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Reducing High-Speed Rail Costs by Combined Double-Single Tracks

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Abstract

This paper aims to demonstrate the advantages of the Alternate Double-Single track (ADST) solution with respect to the traditional double track alternative for railway line design. The paper starts with an introduction and a summary along with a description of the ADST approach and its main advantages. For illustration purposes two real cases, which use this procedure, have been described.

The Santander-Bilbao and the Vitoria-Zaragoza line proposals are analysed in some detail showing the important savings and performances when compared with the double and single track solutions. Finally, some conclusions and recommendations are given.

Keywords: Railway line design, rational investment analysis, optimization, rail capacity, relative travel time

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1. Introduction and motivation

The design of high-speed railway lines could have a new alternative thanks to new methodologies that offer important savings in construction and maintenance costs with no practical losses in travel times.

This case study focuses on an alternate double-single track (ADST) methodology (Castillo, et al., 2015). The main idea behind ADST consists of using single track where the infrastructure is very expensive (tunnels and viaducts) and double track where it is cheaper (smooth orography), if it is necessary.

The ADST methodology is especially suitable for peripheral sections where demand forecast is low or intermediate. A double-track solution in these situations could lead to oversized lines with inefficiency in exploitation and negative social impact investment financial returns. On the other hand, the single-track would not satisfy passenger demand. The ADST performance in peripheral lines is much closer to double- than to single-track performance, whereas the ADST cost is much closer to single- than to double-track cost.

From the previous paragraph, the primacy of considering traffic volumes in rail design could be deduced. An estimation of the demand can determine which the right solution for each case study is: double-track line (high demand) or ADST line (low or intermediate demand).

The main tool required to develop an ADST line is an optimization program that allows us to compare different track combinations and permits us to find the optimal sequence of single- and double-track segments. Thus, construction costs are drastically reduced (up to 40%) and maintenance costs are also substantially reduced (up to 50%) (Castillo, et al., 2015). Some interesting publications related to the optimization of timetables are: (Amit & Goldfarb, 1971) , (Burdett & Kozan, 2010), (Cacchiani & Toth, 2012), (Caprara, et al., 2002), (Carey & Crawford, 2007), (Castillo, et al., 2015), (Castillo, et al., 2011), (Castillo, et al., 2009), (Castillo, et al., 2016), (D'Ariano, et al., 2007), (Pachl, 2014), (Sahin, 1999), etc.

Train routing and other optimization problems have been dealt with in (Assad, 1980), (Carey, 1994), (Carey & Lockwood, 1995), (Cordeau, et al., 1998), (D'Ariano & Pranzo, 2004), (Haghani, 1987), (Hellström, 1998), (Lin & Ku, 2013), (Ouyang, et al., 2009), (Petersen, et al., 1986), (Yang & Hayashi, 2002), etc.

In the same way, the timetable must be optimized in order to reduce travel time. Since travel times of different trains circulating along the network or line could be very different, and the impact of a five-minute delay on a one-hour trip is not the same than on a three-hour trip, the program uses relative travel times.

The relative travel time is the quotient:

$$\textit{Relative travel time (RT)} = \frac{\textit{Travel time}}{\textit{Travel time at maximum speed}} \qquad (1)$$

Then, a relative time 1 means that we travel at maximum speed; contrary a relative time value of 1.10 or 1.20 means that we have been used for the trip a 10% or a 20% more time, respectively.

Delaying or advancing the departure or arrival time without changing the total travel times is achieved forcing the trains to cross inside double-tracked segments.

The design and management of an ADST line is complex, because it requires:

1. Deciding which segments should be constructed in single track and which in double track.
2. Satisfying the safety and timetable constraints of the different services with the aim of obtaining small travel times when we have a single track in some segments.
3. Minimizing costs and travel times and optimize the infrastructure usage.
4. Obtaining all rail timetables of the whole network.

Due to the complexity of the problem, the use of an optimization program is necessary in order to satisfy all the imposed safety and service conditions.

This paper aims to introduce two case studies that clearly show the benefits of using this methodology. Finally, some conclusions will be drawn.

2. Case studies

The case studies used in this paper correspond to the corridors Santander-Bilbao and VitoriaZaragoza (Spain). For each case, the following procedure will be applied: (1) a diagnosis of the current situation will be described; (2) the inputs and outputs of the program will be outlined; and (3) the adopted solution will be justified by carrying out a multi-criteria analysis.

2.1 Santander-Bilbao case

2.1.1 Current line

The existing rail line between the cities of Santander and Bilbao (see Figure 1), in northern Spain, is obsolete compared to modern transportation. Due to the inefficiency of this means of transport, displacements between these two cities are mainly done by private vehicle or bus.

Figure 1. Actual road and railway connections between Santander and Bilbao.

The population of the metropolitan areas of these two capital cities combined comes to more than one million citizens, being Bilbao the most populated one.

This High speed railway line could be part of a possible 'Cantabrian Corridor', from Galicia to the French border, improving connections with Europe. This fact addresses the significance of this infrastructure.

However, the complex orography, characteristic of the North of Spain, makes the construction of a high-speed rail line difficult. In spite of the huge social benefits that a high-speed train could mean, construction costs could be excessively high.

For this reason, there is a strong need for a new solution that offers a considerable reduction in construction and maintenance costs without a great impact on travel times.

After conducting a demand analysis, it has been estimated a demand of approximately 1.1 million passengers in the first year travelling between these two cities.

2.1.2 High speed line proposal

All the factors discussed in the previous section make the alternate double-single track (ADST) line the best solution for the Santander-Bilbao corridor. The features of the proposed line include mixed traffic, Iberian-gauge track (1,668 mm) and a design speed of 250 km/h.

The layout of the line, as depicted in Figure 2, consists on an inland itinerary pursuing a straight line. In order to reduce costs, the existing infrastructure nearby the cities of Santander and Bilbao is used.

Figure 2. Existing railway line and initially proposed HSR line between Santander and Bilbao.

Trying to minimize the environmental impact of this infrastructure, the initial layout has been modified to avoid (see Figure 3): (1) inappropriate land uses; (2) human settlements with more than 100 inhabitants; (3) Site of Community Importance (SCI) in a radius of 1 km; and (4) Protected Areas.

Hence, the ADST line proposal meets the criteria in most of this path as depicted in Figure 4 except for:

- Santander and Bilbao accesses, where the use of the current railway platform is proposed.
- In the vicinity of Bilbao, where potential environmental impacts emerge to coniferous forests. Consequently, to mitigate its impact, tunnels in this area are suggested.

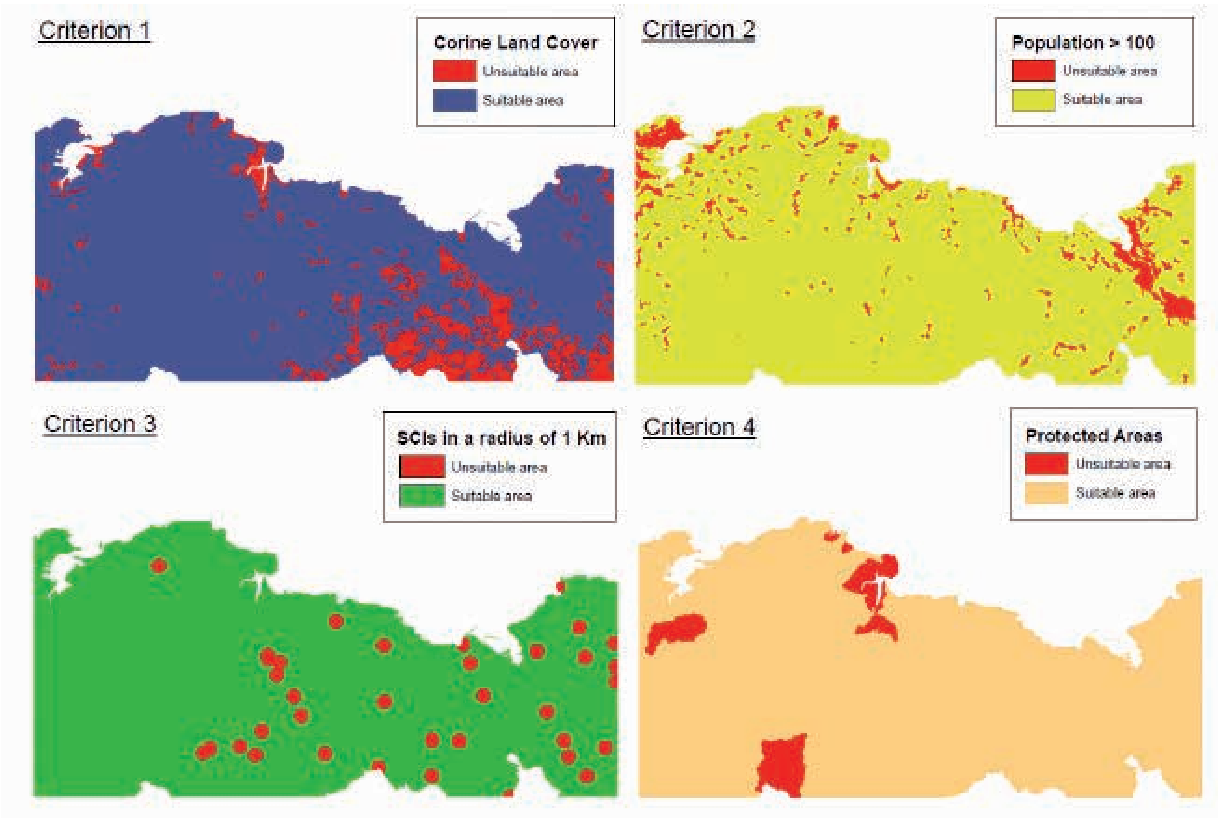

Figure 3. Restricted areas imposed by environmental and other type of constraints.

Figure 4. Final proposal for the Santander-Bilbao line after considerations of required constraints.

The final layout has been modelled in Autocad Civil 3D, meeting the Spanish technical requirements for high-speed railway tracks. The final result consists of a total length of 90.9 km whose 68.18 km are brand new. Due to the complex terrain and the stringent geometrical requirements of this type of lines, the layout includes 28.3% of the total length in tunnel and 13% in viaduct (see Figure 5 and Figure 6).

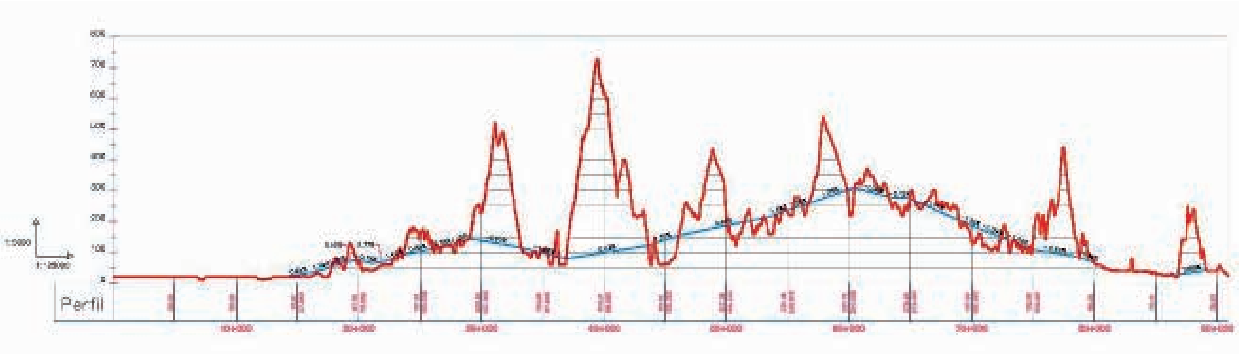

Figure 5. Elevation profile of the proposed HSR line.

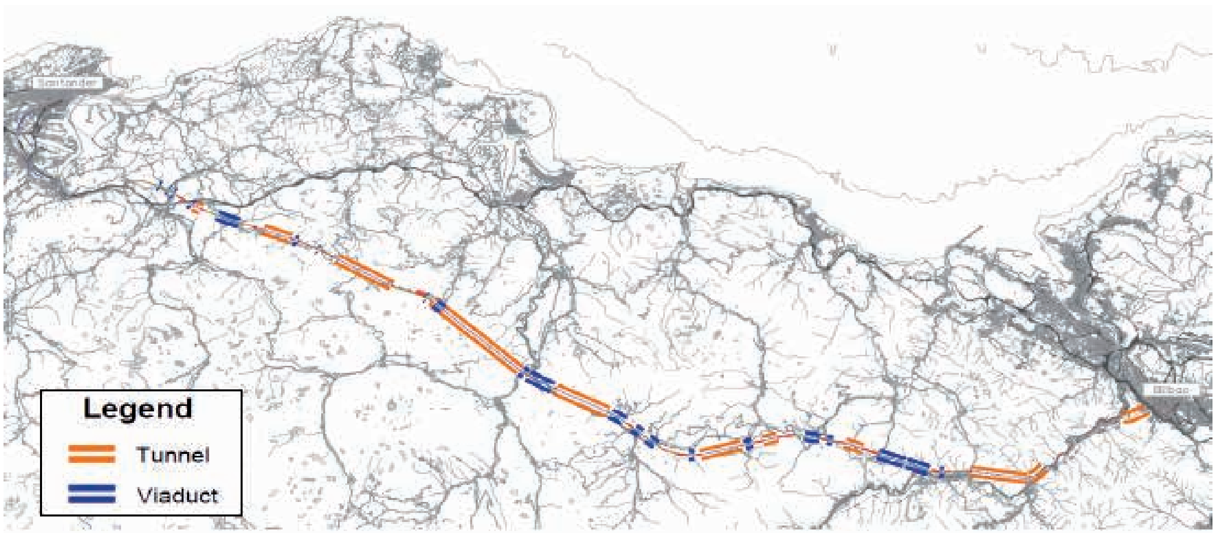

Figure 6. Detailed line layout with the exact tunnel and viaduct locations.

2.1.3 Railway line optimization

To optimize the railway network, the first step for the exploitation study consists of dividing the line into segments of similar characteristics. This is needed in order to obtain an estimation of the cost per kilometre of each segment, in both single- and double-track (see Table 1).

Figure 7. Segments considered in the optimization program. Santander-Bilbao Case

Table 1 Data used for the Santander-Bilbao HSR line, including the segment definition, their lengths and costs in single and double track.

	Segment		Length		Cost (M€/km M£/mi)			
Id	Origin	Destination	Km	Miles	Simple		Double	
1	Santander	Heras	14.0	8.7	1.29 €	£1.82	4.16 €	£5.89
2	Heras	Entrambasaguas	6.7	4.2	5.59 €	£7.92	7.73 €	£10.95
3	Entrambasaguas	Riaño	8.4	5.2	10.21 €	£14.45	17.72 €	£25.10
4	Riaño	San Miguel de Aras	7.8	4.8	13.73 €	£19.45	23.53 €	£33.33
5	San Miguel de Aras	Gibaja	6.6	4.1	16.54 €	£23.42	31.33 €	£44.37
6	Gibaja	La Cadena	6.7	4.2	17.68 €	£25.04	31.52 €	£44.64
7	La Cadena	Mollinedo	9.4	5.8	12.59 €	£17.83	21.87 €	£30.98
8	Mollinedo	Mimetiz	10.8	6.7	13.73 €	£19.44	22.98 €	£32.54
9	Mimetiz	Sodupe	8.9	5.5	13.24 €	£18.75	23.82 €	£33.73
10	Sodupe	Bilbao	11.5	7.1	3.67 €	£5.20	9.77 €	£13.83

The number of services estimated for the new line has been established based on the analysis of the demand, summarized in Table 2. It has been considered a passenger train with a capacity of 238 seats and an average occupancy of 80% (varying from 58% to 95% in 40 years of useful life). This results in 44 daily services, 32 for passengers and 12 for freight.

Table 2 Estimated demand and travel time of the different means of transport between Santander and Bilbao before and after the construction of the HSR line.

Means of transport		Before HSR line		After HSR line	
		Demand	Travel time	Demand	Travel time
Automobile		18,302 p/d/d	1 h 20 min	15,556 p/d/d	1 h 20 min
Bus		1,063 p/d/d	1 h 30 min	956 p/d/d	1 h 30 min
Train	Passengers	0	3 hours	**3,137 p/d/d**	40 min
	Fright	3 trains	-	**6 trains**	-

The segment cost and the estimated services, along with the maximum segment speeds and a proposed schedule, are the inputs to the program that allows us to obtain the optimal combination of single- and double-tracked segments together with the exploitation graphs.

There have been seven alternatives considered. Alternatives 1-5 differ from each other in the maximum relative travel time, varying from 1.20 to 1.00 in a 0.5 interval. In addition, each of these alternatives contemplates two solutions: (1) terminate all the existing train services of FEVE (2) terminate all services except the commuter line between Santander and Liérganes, which will run parallel to the new line in Segment 1. The first solution confers an economic advantage, while the second one a social advantage. Finally, Alternative 6 refers to no action needed and Alternative 7 represents double-track solution.

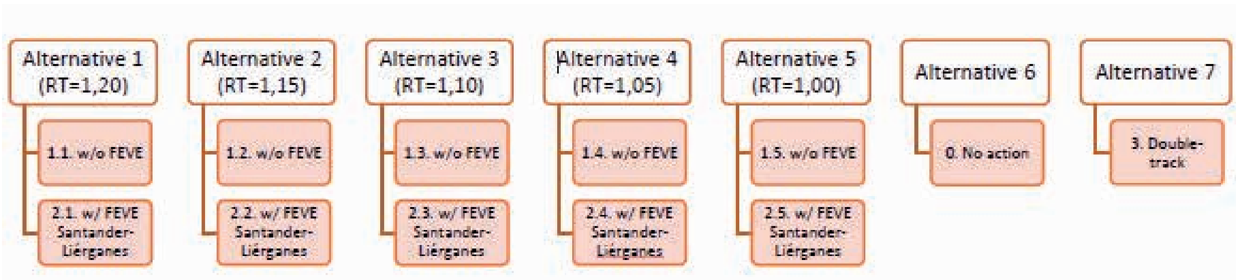

Figure 8. Illustration of the seven alternatives considered.

The program not only minimizes costs and travel times, but also defines the optimal sequence of single- and double-track segments for each alternative. This makes it possible to estimate the construction costs of the infrastructure, as well as the savings compared to the double-track solution.

Table 3 Cost comparison of the 7 alternatives considered. Santander-Bilbao Case

Alternative	Case	Segment										Track Typology		Budget (Mill)		Construction Saving
		1	2	3	4	5	6	7	8	9	10	HS Double	HS Simple	M€	M£	
1	1.1											0%	100%	904.20	795.69	45%
	2.1											0%	100%	944.39	831.07	42%
2	1.2											0%	100%	904.20	795.69	45%
	2.2											0%	100%	944.39	831.07	42%
3	1.3											20%	80%	958.80	843.75	42%
	2.3											20%	80%	1,028.79	905.33	37%
4	1.4											20%	80%	1,007.77	886.83	39%
	2.4											20%	80%	1,077.75	948.42	34%
5	1.5											20%	80%	1,014.38	892.65	38%
	2.5											30%	70%	1,092.16	961.10	33%
6	0											-	-	0.00	0.00	100%
7	3											100%	0%	1,641.18	1,444.24	0%

Single HS Track		Double HS Track	

2.1.4 Rational investment analysis

Once all possibilities have been determined, a multi-criteria analysis will decide which one is the best alternative, not only from the economic perspective (50% weight) but also in regard to the quality from a technical standpoint (50% weigh).

To evaluate the economic perspective, a cost-benefit analysis (CBA) is performed on a long-term scale, with a greater focus on their social benefits. The indicators used for this aim are the following:

(a) Benefit-cost ratio (BCR):

$$BCR = \frac{Discounted\ value\ of\ incremental\ benefits}{Discounted\ value\ of\ incremental\ costs} \qquad (2)$$

(b) Payback period considering a useful life of 40 years (PB).

$$QM = \frac{\sum Services \cdot Weighing}{\sum Services} \qquad (3)$$

Regarding to the technical indicators, the following quality measures have been used:

(a) QM index:

Table 4. Weighing used for the definition of the QM index.

RT	1 <RT<1,05	1,05<RT<1,1	1,1<RT<1,15	1,15<RT<1,2	RT>1,2
Weighing	1	0.8	0.6	0.4	0.2

a) Maximum relative travel time, RTmax
b) Mean relative travel time, RTmean
c) Continuation of services: score 1 if the Santander-Liérganes line is continued and 0 if not.

Table 5. Multi-criteria analysis results. Santander-Bilbao Case

		CBA		Quality indicators				Multi-criteria Analysis
Alternative	Case	BCR	PB	QM	RTmax	RTmean	Cont. Serv.	
1	1.1	1.435	21	0.57	1.52	1.15	0	7.291
	2.1	1.401	22	0.59	1.51	1.15	1	8.197
2	1.2	1.435	21	0.60	1.53	1.17	0	7.418
	2.2	1.327	24	0.57	1.50	1.18	1	7.813
3	1.3	1.381	23	0.83	1.45	1.07	0	8.053
	2.3	1.262	26	0.79	1.41	1.08	1	8.399
4	1.4	1.240	27	0.85	1.39	1.07	0	7.521
	2.4	1.233	28	0.84	1.39	1.07	1	8.432
5	1.5	1.342	24	0.92	1.33	1.03	0	8.256
	2.5	1.220	28	0.93	1.22	1.02	1	8.740
6	0	0.000	0	0.20	5.00	5.00	1	3.905
7	3	0.990	42	1.00	1.00	1.00	0	6.653

2.1.5 Description of the adopted solution

The alternative with highest score is Case 2.5, which is the adopted solution. The solution has the following characteristics:

- The configuration results in 30% of double track against 70% of single track.
- The maximum relative travel time is 1.00. This involves a total duration of the journey of 40 minutes between the city centers of Santander and Bilbao.
- It includes 44 daily services, 32 for passengers and 12 for freight. The resulting timetable is shown in Figure 109.
- This solution also chooses the continuation of the commuter line between Santander and Liérganes.
- The construction cost of the adopted solution amounts to 1,092.16 million euros, saving 549.02 million euros with respect to a double-track solution (33%), which would cost 1,641.18 million euros.
- Considering a useful life of 40 years and meeting the benefits regarding the social welfare, the investment becomes profitable starting from the 28th year in operation.

Figure 9. Final layout of the proposed line showing the single- and double-track segments. Santander-Bilbao Case

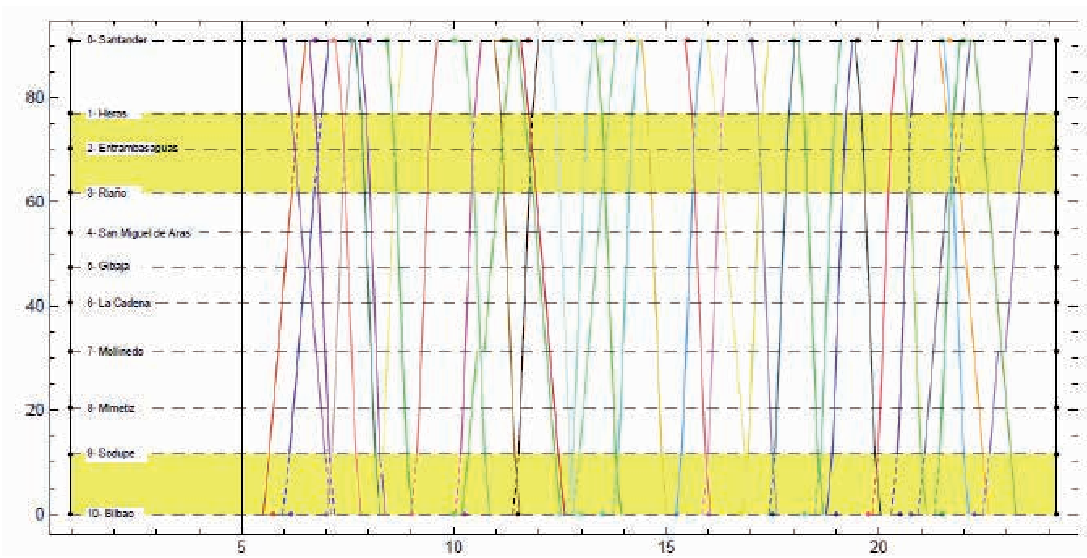

Figure 10. Optimized timetable and selected double- (yellow shade) and single-track segments. Santander-Bilbao Case

2.2 Vitoria-Zaragoza

2.2.1 Current Line

This case describes an ADST proposal between Vitoria and Zaragoza. As Figure 11 shows, in this area there is a railway infrastructure that connects four important cities: Vitoria, Zaragoza, Pamplona and Logroño, which could be considered as four different lines, but for convenience they are assumed to be a unique infrastructure in order to define a global railway improvement for the whole region.

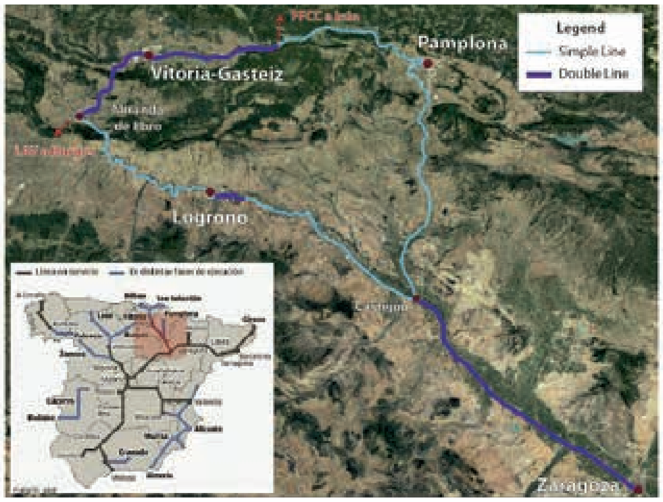

Figure 11. Current line Vitoria-Zaragoza

2.2.2 High Speed line proposal

In this case, similarly to the previous one, a high-speed railway line is projected with:

- Mixed traffic, because this region currently bear an important amount of freight trains and Zaragoza aims to position itself as a major logistic centre.
- Iberian-gauge track (1,668 mm) and a design speed of 250 km/h, in order to reduce the environment impact over this high-value region (La Rioja), to improve the average speed of the current line and to permit the usage of the new line by regional and freight services.

Moreover, due to the high amount of regional services and low-speed freight trains that are currently circulating, it is planned to maintain the conventional line service.

Hence, the proposed line, depicted in Figure 12, mainly consists of a new brand high-speed line together with the rehabilitation of the line through the Logroño metropolitan area and from Castejón (Navarra County) to Zaragoza, which is a segment with a high quality alignment.

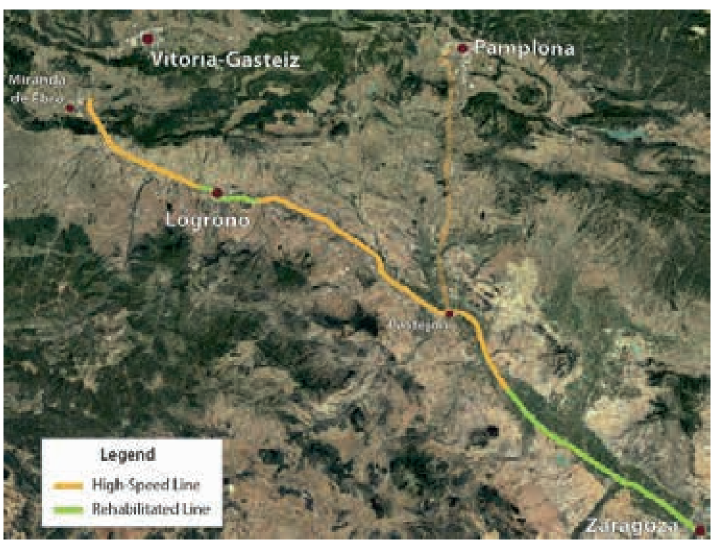

Figure 12. Initial proposal of ADST (Vitoria-Zaragoza Case)

2.2.3 Railway line optimization

In order to define an ADST solution, it is necessary to divide the line in different segments with similar characteristics, see Figure 13. Thus, the 213-km line is divided into fourteen segments with an average cost of 4.6 M€/km and 7.4 M€/Km in single- and double-track respectively, as shown in Figure 13 and Table 6.

Figure 13. Segments proposal of case Vitoria-Zaragoza

Table 6 Data used for the Vitoria-Zaragoza HSR line including the segment definition, their lengths and costs in single and double track.

id	Begin	End	Length (Km)	Cost segment (€)		Cost /km (€/km)		SC/DC (%)
				Single Track	Double Track	Single Track	Double Track	
1	Zaragoza	Alagón	23.0	14,128,988	25,440,536	614,304	1,106,110	55.54
2	Alagón	Gallur	22.0	28,993,623	45,950,485	1,317,892	2,088,658	63.10
3	Gallur	Ribaforada	18.9	11,617,791	20,920,381	614,698	1,106,898	55.53
4	Ribaforada	Murillo	15.1	73,974,914	116,275,615	4,899,001	7,700,372	63.62
5	Murillo	Alfaro	16.0	48,677,810	76,162,378	3,042,363	4,760,149	63.91
6	Alfaro	Rincón de Soto	15.0	34,878,528	56,806,100	2,325,235	3,787,073	61.40
7	Rincón de Soto	Sartaguda	15.0	39,008,833	61,823,412	2,600,589	4,121,561	63.10
8	Sartaguda	Alcanadre	15.0	89,308,075	128,688,296	5,953,872	8,579,220	69.40
9	Alcanadre	Agoncillo	15.0	52,798,000	84,884,756	3,519,867	5,658,984	62.20
10	Agoncillo	Logroño	15.0	9,229,092	79,935,395	615,273	5,329,026	11.55
11	Logroño	Elciego	10.0	135,879,542	211,839,647	13,587,954	21,183,965	64.14
12	Elciego	Bastida	15.0	70,863,223	104,060,948	4,724,215	6,937,397	68.10
13	Bastida	Salinillas	9.0	94,929,137	147,335,037	10,547,682	16,370,560	64.43
14	Salinillas	Armiñón	9.0	93,206,128	144,687,746	9,811,171	15,230,289	64.42
Total			213.5	797,493,684	1,304,810,732	-	-	-
Average values			15.25	56,963,385	93,200,767	**4,583,865**	**7,425,733**	**61.12**

Similarly to the previous case, the costs per km in single- and double-track and mean operating speed of each segment must be used as data for the ADST definition. For this case, 5 main alternatives are defined, which differ from each other in the maximum relative travel time of high speed services, varying from 1.20 to 1.00 in 0.5 intervals.

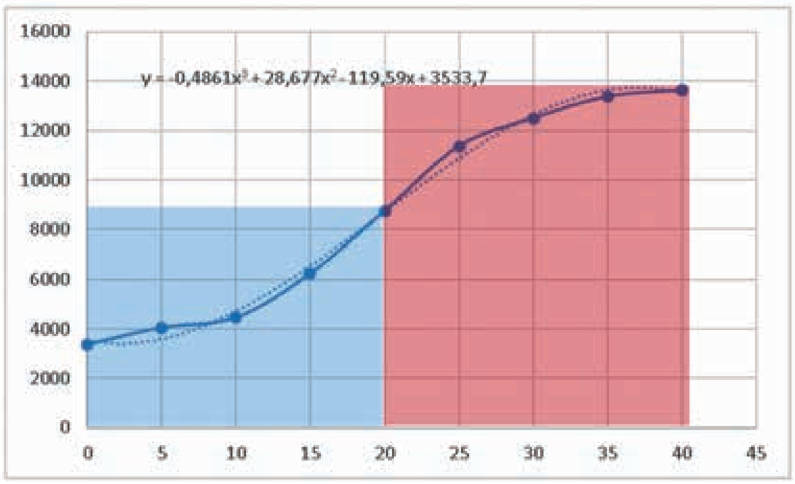

Figure 14. Demand estimate for Vitoria-Zaragoza Case.

Moreover, to estimate the demand of new services for the exploitation period, which is considered of 40 years, a demand analysis is proposed. Thus, as in the previous case, we have considered the current demand, taking into account the travel time and price of each conveyance service. In addition, the passenger redistribution has been estimated with consideration of the existing and the new line, i.e. taking into account not only how many users would maintain their conveyance and how many would change to high-speed services, but also the new generated users.

To calculate the user demand (ordinate axis of Figure 14), two different periods of 20 years have been considered (abscissa axis of Figure 14) in order not to saturate the line unnecessarily and to adapt the rolling stock usage to passenger demand. Consequently, for the initial period (first 20 years), 30 services have been estimated and 60 for the rest of the exploitation period, as

Table 7 shows. Moreover, the current services are added in the first part of the line (ZaragozaCastejón), so that segment will support 116 services (60 high-speed services plus 56 services of conventional lines).

Table 7. High-Speed services estimation

Route	High-Speed Services	
	Year 1-20	Year 21-40
Zaragoza - Logroño - Vitoria	14	28
Logroño - Vitoria	2	4
Pamplona - Zaragoza	12	24
Pamplona - Logroño	2	4
TOTAL	**30**	**60**

Therefore, with all this information, i.e. construction cost, services, speed and proposed schedule, the optimization program calculates which segment should be designed in single- or double- track, in order to define the most cost-effective solution.

The results of the analysis are shown in Table 8 where, in addition to the previously mentioned 5 alternatives, there are two more proposals: Alternative 0, that is, the "No action alternative" that plans to maintain the current line, and Alternative 6, that is, the "Double track alternative", i.e all line in double track. It should be noted that the optimization program has not considered necessary this alternative despite of the high number of 116 circulating services.

Table 8. ADST alternatives for Vitoria-Zaragoza case

Alternative		Segment														Const. Cost (M €)	Saving	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14		M €	%
0	Non Action															0	1,304.8	100%
1	TR_{max} 1,20															849.0	455.8	34.9%
2	TR_{max} 1,15															849.0	455.8	34.9%
3	TR_{max} 1,10															858.3	446.5	34.2%
4	TR_{max} 1,05															897.1	407.7	31.3%
5	TR_{max} 1,00															914.0	390.8	30%
6	Double Track															1,304.8	0	0%

It is convenient to highlight that, with a relative time of 1.00, which means optimal relative time for the high-speed services, the construction cost of the infrastructure is still a 30% (390,8 M€) cheaper than the double track proposal.

2.2.4 Rational investment analysis

Subsequently, with the aim of defining the optimal multi-criteria solution, a rational investment assessment is developed, in which all the alternatives are considered under an economic, social and quality points of view. The criteria to define the multi-criteria evaluation is defined in subsection 2.1.4, where 50% is the economical approach and the other 50% considers the social benefits. This kind of analysis is essential because these infrastructure constructions have two different perspectives, thus the cost-benefit analysis is fundamental in the short-term economic development, while technical indexes reflect the social benefits which are achieved in a medium and long term.

Therefore, in this case, the same indexes explained in subsection 2.1.4 have been used, except for parameter (d) of the Technical indicator, because in this case it is the Environmental Index, IE.

IE is a quality index whose objective is to benefit in the weighting the alternatives that optimize the route scheme against possible future actions to satisfy higher demands. To achieve this, which fraction of common line between the routes Zaragoza - Vitoria and Zaragoza – Pamplona is measured, that is to say, those with noticeably greater demand, is projected in double-track. In this way, it is possible to satisfy a series of premises:

- Minimal environmental impact, since most of the line would be carried out in an unproductive area because there was previously a railway line and, therefore, it consists of a duplication instead of a line construction.
- Performance optimization, since this segment affects both routes at the same time.
- Reduction of construction costs because most of them are track duplication and not new construction.
- Reduction of maintenance costs, because these segments beards both high speed and conventional services.

Finally, the multi-criteria evaluation, shown in Table 10, indicates that the best economic criteria are obtained by those alternatives that imply cheaper construction costs, while the best quality indices come from those alternatives with a higher percentage of double track. However, the optimal multi-criteria final value, which computes the whole indicator bound to equation (3) and its own weights (see Table 9), corresponds to alternative 5, as shown in Table 10.

Table 9 Indicators weights of Case Vitoria-Zaragoza

Indicator	Weighted
BCR	40%
PB	10%
QM	40%
I_E	10%

Table 10 Multicriteria Assessment for Vitoria-Zaragoza Case

Case	Economic Criteria		Quality indices				Multicriteria Value
	BCR	PB	QM	TR_{max}	TR_{medio}	I_E	
0	0.000	1	0.25	-	-	-	1.975
1	2.829	9	0.69	1.29	1.09	-	7.534
2	2.825	9	0.68	1.28	1.09	-	7.473
3	2.819	9	0.83	1.22	1.05	0.20	8.299
4	2.753	9	0.96	1.16	1.02	0.61	9.118
5	2.716	10	0.97	1.11	1.01	0.84	9.328
6	2.333	13	1.00	1.00	1.00	1.00	8.974

2.2.5 Description of the adopted solution

Finally, the alternative with highest score is Alternative 5, which is the adopted solution. The solution has the following characteristics:

- The configuration results in 37.4% of double track against 62.6% of single track.

- The maximum relative travel time is 1.00 for the High speed services and 1.11 for the conventional services.
- It includes 116 daily services, 60 for passengers and 56 freight services. The resulting timetable is shown in Figure 15.
- The construction cost of the adopted solution amounts to 914.03 million euros, saving 390.8 million euros (30%) with respect to a double-track solution, which would cost 1,304.8 million euros.
- Considering a service life of 40 years and meeting the benefits regarding the social welfare, the investment becomes profitable from the 10th year in operation.

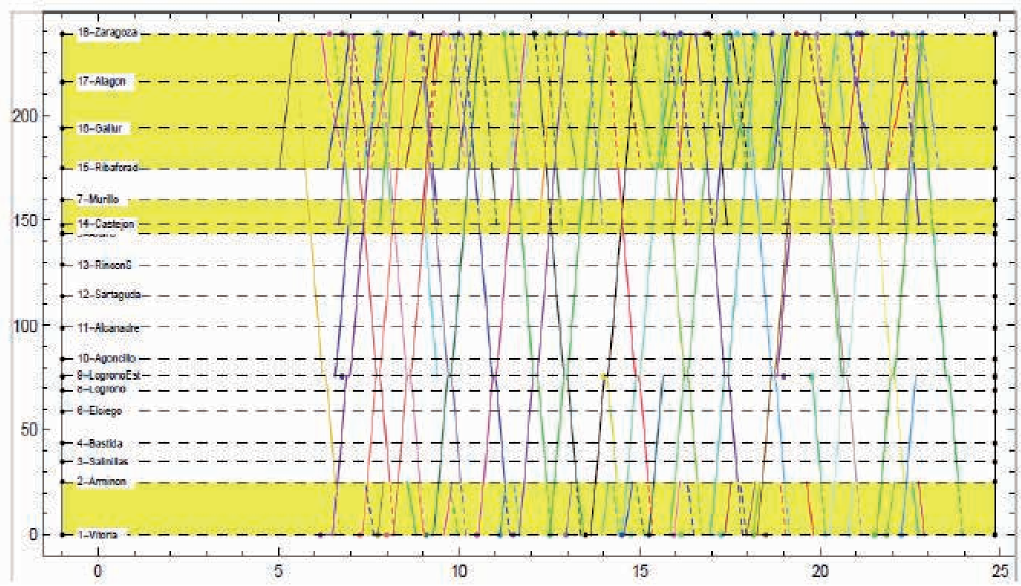

Figure 15. Optimized timetable and selected double- (yellow shade) and single-track segments. Vitoria-Zaragoza Case

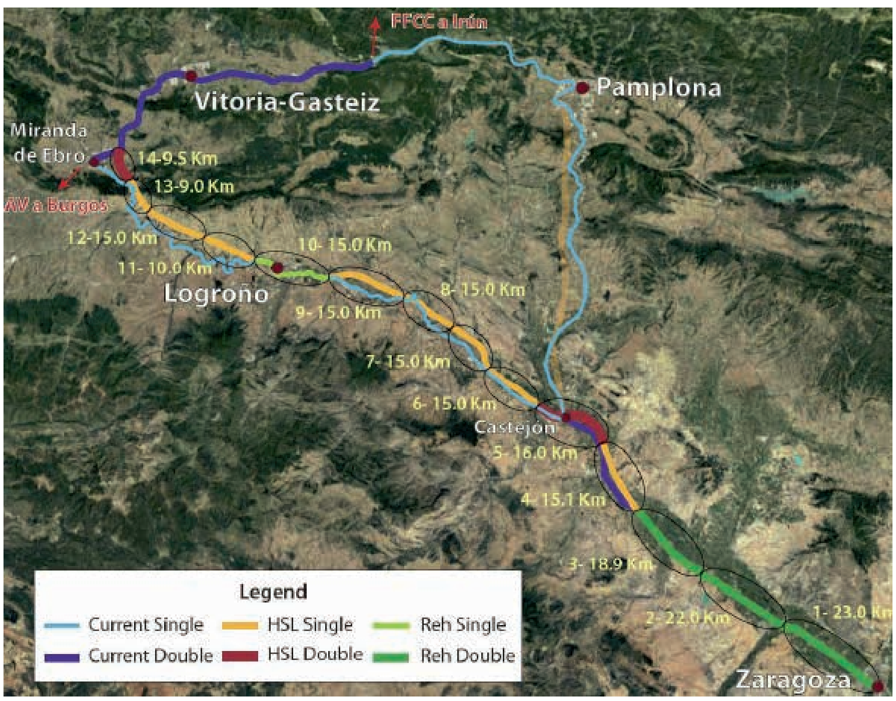

Figure 16. Final layout of the proposed line showing the single- and double-track segments. Vitoria-Zaragoza Case

3. Conclusions

Once the previous examples have been performed, the main conclusions are that the Alternate Double-Single track projects allow to:

- Minimize the construction cost with reduced travel times.
- Design railway lines under current and future demands.
- Define railway alternatives which not impact seriously over the environment.
- Reduce maintenance costs.
- Optimize timetables and improve significantly the current services travel time.
- Model the timetable and the line layout in response to premises of the network.

The case studies have been developed assuming a demand clearly above to de actual one. Despite of that, the ADST alternative provides a solution with far enough rail capacity for all its expected operational life

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