar size and specification (average cost per mile only). Any impacts of station and track layouts, as well as from transition sections with other rail operators (e.g. Caltrain, UPRR), were not considered because of the described approach.
- Dimensioning of the system according to site requirements (e.g. interlockings, switches, signals) specific to each section.
- The section boundary data given in CHSRA's Business Plan 2018 for V2V does not match the additionally information CHSRA provided in 05/2018.

As part of the current scope of work, the ETO cannot comment on the CHSRA design solutions in respect to efficiency, practicability and feasibility. Nevertheless, the ETO would like to highlight the following topics:

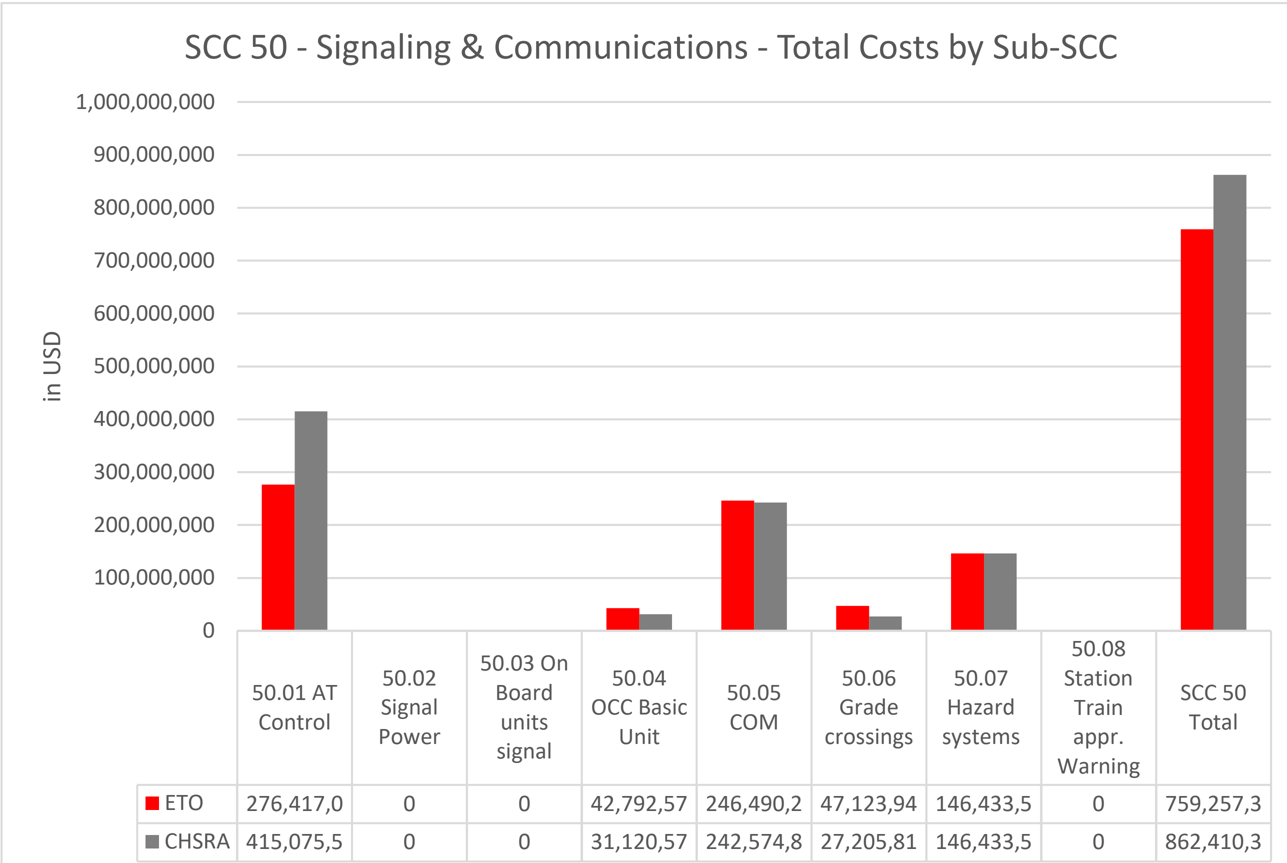
- Potential project improvements may result in new technical requirements.
- The current design level of 15% appears too low to offer substantial technical design improvements
- The change of San Jose Diridon Station from elevated to at-grade will require substantial systems redesign currently not fully considered in the Business Plan.
- The schematic track plan submitted by CHSRA does not completely reflect the current track configuration on site (track layout, turnouts / junctions and transition sections).
  For example
  - In the Business Plan 2018, San Jose Station (passenger part of station only) is described as at-grade, currently operated by Caltrain and UPRR with nine tracks. CHSRA's provided schematic track plan showing an elevated solution with only eight tracks.
  - The freight traffic network, as well as several other connection tracks, is not shown in the plans obtained from CHSRA. ETO expects that the amount of required technical equipment (for signaling & communications) will increase.

Potential factors for the deviation may include:

- Early design stage and unfinished designs, absence of detailed plans
- Unspecific design manual for system functions and operational requirements
- Costs in relation to labor
- Unidentified stakeholders' interests
- Buy America policy

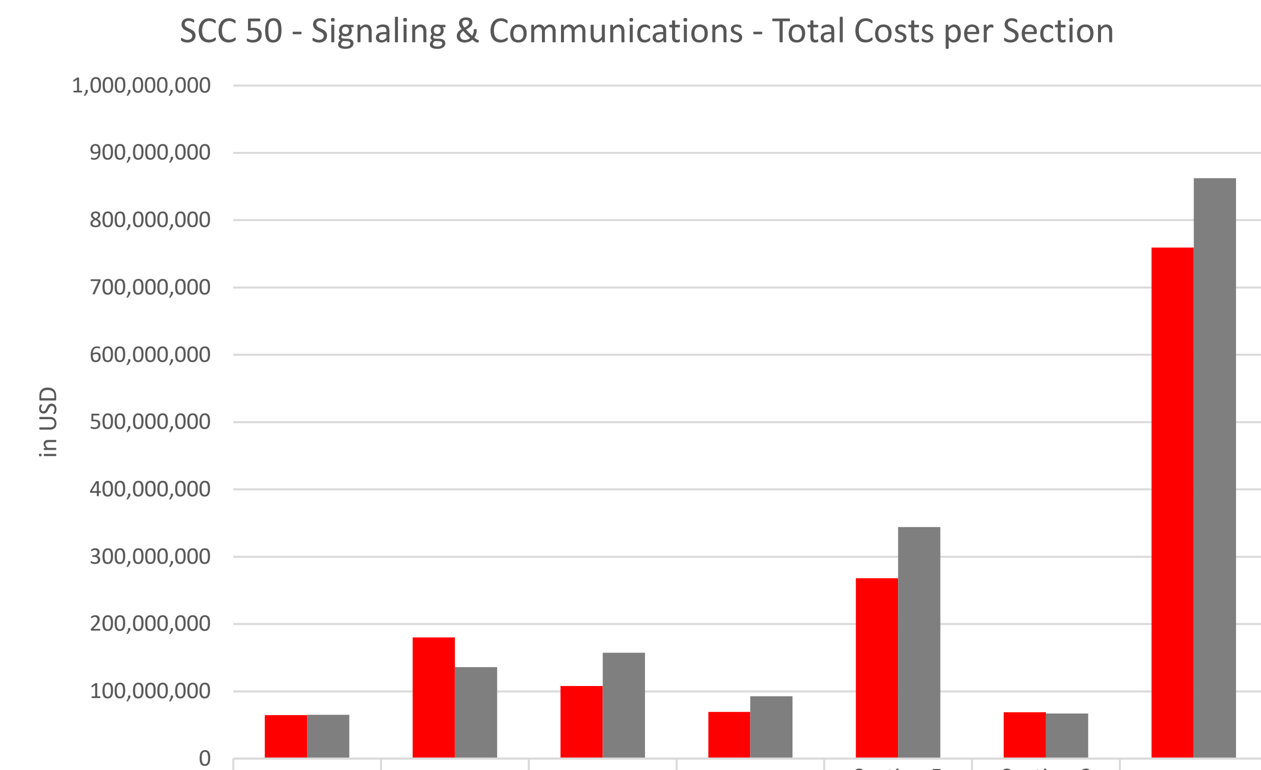
7.6.2 Quantitative estimate of deviations

The charts below show the deviations between costs given in CHSRA Business – Plan 2018 / V2V and DB benchmark calculation results.



	50.01 AT Control	50.02 Signal Power	50.03 On Board units signal	50.04 OCC Basic Unit	50.05 COM	50.06 Grade crossings	50.07 Hazard systems	50.08 Station Train appr. Warning	SCC 50 Total
ETO	276,417,0	0	0	42,792,57	246,490,2	47,123,94	146,433,5	0	759,257,3
CHSRA	415,075,5	0	0	31,120,57	242,574,8	27,205,81	146,433,5	0	862,410,3

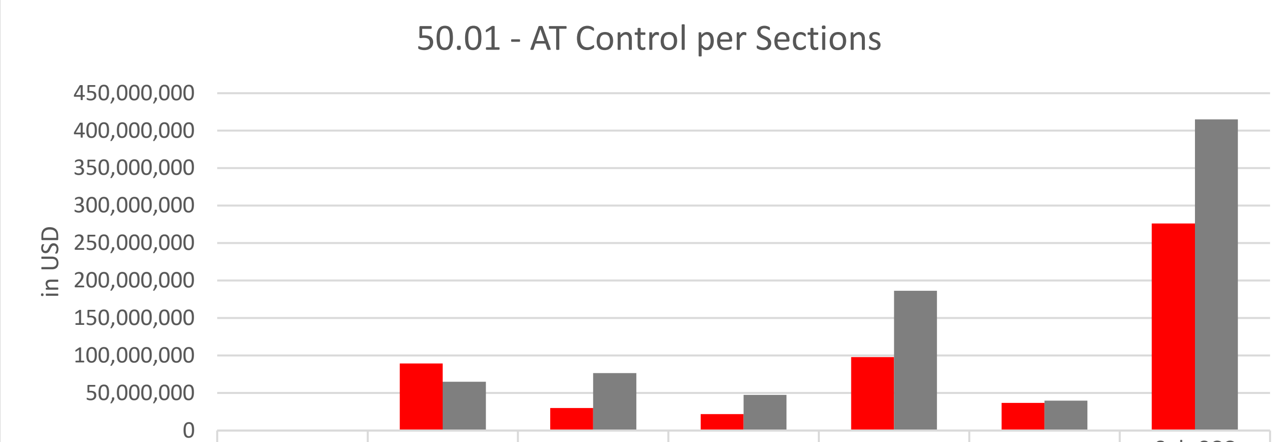
Figure 7-6 - Cost estimation in SCC 50 per sub-SCC



	Section 1 San Francisco to San Jose	Section 2 San Jose to Gilroy	Section 3 Gilroy to Carlucci Rd.	Section 4 Carlucci Rd. To Madera (Wye Leg 2)	Section 5 Madera to Popular Ave. (CP1, CP 2-3, CP4)	Section 6 Popular Ave. To Bakersfield F St. Station	SCC 50 Total
ETO	64,575,908	180,270,572	107,995,142	69,474,484	267,977,273	68,964,003	759,257,381
CHSRA	65,207,673	135,886,360	157,195,192	92,813,731	344,219,762	67,087,677	862,410,396

Figure 7-7 - SCC 50 costs per section

The following diagrams show more detailed cost comparison by sub-chapters and sections.



	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Sub-SCC 50.01 Total
ETO	0	89,532,811	30,259,033	21,748,271	98,151,212	36,725,737	276,417,065
CHSRA	0	65,078,783	76,579,184	47,424,108	186,287,222	39,706,265	415,075,562

Figure 7-8 - SCC 50.01 AT control costs per section

Signal Power (SCC 50.02):

Costs for SCC 50.02 “Signal Power” could not be verified in “2018 Baseline Estimate Optimization 7.1 (V2V)” section “2018 Baseline Budget” and “Track and systems estimate - 09262017_with prices” by CHSRA.

As agreed with CHSRA during systems conference call on 25th June 2018, the costs of SCC 50.02 are included in SCC 50.01. For more detailed information about calculated ETO benchmarking costs of SCC 50.02, please refer to chapter 5.6.2.2 “Quantitative estimation”.

On-Board Units (SCC 50.03):

SCC 50.03 contains the signaling part of ATO on-board units. For SCC 50.03 ETO Specialists could not identify any estimated costs. The provided documents by CHSRA did not contain any information on estimated costs for each section.

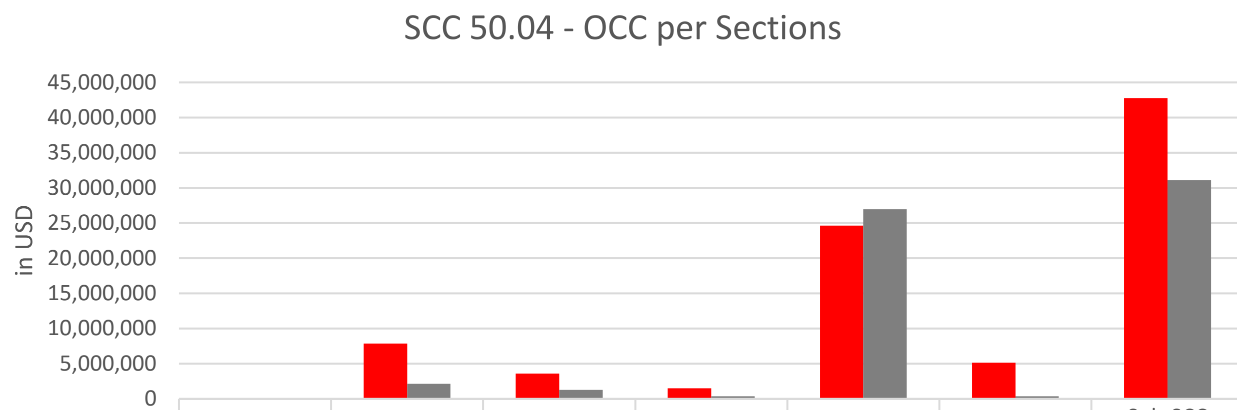
CHSRA also noted that the cost for SCC 50.03 should be counted in SCC 70 (rolling stock). For more detailed information please refer to chapter 5.6.2.2 “Quantitative Estimation”.

OCC Basic Unit (SCC 50.04):

The calculation contains only the OCC basic unit costs. Any additional costs allocated to the OCC (e.g. sections, signals, turnouts etc.) are considered in SCC 50.01.

The partial costs of named interlocking to SUB OCC extension and percentage of named interlocking to OCC extension specified in SCC 50.04, still contain only the interface costs between interlocking and OCC / Sub-OCC.

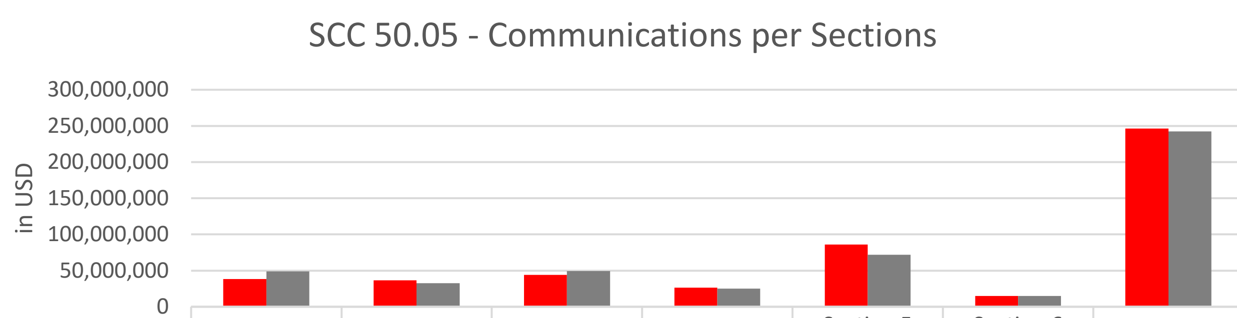
Data transmission system costs for the OCC are allocated to SCC 50.05.



	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Sub-SCC 50.04 Total
ETO	0	7,871,721	3,617,794	1,514,678	24,630,009	5,158,376	42,792,577
CHSRA	0	2,149,786	1,283,411	365,951	26,956,863	364,561	31,120,572

Figure 7-9 - SCC 50.04 OCC basic unit costs per section

Communication Systems (SCC 50.05):
The overall cost comparison for communication systems shows deviations between the estimated costs in the base budget 2018 and the values determined in the benchmarking.



	Section 1 San Francisco to San Jose	Section 2 San Jose to Gilroy	Section 3 Gilroy to Carlucci Rd.	Section 4 Carlucci Rd. To Madera (Wye Leg 2)	Section 5 Madera to Popular Ave. (CP1, CP 2-3, CP4)	Section 6 Popular Ave. To Bakersfield F St. Station	Sub-SCC 50.05 Total
ETO	38,395,939	36,500,919	44,088,260	26,233,271	86,195,980	15,075,875	246,490,245
CHSRA	48,768,858	32,469,647	49,302,541	25,045,408	71,975,606	15,012,835	242,574,895

Figure 7-10 - SCC 50.05 Communication system costs per section

Remarks for SCC 50.05:

- Costs for on-board systems—determined in the benchmarking calculation—were not included, so as not to distort the overall cost comparison also as confirmed by CHSRA. CHSRA Specialists noted that costs for onboard systems (such as TCS on-board units and all radio, passenger information and CCTV equipment) are included in SCC 70 and should not be considered in SCC 50.
- As mentioned in chapter 5.6.1.1, CHSRA provided the file “Track and systems estimate - 09262017_with prices” in addition to the Business Plan Budget 2018. ETO identified a conflict between the provided cost figures in these documents; it was agreed to use the file “Track and systems estimate - 09262017_with prices”.
- For radio systems, contractors will use frequencies in the range of 757-758 MHz, paired with 787-788 MHz, according to the technical description. Providing additional, suitable frequencies can increase costs.

Grade Crossings (SCC 50.06):

The overall cost comparison for grade crossings shows a negative deviation between the estimated ETO costs and the CHSRA estimated costs by over 170%.

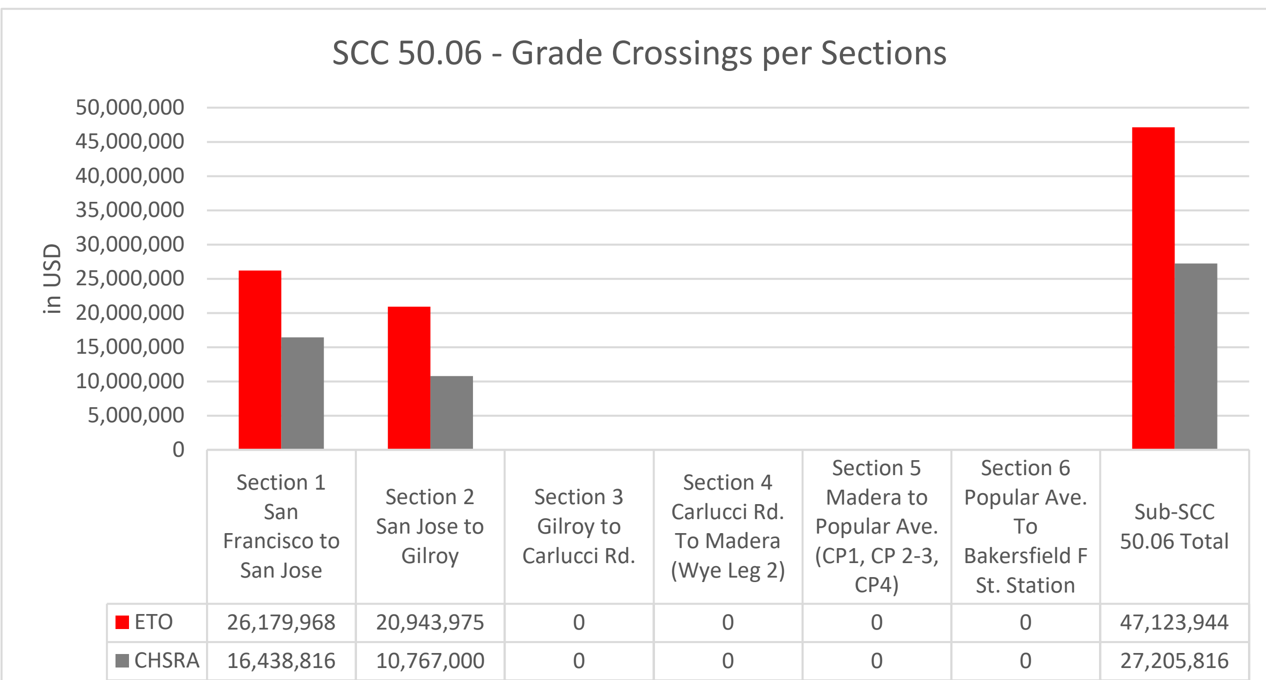


Figure 7-11 - SCC 50.06 – Grade crossings per section

Hazard systems (SCC 50.07):

Costs were considered as given in accordance to CHSRA’s decision made during systems conference call on 25th June 2018. Therefore, no benchmarking for SCC 50.07 was done.

<u>Station train approach warning</u> (SCC 50.08):

ETO could not verify any information concerning SCC 50.08 in documents submitted by CHSRA, thus not allowing any benchmark.

CHSRA noted that the costs for SCC 50.08 are included in SCC 50.07. However, ETO cannot confirm that the costs are included in SCC 50.07. Consequently, a benchmark for SCC 50.08 was not performed.

7.7 SCC 60 - Traction electrification systems

7.7.1 Qualitative deviation analysis

In addition, deviations were caused by:

- The Unit Price Elements (UPE) lists were not available for the entire Valley to Valley network (please refer to Chapter 5.7.1.1).
- The available level of detail for the different UPE subcategories varies substantially.
- High level cost comparison with international projects of similar size and specification (average cost per mile only). Any impacts of station and track layouts, as well as from transition sections with other rail operators (e.g. Caltrain, UPRR) were not considered because of the described approach.
- The section boundary data given in CHSRA's Business Plan 2018 for V2V does not match the additionally provided CHSRA information in 05/2018.

As part of the current scope of work, the ETO cannot comment on the CHSRA design solutions in respect to efficiency, practicability and feasibility. Nevertheless, the ETO would like to highlight the following topics:

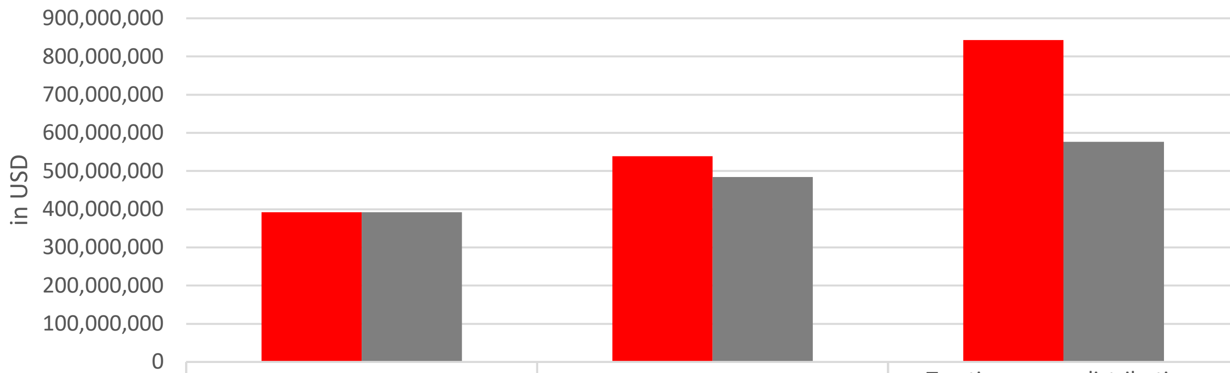
- Potential project improvements may result in new technical requirements.
- Further required project design and implementation changes (e.g. to change the San Jose Diridon Station from elevated to at-grade).
- The schematic track plan submitted by CHSRA does not completely reflect the current track configuration on site (track layout, turnouts / junctions and transition sections), for example
  - In the Business Plan 2018, San Jose Station (passenger part of station only) is described as at-grade, currently operated by Caltrain and UPRR with nine tracks. CHSRA's provided schematic track plan showing an elevated solution with only eight tracks.
  - The freight traffic network, as well as several other connection tracks, is not shown in the plans obtained from CHSRA. ETO expects that the amount of required technical equipment (for traction electrification systems) will increase.
- The current design level of 15% appears too low to offer substantial technical design improvements

Potential factors for the deviation may include:

- Early design stage and unfinished designs, absence of detailed plans
- Unspecific design manual for system functions and operational requirements
- Costs in relation to labor
- Unidentified stakeholders' interests
- Buy America policy
- Material prices

7.7.2 Quantitative estimate of deviations

Results of ETO specialists' benchmark cost calculation compared to CHSRA Business – Plan 2018 / V2V

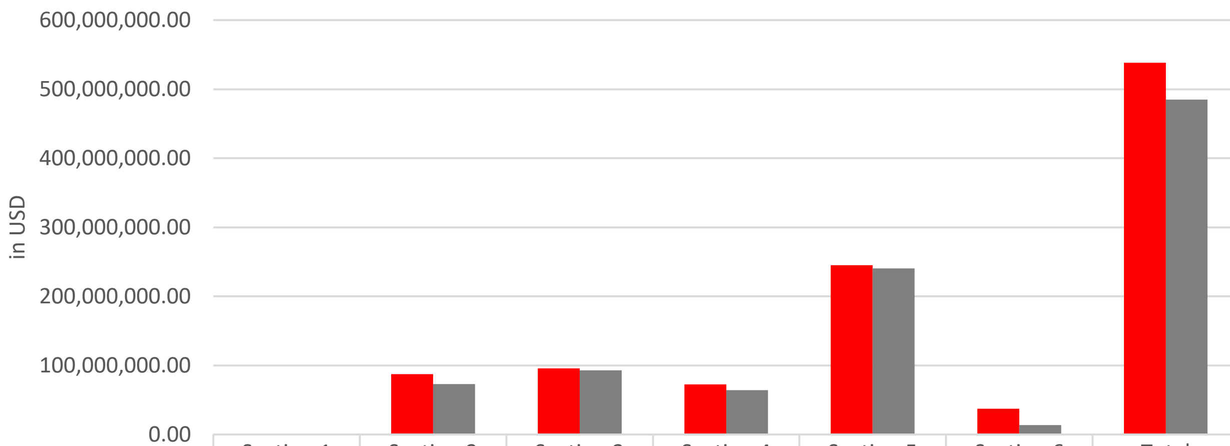


	Traction power transmission: High voltage 60.01	Traction power supply: Substations 60.02	Traction power distribution: Catenary and Traction power control 60.03 + 60.04
ETO	392,572,682	538,452,693	842,665,563
CHSRA	392,572,682	484,753,573	576,330,732

Figure 7-12 - Benchmark result SCC 60 - traction electrification systems in USD

Traction power supply (SCC 60.02):

The overall cost comparison for traction power supply shows deviations between the estimated costs in the base budget 2018 and the values determined in the benchmarking.

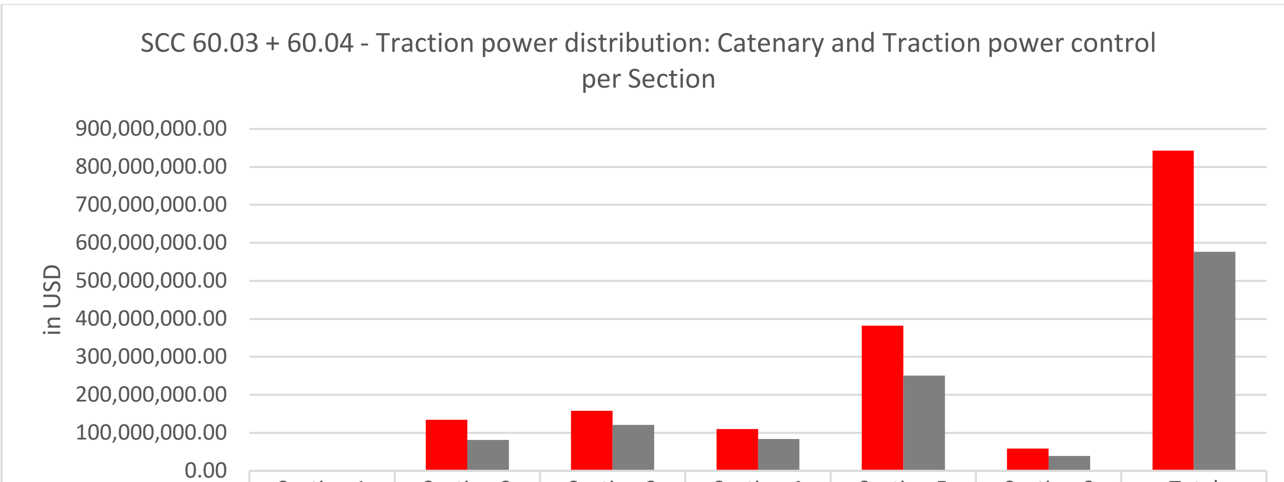


	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
ETO	0	87,316,653	95,632,525	72,763,877	245,318,215	37,421,423	538,452,693
CHSRA	0	73,228,839	93,090,273	64,417,488	240,398,465	13,618,508	484,753,573

Figure 7-13 - SCC 60.02 - Traction power supply: Substations per Section

<u>Traction power distribution: Catenary and Traction power control (SCC 60.03 & SCC 60.04):</u>

The overall cost comparison for Catenary and Traction power control shows deviations between the estimated costs in the base budget 2018 and the values determined in the benchmarking.



	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Total
ETO	0	134,529,658	157,768,122	109,658,015	382,015,589	58,694,180	842,665,563
CHSRA	0	81,441,365	120,903,605	83,888,407	250,952,834	39,144,521	576,330,732

Figure 7-14 - SCC 60.03 + 60.04 - Traction power distribution: catenary and traction power control per section

General conclusion comparing DB benchmark 2018/08 and CHSRA Business Plan 2018 / V2V cost estimates in terms of SCC 60 traction electrification systems

1. The calculated ETO benchmark costs for SCC 60 are 22% higher than the estimated costs given in CHSRA Business Plan 2018 / V2V.
2. CHSRA's cost estimate for SCC 60 seems adequate to realize the California High-Speed Rail system based on the described technical solution in Business Plan 2018 / V2V.
3. A possible increase in costs affected by increasing building costs should be considered.

7.8 SCC 70 - Vehicles

7.8.1 Qualitative deviation analysis

This estimation is not possible at this point in time. The “Buy American Factor” can only be demonstrated based on a theoretical approach, by simply scaling up all cost/price estimations as a total cost figure.

Currently, none of the identified train patterns would be assembled in the US using US components throughout. It could be considered for additional trainsets in CHSRA Phase 2. Some components were identified for future local production. The share of components produced in the US can potentially be raised over a longer time period.

With respect to document “ITP Attachment E4 - Buy America Component Worksheets (4-21-15)”, it is evident that for prototypes, as well as a small-series trainset production, a large number of items will not be produced in the US. The high-level technical specification, in conjunction with the short production timeline, would increase the risk of defects as well as the overall production costs (e.g. research and technological development, test and commissioning, warranty etc.).

The ETO identified 129 potential components for prototypes and 123 for serial production for the CHSRA fleet. It is customary to use established production facilities for prototype trains, which very likely will reduce the share of US components.

For production of a trainset series, this number can be reduced to 21 components. Nevertheless, the significant uncertainty, considering the raised number of “unclear” attributed components on the serial production level, depends mainly on the US manufacturing quality standards from potential suppliers as well as the design characteristics of these components used for respective train design.

It is expected that acquiring or manufacturing all components on the US market might raise the cost contribution.

Category	Prototypes (up to two trainsets)	Small series Production (up to 25 Train sets)
risk	44	21
unclear	22	45
no risk	68	68
of in total	134	134

Table 7-12 - First analysis of components considered for local US production

The linear calculation of total trainset prices includes inflation adjustments up to 31 Dec 2017.

7.8.2 Quantitative deviation estimate

Illustration			
Name	**Alstom AGV**	**Alstom TGV Duplex**	**AnsaldoBreda V250**
Total amount per trainset (adjusted to 2017 in USD)	USD 35,576,608	USD 37,885,484	USD 41,793,187.64
Total amount per trainset with "Buy America" factor (≤60% US content) (+100%)	USD 71,153,217	USD 75,770,968	USD 83,586,375
Total amount per trainset with "Buy America" factor (≤80% US content) (+160%)	USD 92,499,182	USD 98,502,259	USD 108,662,288
Total amount per trainset with "Buy America" factor (≤95% US content) (+220%)	USD 113,845,147	USD 121,233,549	USD 133,738,200
Picture source	https://www.railway-technology.com/projects/alstom-agv-very-high-speed-trains-france/	Alaric Favier, own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19808904	Arnold de Vries https://commons.wikimedia.org/w/index.php?curid=8805902

Table 7-13 - Quantitative deviation estimate for Alstom AGV, Alstom TGV Duplex & AnsaldoBreda V250

Illustration			
Name	**AnsaldoBreda/Bombardier Zefiro V300**	**Bombardier Zefiro 380**	**CSR CRH380A**
Total amount per trainset (adjusted to 2017 in USD)	USD 40,854,841	USD 36,836,300	USD 24,396,434
Total amount per trainset with "Buy America" factor (≤60% US content) (+100%)	USD 81,709,681	USD 73,672,599	USD 48,792,867
Total amount per trainset with "Buy America" factor (≤80% US content) (+160%)	USD 106,222,586	USD 95,774,379	USD 63,430,727
Total amount per trainset with "Buy America" factor (≤95% US content) (+220%)	USD 130,735,490	USD 117,876,159	USD 78,068,587
Picture source	Netse Silva https://commons.wikimedia.org/w/index.php?curid=45679151	https://upload.wikimedia.org/wikipedia/commons/b/b2/	Jucember – Own work, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=17893723

Table 7-14 – Quantitative deviation estimate for AnsaldoBreda/Bombardier Zefiro V300, Bombardier Zefiro 380, CSR CRH380A

Illustration			
Name	**Japan Series E5**	**Japan Series N700A**	**Rotem KTX-II**
Total amount per trainset (adjusted to 2017 in USD)	USD 32,397,889	USD 22,521,877	USD 33,335,957
Total amount per trainset with "Buy America" factor (≤60% US content) (+100%)	USD 64,795,778	USD 45,043,753	USD 66,671,914
Total amount per trainset with "Buy America" factor (≤80% US content) (+160%)	USD 84,234,511	USD 58,556,879	USD 86,673,488
Total amount per trainset with "Buy America" factor (≤95% US content) (+220%)	USD 103,673,244	USD 72,070,005	USD 106,675,062
Picture source	https://upload.wikimedia.org/wikipedia/commons/7/74/E5_S11_Sendal_20090725.JPG	https://upload.wikimedia.org/wikipedia/commons/9/97/JRW_N700-7000series_S1.jpg	Minseong Kom – Own work CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37103539

Table 7-15 – Quantitative deviation estimate for Japan Series E5, Japan Series N700A, Rotem KTX-II

Illustration			
Name	**Siemens Velaro CN**	**Siemens Velaro D**	**Siemens Velaro E**
Total amount per trainset (adjusted to 2017 in USD)	USD 54,851,132	USD 45,611,037	USD 36,503,479
Total amount per trainset with "Buy America" factor (≤60% US content) (+100%)	USD 109,702,265	USD 91,222,073	USD 73,006,959
Total amount per trainset with "Buy America" factor (≤80% US content) (+160%)	USD 142,612,944	USD 118,588,695	USD 94,909,047
Total amount per trainset with "Buy America" factor (≤95% US content) (+220%)	USD 175,523,624	USD 145,955,317	USD 116,811,134
Picture source	https://de.wikipedia.org/wiki/CRH3#/media/File:CRH3_in_Tianjin.JPG	DB AG	https://upload.wikimedia.org/wikipedia/commons/1/10/Renfe_clase_103.JPG

Table 7-16 - Quantitative deviation estimate for Siemens Velaro CN, Siemens Velaro D, Siemens Velaro E

Illustration			
Name	**Siemens Velaro e320**	**Siemens Velaro TR**	**Talgo 350**
Total amount per trainset (adjusted to 2017 in USD)	USD 39,793,676	USD 50,988,541	USD 59,013,900
Total amount per trainset with "Buy America" factor (≤60% US content) (+100%)	USD 79,587,352	USD 101,977,083	USD 118,027,801
Total amount per trainset with "Buy America" factor (≤80% US content) (+160%)	USD 103,463,558	USD 132,570,208	USD 153,436,141
Total amount per trainset with "Buy America" factor (≤95% US content) (+220%)	USD 127,339,763	USD 163,163,333	USD 188,844,481
Picture source	https://www.hochgeschwindigkeitszuege.com/england/fotos-england/eurostar-e320-langzug-01-fhd.jpg	By Mikhail krivyy – TrainPix, CC BY – SA 3.0 https://commons.wikimedia.org/w/index.php?curid=55022953	https://upload.wikimedia.org/wikipedia/commons/4/46/Talgo_350.jpg

Table 7-17 - Quantitative deviation estimate for Siemens Velaro e320, Siemens Velaro TR, Talgo 350

7.9 SCC 80 - Professional Services (associated with categories 10-60)

7.9.1 Qualitative deviation analysis

It is not possible to calculate the effects on total cost, because a variety of ETO reference projects with different cost basis is used for this assessment.

The allocations for professional services have the same order of magnitude. The accumulated deviations for all professional services account for a total of 3.5 percent and 15.6 percent relative to the DB benchmark values, which can be attributed to different contractual parameters in the respective countries (e.g. ROW, legal parameters, permitting, labor laws, etc.).

7.9.2 Quantitative deviation estimate

SCC 80 Professional Services	CHSRA assumed value [%]	DB benchmark value [%]	Deviation [%]	Deviation [%] / DB benchmark value [%]
80.02	2.50	2.70	-0.2	-7.41
80.03	6.00	6.90	-0.9	-13.04
80.04	4.00	4.50	-0.5	-11.11
80.05	3.00	4.70	-1.7	-36.17
80.06	0.00	0.00	0	0.00
80.07	0.50	0.25	0.25	100.00
80.08	0.00	0.00	0	0.00
80.09	0.00	0.00	0	0.00
80.10	0.50	0.50	0	0.00
Total	**16.5**	**19.55**	**-3.05**	**-15.60%**

Table 7-18 – Professional services deviation of DB benchmark value

8 Recommendations from ETO perspective

8.1 Introduction

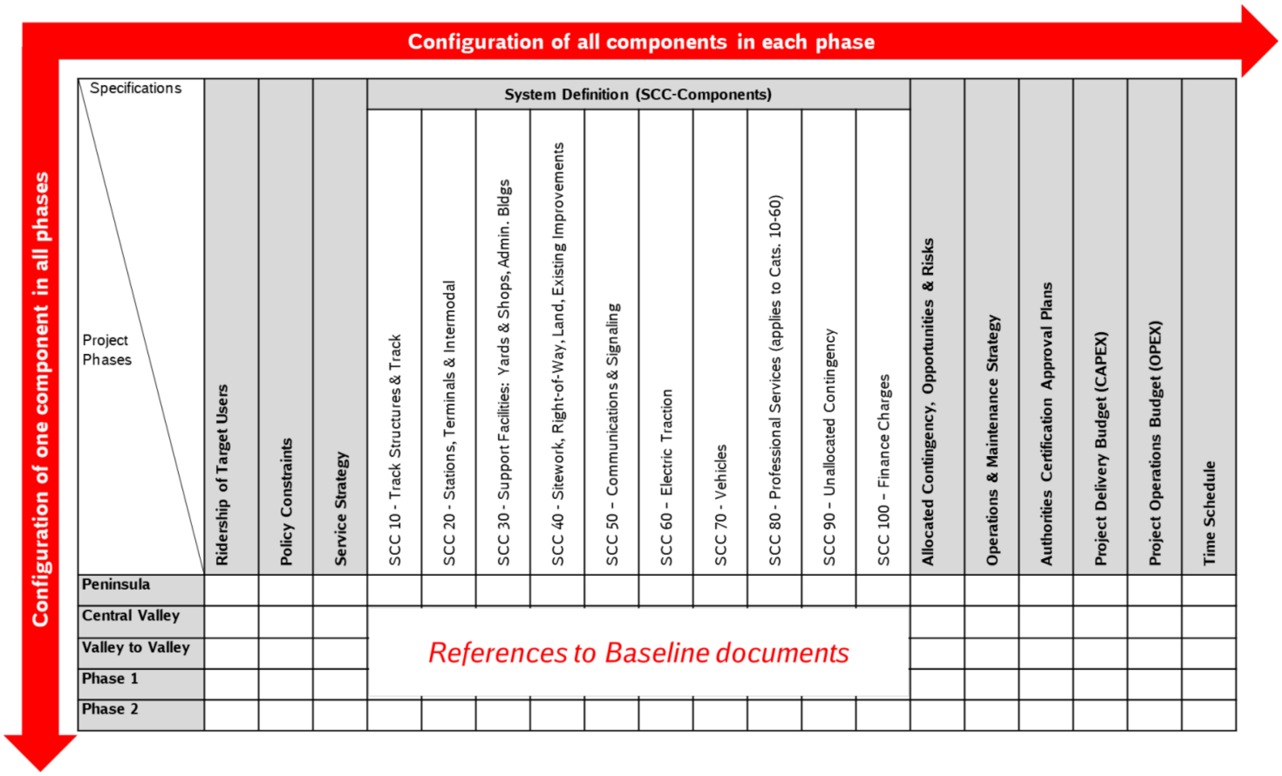
Under the assumption that CHSRA will procure the rolling stock, track, systems and stations under a Design-Built-Maintain contract, the ETO put together recommendations from our standard practices, as outlined in this chapter.

These recommendations shall be included in the Risk and Opportunities register to manage the associated risk properly or to exploit an improvement opportunity accordingly in each case.

Several recommendations should be included in the budgeting phase for the next revisions of the baseline, while the others must be executed during the design phase.

8.2 General recommendations

- Baseline component relations, traceability and integrity: ETO recommends implementing a baseline configuration traceability matrix with a pointer to the information and the relevant documents, so the team has a common understanding, and to provide traceability, so that in case one document changes, the impact on other elements can be identified.



- The values in our DB cost catalogue represent actual values of the different cost elements, which include the risks and opportunities that were materialized in our reference high speed projects. CHSRA is developing the risk register for the new baseline release, therefore it was not available to the ETO at the time of this analysis. Once finalized, the ETO can review it if required by the CHSRA.

8.3 SCC 10 - Track Structures and Track

- Innovative construction methods for viaducts and bridges, as described in Chapter 5.2.2, were successfully used in Germany, reducing the costs of infrastructure. ETO recommends that CHSRA conduct further analyses in the budgeting phase to determine if these innovative designs are applicable in the seismic conditions of California.
- The information related to earthwork and drainage provided by CHSRA covers only Section 3 (Gilroy to Carlucci Road). The ETO recommends that CHSRA check all sections for completeness of data. In addition, CHSRA should conduct further geotechnical investigation in the budgeting phase to minimize the costs associated with unidentified risks.
- ETO recommends detailing the geotechnical parameters and operational tunnel design requirements in the budgeting phase. This includes in particular:
    I. Conduct a tunnel-specific geotechnical investigation program, because the Pacheco Tunnel alignment is currently based on an empirical approach.

II. Validate the Pacheco Tunnel design criteria, in particular the permeability concept for the segmental lining to resist the currently expected water pressure of up to 1,000 ft. It is our standard practice to specify leakage criteria for such lining systems. The ETO is not aware of a reference project with comparable stringent design requirements concerning water pressure up to 1,000 ft.

III. Validate the Pacheco Tunnel diameter to determine if the design speed is compatible with the current design diameter in relation to the aerodynamic effects on passenger comfort and power consumption. The CHSRA project has a smaller internal diameter than DB reference projects.

IV. Validate the Pacheco Tunnel drainage concept for removal of residual and forge water. The tunnel is currently designed with a low point in the alignment.

V. Perform a smoke extraction study to determine the adequacy of the current mechanical ventilation for the long tunnel length and high point in the alignment of the Pacheco Tunnel 2.

VI. Validate and coordinate the safety concept for the tunnels with the authorities, the relevant fire departments, and other stakeholders.

- CHSRA only provided cost information for retaining walls for Sections 2 and 6. The ETO recommends that CHSRA check all sections for completeness of data, because retaining walls will likely occur in other project sections as well, based on the topography. In addition, CHSRA should conduct further geotechnical investigations in the budgeting phase to minimize the costs associated with unidentified risks.
- CHSRA intends to build the centerline of the track with a maximum longitudinal gradient of 12%o. The EU Commission Regulation No. 1299/2014 of November 18, 2014 (Chapter 4.2.3 – Line Layout) allows a gradient as steep as 35%o for main tracks on new P1 lines dedicated to passenger traffic at the design phase if the slope of the moving average profile over 10 km is less than or equal to 25%o and the maximum length of continuous 35%o gradient does not exceed 6 km.

  Advantages through increasing the gradient from 12%o to 35%o:

  – Cost reduction (e.g. for LGV Sud-Est - French high-speed rail line linking Paris's and Lyon's suburbs - result in a decrease in costs of 30-35% compared to the original gradient of 15%o)
  – Shortage of the tunnel´s and viaduct´s length as a result from an improved adjustment of the track to the terrain´s conditions leading to decreasing costs for safety- and rescue-systems for tunnels
  – A shortage of platforms for grade separation structures up to 35% of their original length enables their construction and space-saving especially in heavily populated areas such as in Section 1 and 2

- The CHSRA cost information for ballasted track and direct fixation was similar. Cost for ballasted track appears high compared to cost benchmark data from Europe and other parts of the world.

  I. The ETO recommends an in-depth cost comparison study for both technologies including a Lifecycle Cost (LCC) analysis.

II. ETO recommends that the cost for sub-ballast be checked, because this is also mentioned within the earthwork section.

8.4 SCC 20 – Stations, terminals, and intermodal

- The documents given by CHSRA contain preliminary descriptions of the stations. The ETO recommends developing a corporate- and transit-oriented development concept for station designs in the budget phase, including not only the operations and maintenance perspective but also the purpose of each station such as:
    I. Node station: Designed from the perspective of rail operations efficiency
    II. Park & Ride station: designed with to take the most cars off of the highways
    III. Community Center station: designed as a destination itself
    IV. Urban development station: designed to change the social and economic development of an area
- The review of the station requirements should be performed after the purpose of each station has been defined.
- Each station must become part of its surroundings by being woven into the fabric of the existing city. Depending on the station's location, integrating historic buildings may present an attractive way to establish a connection between the new high-speed rail stations and the city's historical roots, as well as existing and future buildings. integrating historical buildings and the station's surroundings into the station design at an early stage might reduce the risk of future alterations to the station design.
- The seismic risks are included in the benchmark as an adjustment based on values provided by CHSRA. One set of values was provided for all station locations by CHSRA. ETO recommends reviewing the seismic conditions again. Assuming that the seismic risk in the Central Valley is comparatively lower than on the Peninsula, the allowance may be reduced by a yet to be determined amount, resulting in lower overall costs for the Central Valley stations.
- With the update of the section boundaries for the Valley to Valley concept, the evaluated Bakersfield station (at Golden State Ave) lies outside the section boundary. Section 6 ends at the temporary station Bakersfield F-Street (not evaluated by ETO). Required systems and civil works currently end at the temporary Bakersfield F-Street station, too. Consequently, the evaluated Bakersfield station (at Golden State Ave) is not connected to the Valley to Valley line. In case CHSRA decides to build Bakersfield Station (at Golden State Ave) as part of the Valley to Valley concept, additional cost for civil and systems works will be incurred. ETO recommends extending the section boundaries in order for the systems and civil works to end at Bakersfield Station, thus connecting it to the Valley to Valley line.

8.5 SCC 30 - Support facilities, yard & shops, admin, etc.

- The ETO recommends a detailed breakdown of the maintenance facilities into their basic elements to allow the development of a more reliable cost estimate.

- Costs related to material, labor, equipment, and overhead for these elements should be accumulated and rolled up to provide an inclusive unit cost for the various components required to develop the maintenance facilities.
- Potential cost reductions and optimizations should be identified within life cycle costs investigations.
- The ETO recommends including a RAMS and O&M requirements analysis as part of the budgeting phase and to keep a traceability between the requirements changes and the budget.

8.6 SCC 40 - Site work, right of way, land, improvements

- ETO recommends performing additional geotechnical analysis during the budgeting phase, in order to validate the possibility of implementing innovative construction methods for reducing construction costs. Several of these methods were discussed between the teams of specialists, but complementary seismic data is required.
- A high number of grade crossings are considered by CHSRA along the alignment between Gilroy and San Francisco. This number of grade crossings will represent operational challenges. ETO recommends performing a detailed simulation including freight, local, and high-speed rail traffic to estimate the impact of the grade crossings on the roads. Preliminary calculations done by ETO highlighted that the gate down time could create traffic issues (see recommendations in SCC 50)
- After the impact on the grade crossings is reviewed, and the safest operational, cost effective solution is identified, the grade separation requirements should be reviewed, and the scope and budget adjusted accordingly.
- ETO performed a preliminary check of the space requirements for fitting two electrified parallel tracks into Sections 1 and 2, plus one additional non-electrified track for UPRR operations in Section 2. A railway cross-section to current standards of two electrified tracks and one non-electrified track, including required noise barriers, requires a width of about 68.9 ft (21 m). ETO recommends that CHSRA verify the space requirements in these sections.

8.7 SCC 50 - Communication and signaling

- ETO recommends performing a detailed analysis of operation simulations, scheduling, and planning to determine the minimum required infrastructure, specifically in sections 1 and 2 (San Francisco to Gilroy) including:
  I. Caltrain traffic
  II. High-speed traffic
  III. Freight traffic
  IV. At grade road crossings
- The simulation will identify and validate whether the specified required travel time is archivable. ETO Specialists performed preliminary estimations and highlighted that the current planned technical solution could require further upgrades of the existing network in Sections 1 and 2. The expected high density of Caltrain operations, combined with a large number of Caltrain stops, makes it unlikely that the CHSRA trains will reach the required speed without these upgrades.
- ETO recommends performing an operations analysis running freight, commuter, and high-speed trains simultaneously in these sections to validate the technical capacity and to confirm which operational speeds and journey times are realistically achievable for all kinds of traffic, not just HSR.
- Sections 1 and 2, with a common section length of 86 miles, include 72 grade crossings. ETO performed a preliminary calculation, which highlighted that the level crossings could be activated up to 18 times per hour, with an estimated time of 2.5 minutes, which could create

traffic issues on the road. ETO suggests performing an impact analysis on the crossing road traffic and reviewing the requirement of grade separation between road and rail in these sections.

- ETO budget estimation benchmarking against similar high-speed lines, shows several improvement opportunities. Nevertheless, until all previous recommendations are executed, ETO recommends keeping the actual budget in the Business Plan 2018 for SCC 50, even if the calculated ETO reference costs are lower. ETO also recommends keeping the deviation amount as a contingency.

8.8 SCC 60 - Traction electrification systems

- ETO recommends reviewing the following cost elements and the associated allowances in the CHSRA budget, since no specific information was found related to:
  i. Temporary construction site facilities
  ii. Waste disposal and temporary storage
  iii. Environmental protection measures
  iv. Unknown number of crossing overhead lines and buildings under/over HSR tracks in each section

ETO recommends identifying and verifying that the cost mentioned above are included in SCC 60.

- The ETO Specialist could not verify that costs for SCCs 60.1 and 60.4 were estimated in the Business Plan 2018 / V2V - SCC 60 for Section 6. The costs were estimated by CHSRA as USD “0”. A reassessment and potential adjustment is recommended as well as recording the explanation for the decision.
- Space Requirements for electrified tracks in Sections 1 and 2 require verification (See Recommendations in SCC 40).
- ETO recommends performing an actual power study for infrastructure calculated in sub-chapter 60.02 and validation of the allowances in the budget.
- ETO recommends verifying personal, material, and tax costs in each cost element; in several cases they are not specifically identified.
- ETO Specialists could not verify that an OCS design concept is defined. Main driving costs cannot be verified without this concept. ETO recommends defining a concept in the budget phase.

8.9 SCC 70 – Vehicles

- None of the CHSRA collection of identified trainsets fits suitably into the “TIER III trainsets specification” requests. A remarkable amount for modification will be required as a result. These types of modification costs vary per trainset and would require a more in-depth analysis.
- Some of the identified, most advanced train designs follow the “Technical Specification for Interoperability” (TSI). These specifications are a coordinated collection of specifications and standards for the design of railway vehicles for the liberalized European railway market. They represent the most recent technological and regulatory knowledge to assure rail operation

safety and ruggedness, as well as suitability for European-type infrastructure. Because of the "state of the art" character of these specifications, many countries outside Europe have also adopted them. These TSI-oriented train designs are not capable of using platform tracks on the line stretches for combined use with Caltrain and UPRR without special measures, because they follow European loading gauge dimensions. This means different levels of distance/height above rail of platform edges. On the other hand, the TSI-oriented trains on the CHSRA list allow better adaptability to the crash safety requirements needed because of the planned mixed traffic in Sections 1 and 2. It is therefore expected that the design adaptation costs will be remarkably lower than for other trainsets.

- The use of overhead catenary on (TSI-oriented) HSR OCS system, and of non-TSI-type on existing lines, also will lead to further expected trainset modifications, especially in regards to modifications of pantograph design, car body design, and train equipment with several types of pantograph. Adaptation costs are remarkably high, but not identical, comparing the different trainset examples.
- The necessary adaptation to required standards and regulations concerning EMC characteristics of traction and auxiliary supply will also lead to substantial investigations by the suppliers. This will require further modification of the system and/or control software. Adaptation costs are remarkably high, but not identical, comparing the different trainset examples. It includes a remarkable amount of testing expense in any case. That feature varies widely, depending on the technology used and the number and repartition of electric/magnetic active components along the trains.
- The passenger comfort requirement levels of the listed trains were not considered at this level of benchmarking. The train examples represent a very wide variety of levels. Nevertheless, the final definition of passenger comfort level and offers may cause a remarkable price impact because of necessary, nonrecurring costs for modification and investment for the intended equipment.

Technical Modification and "Buy America" consequences:

- CHSRA's current plan to tender on a very generic approach with a Buy America attempt increases the risk of overpriced bids. A generic tender process must be based on the document "SCHEDULE 1 PART A: AUTHORITY TIER III TRAINSETS PERFORMANCE SPECIFICATION REV.0,04/13/2016" provided by CHSRA. The ETO Specialists have interpreted the technical specifications given in this document such that all technical solutions are still feasible, and potential contractors cannot price on a clearly defined scope of work. To be flexible enough on the given technical specifications, we expect contractors to calculate a higher risk contingency. In addition, the need to consider "Buy America" directives increase the risk of higher commercial bid proposals. The risk of overpriced bids increases because no high-speed trainsets of the stipulated quality class are, manufactured in the USA. Potential contractors must invest (facilities and know-how transfer) a lot in the production capabilities for the required components and/or trainsets.
- Pantograph type and equipment:

  The generic specifications must express clearly the need to install the fitting pantograph types required for different OCR types that the trains will likely encounter.
- Electromagnetic Characteristics (EMC) compliance:

Compliance with required standards and regulations concerning EMC traction and auxiliary supply characteristics must be proven carefully. If the applicable standards do not describe tests and documentation clearly, CHSRA must specify them.

- Passenger comfort:

  The generic specification must include a final definition of passenger comfort level, which should be scalable, e.g. in terms of required number of seats, seat pitch, dining car or not, on-board catering service, air conditioning level, and restroom characteristics. This is especially required if so-called “empty tube” designs are requested by the client or are informally offered by the bidders.

- Life Cycle Cost Analysis (LCCA):

  Even though, a Design-Built-Maintain contract approach is assumed, a model of verification measures that takes into account the trusted and reliable collection of data must be defined and placed into the tender documents. LCCA will help to determine the most cost-effective option among competing proposals to purchase, own, operate, maintain and, finally, dispose of the trainset, when each is equally appropriate for implementation on technical grounds. CHSRA must define the demonstration model. Therefore, based on ETO’s experience, a call for bidder demonstration model proposals is not recommended.

- ETO recommends that CHSRA identify trainsets that align most closely with their technical specifications.
- We recommend that a generic train specification based on “AUTHORITY TIER III TRAINSETS PERFORMANCE SPECIFICATION REV.0 ,04/13/2016”, or a more recent version of this document, be developed, because any orientation on trains of “historic origin” will no longer be available or offered by advanced suppliers at the time of the currently envisioned start of operation. This also allows the definition of train characteristics that could be realized effectively with respect to “Buy America” obligations.
- The cost estimates shown in chapter 7.8.2 are valid and can be used for further budget planning. All limitations reported in the vehicle chapters are still valid indicators of the expected price level in the market. Additional costs caused by varying technical characteristics, current technical assumptions, considered yearly inflation, and the Buy America contributions, as well as the development and modification costs of the trainsets by the bidders, must be considered as soon as data is available.

8.10 SCC 80 - Professional services (associated with categories 10-60)

- On the conference call, held June 11th, 2018, CHSRA informed us that the interface management and risk management for the CHSRA project is mainly within the scope of work (SoW) of the “Design-Build-and-Maintain-Contractors”. The interface management between the transaction phase from planning to construction, as well as between the contractors themselves, is not primarily managed by CHSRA. The selected contractors are mainly responsible for managing the interfaces and the risks, which results in less interaction options for CHSRA. The ETO recommends that CHSRA keep the SoW for the interface management and risk management primarily in its own hands. The current technical requirements and alignment alternatives can be interpreted broadly, which increases the risk of later amendment to the awarded contracts (forced by the contractors). Furthermore, agreements by the contractors during the interface progress can be hardly controlled. If the SoW in regard to the interface management and risk management stays primarily with the CHSRA, this could be avoided. Active interface management between the different parties can reduce the risk of amendment to the awarded contracts, as well as decisions made that are not in the interest of CHSRA and the State of California.

- For SCC 80.05, only the costs for projects in the process of implementation were calculated. To get a value for the whole project, we advise that the costs for the total V2V network be considered. This will probably increase the overall costs, but it provides a more realistic forecast for the CHSRA program.
- The costs for SCCs 80.08 (surveys, testing, investigation) and SCC 80.09 (engineering inspection) are planned to be the designer-builder's costs. We recommend including these key costs in the overall program management budget managed by CHSRA. Both cost elements have direct impact on the project's success related to cost and time.

8.11 Conclusion

In conclusion, the assessment of the CAPEX benchmarking depicts areas for improvement and further opportunities. Subsequently, the ETO suggests the following recommendations and next steps to be taken:

I. As highlighted in the executive summary the below listed major cost drivers should be reassessed from the CHSRA experts before the release of Baseline Revision 1 since they have the most significant impact on the overall budget:
   - Bridges and Viaducts
   - Earthwork
   - Tunnels
   - Retaining Walls
   - Track (Ballasted)
   - Grade Separations
   - Overhead Catenary System

II. Regardless of the impact on the budget, the ETO suggests to review the technical recommendations given in Chapter 8.2-8.10. to prevent additional risks (e.g. design changes or amendments of awarded contracts). Furthermore, negative effects on the operational concept of CHSR can be reduced at an early design stage.

III. Creation of a register displaying the actual status of risks and opportunities in the CHSR project and the continuous adjustment of the contingencies (allocated / unallocated) for each SCC

IV. Creation of a baseline configuration traceability matrix including the additional elements enabling to track the impact of changes between the different components (as described in chapter 8.2)

V. Update the project time schedule containing a detailed breakdown of milestones and work packages for the identification of the critical path

VI. A comparison of the valley to valley sections and its cost components should be conducted in order to detect additional or costs components not being considered within specific sections and subsequently within the current estimated budget

The ETO offers its full support to the CHSRA in order to achieve the fulfillment of the above mentioned recommendations and to implement successfully the CHSR project.

9 Appendices

Appendix 1 - Provided Documents from CHSRA

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
1	18-Feb-18	Initial - Basis of Capital Cost Estimate_02092018	PDF	X	X	X	X	X	X	X	X	X	
2	18-Feb-18	Initial - Maps from Transbay Transet Center to Anaheim	PDF	X	X		X	X	X			X	
3	18-Feb-18	Initial - TEMP Target Analysis - Built-Up by SCC Minors 10.24.2017 v0	PDF		X			X				X	
4	18-Feb-18	Initial - Env. Mitigation Assessment (by section 2017 $$)	PDF			X							
5	18-Feb-18	Initial - CP 1-4 Projects Estimate at Completion 09282017	PDF									X	
6	18-Feb-18	Initial - 2018 Baseline Estimate Optimization 7.1	xlsx	not to be used									
7	18-Feb-18	Initial - SCC80 Costs - TCRP 138 Calculator	PDF			X		X				X	
8	18-Feb-18	Initial - Central Valley Wye BOQ	PDF	X	X		X						
9	18-Feb-18	Initial - San Jose to Wye Quantities	PDF	X									
10	18-Feb-18	Initial - Trainset Costs 040816_0	PDF									X	
11	18-Feb-18	Initial - Central Valley Wye UPE Report	PDF	X			X	X					
12	18-Feb-18	Initial - Central Valley Wye Qty	PDF	X			X	X					
13	18-Feb-18	Initial - Poplar to Bakersfield UPE Report	PDF	X	X		X	X					
14	18-Feb-18	Initial - San Jose to Wye Qty	PDF	X	X		X	X					
15	18-Feb-18	Initial - San Jose to Wye UPE Report	PDF	X	X		X	X					
16	27-Feb-18	2017-02-21_EXH-Systemwide-Track.-2018Q1-Full_rev0	PDF		X			X				X	
17	27-Feb-18	2018-02-21_EXH-TS-1-Track-Chart-Rev0	PDF					X					
18	01-Mar-18	Track and systems estimate - 09262017 (1)	xlsx	X		X	X	X					
19	01-Mar-18	TS01 Specifiaction 06-30-2017 INDUSTRY DRAFT Version	PDF					X	X			X	
20	01-Mar-18	NPRM PEQ Standards 11-18-16 FINAL	PDF										
21	01-Mar-18	P14-30-IR-TS-ITP Attachments	PDF										
22	01-Mar-18	Schedule 1 Part A _Authority Tier III Trainsets Spec Rev 0 012518 (Redline)	PDF					X				X	
23	02-Mar-18	TS-1 Contract Term Sheet (9-9-16) (720498751_11)	PDF					X					
24	02-Mar-18	TS-1 General Provisions (9-9-16) (720500666_12)	PDF										
25	02-Mar-18	TS-1 GP Schedules (9-9-16) (720500668_11)	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
26	02-Mar-18	TS-1 Signature Document (9-9-16) (720500667_10)	PDF										
27	02-Mar-18	Evaluation Criteria 011717	PDF										
28	02-Mar-18	P14-30-IR-TS-General Provisions	PDF										
29	02-Mar-18	P14-30-IR-TS-GP Schedules	PDF										
30	02-Mar-18	P14-30-IR-TS-ITP Attachments	PDF										
31	02-Mar-18	P14-30-IR-TS-Signature Document	PDF										
32	02-Mar-18	Term Sheet 4-22-16	PDF										
33	04-Mar-18	2018 Baseline Estimate Optimization 7.1 (V2V)	xlsx	not to be used									
34	04-Mar-18	V2V Program Summary Schedule Draft _V6	PDF					X					
35	05-Mar-18	San Jose to CV Wye - 1.2. Draft PEPD Alternative 2 – Embankment to Downtown Gilroy (Book 2 of 3)	PDF	X			X						
36	05-Mar-18	San Jose to CV Wye - 2.1. Draft PEPD Advance Planning Study Technical Report	PDF	X			X						
37	05-Mar-18	San Jose to CV Wye - 2.7. Draft PEPD High Risk and Major Utilities Conflict Memorandum	PDF	X			X						
38	05-Mar-18	San Jose to CV Wye - 2.8. DRAFT PEPD Tunnels Report	PDF	X			X						
39	05-Mar-18	Supplement 1 - 15% Design (PEPD) - CV Wye - CVY-ENG-RS-PLAN-CV-20160909-4_OF_4	PDF	X			X						
40	05-Mar-18	Supplement 1 - 15% Design (PEPD) - CV Wye - CVY-ENG-RS-RPRT-ST-20160916-APS	PDF	X			X						
41	05-Mar-18	Supplement 1 - 15% Design (PEPD) - CV Wye - CVY-ENG-RS-RPRT-UT-20160916	PDF	X			X						
42	05-Mar-18	Supplement 1 - 15% Design (PEPD) - Poplar Ave. to Bakersfield - FBLGA_PEPD_RS_DesignSubm_AdvPlanngStudy_Rpt_2016-10-28	PDF	X			X						
43	05-Mar-18	Supplement 1 - 15% Design (PEPD) - Poplar Ave. to Bakersfield - FBLGA_PEPD_RS_DesignSubm_Align_Typical_Sections_2016-10-28	PDF	X			X						
44	05-Mar-18	Supplement 1 - 15% Design (PEPD) - Poplar Ave. to Bakersfield - FBLGA_PEPD_RS_DesignSubm_Bridges_ Elevated_Structures_2016-10-28	PDF	X			X						

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
45	05-Mar-18	Supplement 1 - 15% Design (PEPD) - Poplar Ave. to Bakersfield - FBLGA_PEPD_RS_DesignSubm_High_Risk_Utility_Impact_Rpt_2016-10-28	PDF	X			X						
46	05-Mar-18	Supplement 1 - 15% Design (PEPD) - Poplar Ave. to Bakersfield - FBLGA_PEPD_RS_DesignSubm_Station_Area_Plans_2016-10-28	PDF		X								
47	05-Mar-18	Supplement 1 - 15% Design (PEPD) - San Jose to CV Wye - 1.2. Draft PEPD Alternative 2 – Embankment to Downtown Gilroy (Book 2 of 3)	PDF	X			X						
48	05-Mar-18	Supplement 1 - 15% Design (PEPD) - San Jose to CV Wye - 1.2. Draft PEPD Alternative 2 – 2.1. Draft PEPD Advance Planning Study Technical Report	PDF	X			X						
49	05-Mar-18	Supplement 1 - 15% Design (PEPD) - San Jose to CV Wye - 1.2. Draft PEPD Alternative 2 – 2.7. Draft PEPD High Risk and Major Utilities Conflict Memorandum	PDF	X			X						
50	05-Mar-18	Supplement 1 - 15% Design (PEPD) - San Jose to CV Wye - 1.2. Draft PEPD Alternative 2 – 2.8. DRAFT PEPD Tunnels Report	PDF	X			X						
51	05-Mar-18	Supplement 1 - Rolling Stock - Evaluation Criteria 011717	PDF							X			
52	05-Mar-18	Supplement 1 - Rolling Stock - NPRM PEQ Standards 11-18-16 FINAL	PDF										
53	05-Mar-18	Supplement 1 - Rolling Stock - P14-30-IR-TS-General Provisions	PDF							X			
54	05-Mar-18	Supplement 1 - Rolling Stock - P14-30-IR-TS-GP Schedules	PDF										
55	05-Mar-18	Supplement 1 - Rolling Stock - P14-30-IR-TS-Instructions to Proposers	PDF										
56	05-Mar-18	Supplement 1 - Rolling Stock - P14-30-IR-TS-ITP Attachments	PDF										
57	05-Mar-18	Supplement 1 - Rolling Stock - P14-30-IR-TS-Signature Document	PDF										
58	05-Mar-18	Supplement 1 - Rolling Stock - Schedule 1 Part A _Authority Tier III Trainsets Spec Rev 0 012518 (Redline)	PDF					X		X			
59	05-Mar-18	Supplement 1 - Rolling Stock - Term Sheet 4-22-16	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
60	05-Mar-18	Supplement 1 - Track & Systems - TS01 Specifiaction 06-30-2017 INDUSTRY DRAFT Version	PDF	X				X					
61	05-Mar-18	Supplement 1 - Track & Systems - TS-1 Contract Term Sheet (9-9-16) (720498751_11)	PDF	X				X					
62	05-Mar-18	Supplement 1 - Track & Systems - TS-1 General Provisions (9-9-16) (720500666_12)	PDF	X									
63	05-Mar-18	Supplement 1 - Track & Systems - TS-1 GP Schedules (9-9-16) (720500668_11)	PDF	X									
64	05-Mar-18	Supplement 1 - Track & Systems - TS-1 Signature Document (9-9-16) (720500667_10)	PDF	X				X					
65	05-Mar-18	Supplement 1 - 2018 Baseline Estimate Optimization 7.1 (V2V)	xlsx	not to be used									
66	05-Mar-18	Supplement 1 - V2V Program Summary Schedule Draft _V6	PDF					X					
67	06-Mar-18	Design Criteria Manual - P14_32_EX_IIIA_01_Design_Criteria_Manual	PDF	X	X	X	X	X					
68	06-Mar-18	Directive Drawings - P14_32_EX_IIIB_01_Directive_Drawings	PDF	X		X	X	X					
69	06-Mar-18	Google - kmz files	kmz	X		X	X	X					
70	06-Mar-18	Supplement 2 - Summary of Requirements for O&M Facilities 130321	PDF			X		X					
71	06-Mar-18	Supplement 2 - Fresno_Bakersfield_Station_Plans	PDF		X			X					
72	06-Mar-18	Supplement 2 - San Jose to Gilroy via UPRR - ES Cross Sections 09 29 2017	PDF	X			X	X					
73	06-Mar-18	Supplement 2 - San Jose to Gilroy via UPRR - Gilroy to San Jose track charts	PDF	X			X	X					
74	06-Mar-18	Supplement 2 - San Jose to Gilroy via UPRR - Least cost alternative memo 10 4 2017	PDF	X			X	X					
75	06-Mar-18	Supplement 2 - San Jose to Gilroy via UPRR - Least cost alternative review with cost esitmating and Rail Group 10 5 2017	docx	X			X	X					
76	06-Mar-18	Supplement 2 - San Jose to Gilroy via UPRR - SJ to Gilroy Least Cost Alternative_Rev7_ Oct 11 2017	xlsx	X			X	X					
77	08-Mar-18	Track and systems estimate - 09262017	PDF	X		X	X	X					
78	09-Mar-18	Business Plan 2018 - Draft - 2018_HSR_Releases_Draft_2018_Business_Plan_Seeks_Public_Comment	PDF	X		X	X	X					

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
79	09-Mar-18	Business Plan 2018 - Draft - Draft_2018_Business_Plan	PDF	X		X		X	X			X	
80	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_50_Year_Lifecycle_Capital_Cost_Model	PDF			X		X	X			X	
81	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_Basis_of_Estimate_Report	PDF	X		X	X	X	X			X	
82	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_High_Medium_Low_Cash_Flows	PDF			X		X					
83	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_Operations_Maintenance_Cost_Model	PDF			X		X					
84	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_Ridership_Revenue_Forecasting	PDF			X							
85	09-Mar-18	Business Plan 2018 - Draft - DRAFT_2018_Business_Plan_Service_Planning_Methodology	PDF			X							
86	09-Mar-18	Supplement 3 - Maintenance Facilities - TM 5.1 Directive Drawings A-G 110711	PDF			X				X			
87	09-Mar-18	Supplement 3 - Maintenance Facilities - TM 5.1 Terminal and HMF Guidelines R0 090825	PDF			X							
88	09-Mar-18	Supplement 3 - Maintenance Facilities - TM 5.2 Directive Drawings 090723	PDF			X							
89	09-Mar-18	Supplement 3 - Maintenance Facilities - TM 5.3 Facilities Requirements Summary 090831	PDF			X							
90	09-Mar-18	Supplement 3 - Stations - 2018 Baseline Station Costs Summary	PDF		X								
91	09-Mar-18	Supplement 3 - Stations - NTD 02 EMT Memo 101109 Station Function Design	PDF		X								
92	09-Mar-18	Supplement 3 - Stations - NTD 13 RDP_Memo_Station_Platform_and_Track_Layout	PDF		X								
93	09-Mar-18	Supplement 3 - Stations - Statewide_CHSR Map (V2V stations)	PDF		X								
94	09-Mar-18	Supplement 3 - Stations - TM 2 2 2 Station Program Design Guidelines R1 110603	PDF		X								

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
95	09-Mar-18	Supplement 3 - Stations - TM 2.2.3 HST Passenger Station Site Des Guidelines R0 090410	PDF		X								
96	09-Mar-18	Supplement 3 - Stations - TM 2.2.4 C and D Directive Dwgs 100604	PDF		X								
97	09-Mar-18	Supplement 3 - Stations - TM 2.2.4 Station Platform Geometric Design R1 100630	PDF		X								
98	09-Mar-18	Supplement 3 - Track and systems estimate - 09262017	xlsx	X				X					
99	13-Mar-18	2018 Baseline Estimate Optimization 7.2 (V2V)	xlsx	X	X	X	X	X					
100	13-Mar-18	Risk and Contingency Assessment	PDF			X						X	
101	13-Mar-18	Caltrain Stations Scope - SD3001	PDF		X								
102	13-Mar-18	Caltrain Stations Scope - SD3003	PDF		X								
103	13-Mar-18	UPE Reports (follow up) - Fresno Station UPE Report	PDF		X			X					
104	13-Mar-18	UPE Reports (follow up) - Poplar to Bakersfield Qty	PDF	X	X		X	X					
105	13-Mar-18	UPE Reports (follow up) - Poplar to Bakersfield UPE Report	PDF	X	X		X	X					
106	14-Mar-18	Risk Management - PLAN_RISK_01_Program_Risk_Management_Plan_March_2017	PDF			X		X				X	
107	14-Mar-18	Traction Power Supply - Tractio_03142018153431	PDF							X			
108	14-Mar-18	Tunnel information - 20170615-Atl2-Qty_OverallDiagram	PDF	X						X			
109	14-Mar-18	Tunnel information - TM 2.4.2 Basic HST Tunnel Config R1 101115	PDF	X									
110	14-Mar-18	Tunnel information - TM 2.4.2 Directive Drawings A-F	PDF	X						X			
111	15-Mar-18	1.1. Draft PEPD Alternative 1 – Gilroy to Carlucci Rd.	PDF	X			X						
112	21-Mar-18	HMF & MOWF UPE Report	PDF			X							
113	21-Mar-18	HSR_13_06_B2_PtC_Sub1_Scope_Work	PDF			X							
114	21-Mar-18	P13_57_IC_01_EX_CP23_Scope_of_Work	PDF			X							
115	21-Mar-18	P14_32_03_IC_01_CP4_Scope_of_Work	PDF			X							
116	23-Mar-18	Gilroy to Carlucci Rd. UPE Report	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
117	23-Mar-18	SD2001 - Track Clearance AAR Plate F and H Car Clearance Envelopes	PDF	X			X			X			
118	27-Mar-18	BP 2018 Cost Data for Comparison to James Values UPE_Stations_11-01-10	PDF										
119	28-Mar-18	DTX Final PE Plans - Task 5.1 Track Alignment 20170928	PDF			X							
120	29-Mar-18	CA High-Speed Train Project_StudyReport_09022016_clean LM	PDF			X			X				
121	30-Mar-18	01_EEPB-SEN-TK04-RE-0008_REV00_Draft PEPD_Alignment Plans	PDF										
122	30-Mar-18	2016-06-30_Draft-PEPD_K2L_Vol1_11x17_Compressed	PDF	X									
123	30-Mar-18	170118-001 LO-PEPD-Vol1_Draft Submmital_Track and ROW	PDF										
124	30-Mar-18	BP_TYLI_DrPEPDTrackPlans_WBS_4.9.6_2016-09-07	PDF	X									
125	08-May-18	V2V Estimating Section Limits - outdated!.	PDF										
126	09-May-18	DTX track charts	PDF										
127	09-May-18	RE follow up items	PDF										
128	09-May-18	V2V Estimating Section Limits	PDF										
128	24-May-18	Structures Cost Breakdown	xlsx	X									
129	24-May-18	Tunnels Cost Breakdown	xlsx	X									
130	08-Jun-18	Risk and Contingency Assessment	PDF										
131	08-Jun-18	TEMP Target Analysis - Built-Up by SCC Minors 10.24.2017 v0	PDF										
132	08-Jun-18	ES Cross Sections 09 29 2017	PDF										
133	08-Jun-18	Gilroy to San Jose track charts	PDF										
134	08-Jun-18	LCA	kmz										
135	08-Jun-18	Least cost alternative memo 10 4 2017	PDF										
136	08-Jun-18	SJ to Gilroy Least Cost Alternative_Rev7_ Oct 11 2017	xlsx										
136	08-Jun-18	HSR_13_06_B2_PtC_Sub1_Scope_Work	PDF										
137	08-Jun-18	P13_57_IC_01_EX_CP23_Scope_of_Work	PDF										
138	08-Jun-18	P14_32_03_IC_01_CP4_Scope_of_Work	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
139	08-Jun-18	DTX Final PE Plans - Task 5.1 Track Alignment 20170928	PDF										
140	08-Jun-18	SharePoint Links to Draft PEPD	PDF										
141	08-Jun-18	Env. Mitigation Assessment (by section 2017 $$)	PDF										
142	08-Jun-18	2018_Business_Plan_Basis_of_Estimate	PDF	X									
143	08-Jun-18	V2V Estimating Section Limits	PDF										
144	08-Jun-18	Structures Cost Breakdown - Gil to Carlucci	xlsx	X									
144	08-Jun-18	Tunnels Cost Breakdown - Pacheco Pass	xlsx										
145	08-Jun-18	Central Valley Wye BOQ	PDF										
146	08-Jun-18	San Jose to Wye Quantities	xlsx	X									
147	08-Jun-18	Central Valley Wye UPE Report	PDF	X									
148	08-Jun-18	Central Valley Wye Qty	PDF	X									
149	08-Jun-18	Fresno Station UPE Report	PDF										
150	08-Jun-18	Gilroy to Carlucci Rd. UPE Report	PDF										
151	08-Jun-18	HMF & MOWF UPE Report	PDF										
152	08-Jun-18	Poplar to Bakersfield Qty	PDF	X									
152	08-Jun-18	Poplar to Bakersfield UPE Report	PDF	X									
153	08-Jun-18	San Jose to Wye Qty	PDF	X									
154	08-Jun-18	San Jose to Wye UPE Report	PDF	X									
155	08-Jun-18	2018 Baseline Estimate Optimization 7.2 (V2V)	xlsx	X									
156	08-Jun-18	CP 1-4 Projects Estimate at Completion 09282017	PDF	X									
157	08-Jun-18	Track and systems estimate - 09262017	xlsx										
158	08-Jun-18	Trainset Costs 040816_0	PDF							X			
159	08-Jun-18	Summary of Requirements for O&M Facilities 130321	PDF										
160	08-Jun-18	TM 5.1 Directive Drawings A-G 110711	PDF										
160	08-Jun-18	TM 5.1 Terminal and HMF Guidelines R0 090825	PDF										
161	08-Jun-18	TM 5.2 Directive Drawings 090723	PDF										
162	08-Jun-18	TM 5.3 Facilities Requirements Summary 090831	PDF										
163	08-Jun-18	SCC80 Costs - TCRP 138 Calculator	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
164	08-Jun-18	Evaluation Criteria 011717	PDF										
165	08-Jun-18	NPRM PEQ Standards 11-18-16 FINAL	PDF										
166	08-Jun-18	P14-30-IR-TS-General Provisions	PDF										
167	08-Jun-18	P14-30-IR-TS-GP Schedules	PDF										
168	08-Jun-18	P14-30-IR-TS-Instructions to Proposers	PDF										
168	08-Jun-18	P14-30-IR-TS-ITP Attachments	PDF										
169	08-Jun-18	P14-30-IR-TS-Signature Document	PDF										
170	08-Jun-18	Schedule 1 Part A _Authority Tier III Trainsets Spec Rev 0 012518 (Redline)	PDF							X			
171	08-Jun-18	Term Sheet 4-22-16	PDF										
172	08-Jun-18	V2V Program Summary Schedule Draft _V6	PDF										
173	08-Jun-18	SD3001	PDF										
174	08-Jun-18	SD3003	PDF										
175	08-Jun-18	2018 Baseline Station Costs Summary	PDF										
176	08-Jun-18	Bakersfield Station Options 03-23-2018 JMH FINAL	PDF										
176	08-Jun-18	Interim 4&King platforms	PDF										
177	08-Jun-18	NTD 02 EMT Memo 101109 Station Function Design	PDF										
178	08-Jun-18	NTD 13 RDP_Memo_Station_Platform_and_Track_Layout	PDF										
179	08-Jun-18	Statewide_CHSR Map (V2V stations)	PDF										
180	08-Jun-18	TM 2 2 2 Station Program Design Guidelines R1 110603	PDF										
181	08-Jun-18	TM 2.2.3 HST Passenger Station Site Des Guidelines R0 090410	PDF										
182	08-Jun-18	TM 2.2.4 C and D Directive Dwgs 100604	PDF										
183	08-Jun-18	TM 2.2.4 Station Platform Geometric Design R1 100630	PDF							X			
184	08-Jun-18	TS-1 Contract Term Sheet (9-9-16) (720498751_11)	PDF										
184	08-Jun-18	TS-1 General Provisions (9-9-16) (720500666_12)	PDF										
185	08-Jun-18	TS-1 GP Schedules (9-9-16) (720500668_11)	PDF										
186	08-Jun-18	TS-1 Signature Document (9-9-16) (720500667_10)	PDF										

No.	Received	Document	Doc. Type	SCC 10	SCC 20	SCC 30	SCC 40	SCC 50	SCC 60	SCC 70	SCC 80	SCC 90	SCC 100
187	08-Jun-18	TS01 Specifiaction 06-30-2017 INDUSTRY DRAFT Version	PDF										
188	08-Jun-18	TM 2.4.2 Basic HST Tunnel Config R1 101115	PDF	X						X			
189	08-Jun-18	TM 2.4.2 Directive Drawings A-F	PDF	X									
190	08-Jun-18	V2V Baseline (Consolidated)	zip										
191	11-Jun-18	Estimating Soft Costs for Major Public Transportation - TCRP 138	PDF	X									
192	13-Jun-18	CHSR - Technical Memoranda (TMs)	PDF										
192	29-Jun-18	Fresno Station UPE Report	PDF										
193	10-Jul-18	Avenue 15 Grade Separation Final Design	PDF	X									
194	10-Jul-18	Fresno River HSR Viaduct Final Design	PDF	X									
195	03-Aug-18	LMF and MOIF (Soap Lake)_Optimized	PDF										
196	08-Aug-18	NEST-CP1-CV-MSTR	kmz										
197	08-Aug-18	NEST-CP1E-CV-MSTR-EXT	kmz										
198	08-Aug-18	NEST-CP1E-TT-MSTR	kmz										
199	08-Aug-18	NEST-CP1-TT-MSTR	kmz										
200	08-Aug-18	Structures	kmz	X									
200	08-Aug-18	2017Apr10_SJRV_ATC_REV0_Calcs_Vol_3_Pergola	PDF										
201	08-Aug-18	2017Apr10_SJRV_ATC_RFC_Plans	PDF										
202	10-Aug-18	20180810_Vladimir Kanevsky	PDF										
203	10-Aug-18	Trackwork backup	PDF	X									
204	10-Aug-18	20180810_Vladimir Kanevskiy,	PDF										
205	10-Aug-18	City Cost Index - Los Angeles - As of July 2018	PDF										
206	10-Aug-18	City Cost Index - San Francisco - As of July 2018	PDF										
207	15-Aug-18	Please open	txt										
208	20-Aug-18	Action Overview(VK 08202018)	xlsx										
208	21-Aug-18	Factor - Seismic Risks for Station	PDF										
209	27-Aug-18	Grade Separation 26 in Madera	PDF										

Appendix 2 – Assumptions List

Reference Document ETO_MGM_CAPEX2018-AL_R2.0_20181031_16000

Appendix 3 – Train examples – Overview

Train type	Illustration	Principal technical characteristics
Alstom AGV Origin: France Assembly: France		Train length:7 coaches 132 m, 11 coaches 201 m Max Speed: designed for 360 km/h, 224mph Max power output: 7500 kW (11 coaches) Seat capacity: up to 460 realised (UIC loading gauge , 11 intermediate coaches)
Alstom TGV Duplex Origin: France Assembly: France		Train length:2 power cars, 8 intermediate coaches, 200 m Max Speed: designed for 360 km/h, 224mph Max power output: 9600 kW Seat capacity: ca 500-520 normal Layout, high density 620 (UIC loading gauge , no inboard restauration available)
AnsaldoBreda V250 Origin: Italy Assembly: Italy		Train length: 8 coaches, 201 m Max Speed: designed for 250 km/h, 155 mph Max power output: 5500 kW Seat capacity: 546 (UIC loading gauge , onboard restauration air plane system 1st class) Remark: no more available in the market

Train type	Illustration	Principal technical characteristics
AnsaldoBreda/Bombardier Zefiro V300 Origin: Germany/ Italy Assembly: Italy		Train length: 8 coaches, 202 m Max Speed: designed for 350 km/h, 217 mph Max power output: 9800 kW Seat capacity: 455 (UIC loading gauge , onboard restauration air plane system 1st class, + café bar)
Bombardier Zefiro 380 Origin: Germany Assembly: China		Principal technical characteristics: Train length: 8 coaches, 202 m Max Speed: designed for 380 km/h, 236 mph Max power output: 9800 kW Seat capacity: 455 (broad loading gauge, restauration buffet)
CSR CRH380A Origin: China Assembly: China		Train length: 8 coaches, 203 m, 16 coaches, 406m Max Speed: designed for 350 km/h, 217 mph Max power output: 9600 kW 8 coaches, 20440 kW 16 coaches Seat capacity: 450 – to 556 (8 coaches), ~1030 (16 coaches; broad loading gauge; onboard restauration: buffet)

Train type	Illustration	Principal technical characteristics
Series E5 Origin: Japan Assembly: Japan		Train length: 10 coaches, 253 m Max Speed: designed for 320 km/h, 199mph Max power output: 9600 kW Seat capacity: 731 (broad loading gauge; onboard restauration: not availible)
Series N700A Origin: Japan Assembly: Japan		Train length: 8 coaches, 253 m, 16 coaches Max Speed: designed for 300 km/h, 186 mph Max power output: 8540 kW 8 Coaches, 17080 16 Coaches Seat capacity: 546 8 coaches 1323 16 coaches (broad loading gauge; onboard restauration: not availible)
Rotem KTX-II Origin: South Korea Assembly: South Korea		Train length: 2 power cars, 8 intermediate coaches, 201 m Max Speed: designed for 330 km/h, 205 mph Max power output: 8800 kW Seat capacity: 363 - 410 (UIC loading gauge; onboard restauration: buffet type available)

Train type	Illustration	Principal technical characteristics
Siemens Velaro CN Origin: Germany Assembly: Germany/ China		Train length: 8 coaches, 200m Max Speed: designed for 350 km/h, 217 mph Max power output: 8800 kW Seat capacity: max 728 (high density; broad loading gauge, no restauration available)
Siemens Velaro D Origin: Germany Assembly: Germany		Train length: 8 coaches, 200 m Max Speed: designed for 320 km/h,199 mph Max power output: 8000 kW Seat capacity: 444 (UIC loading gauge, restauration full kitchen, 16 places additional)
Siemens Velaro E Origin: Germany Assembly: Germany/ Spain		Train length: 8 coaches, 200 m Max Speed: designed for 350 km/h, 217mph Max power output: 8800 kW Seat capacity: 404 (UIC loading gauge, restauration Cafeteria and at place service)

Train type	Illustration	Principal technical characteristics
Siemens Velaro e320 Origin: Germany Assembly: Germany		Train length: 16 coaches, 401 m Max Speed: designed for 320 km/h, 199 mph Max power output: 16000 kW Seat capacity: 902 (UIC loading gauge, restauration buffet and at seat service)
Siemens Velaro TR Origin: Germany Assembly: Germany		Train length: 8 coaches, 200 m Max Speed: designed for 320 km/h, 199mph Max power output: 8000 kW Seat capacity: 460 - 519 (UIC loading gauge, restauration buffet or restaurant available)
Talgo 350 Origin: Spain Assembly: Spain		Train length: 8 coaches, 200 m Max Speed: designed for 330 km/h, 205mph Max power output: 8000 kW Seat capacity: 318 (UIC loading gauge, restauration buffet or restaurant available)