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High Speed Rail in Spain - a statement from a foreign expert

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Abstract

In Spain all high speed trains run over tracks in a special built high speed network. No disturbing influences have to be taken into account for daily operation process. This is a great advantage. Spain shares this advantage with the high speed rail networks in Japan, Taiwan and

China. Running trains on parallel train paths and at least from case to case in 3 minutes headway to each other is a basic condition to reach a high use to capacity. But Spain is running trains with different speeds on its high speed lines. Another condition for a high cost-benefitratio is a strict regular service with at least one service per hour. RENFE however is running the AVE trains in a rather irregular timetable. Some examples will be presented to demonstrate this fact.

The author gives some comparisons of travel times in Spain, Japan and China. The routing data of the AVE line Madrid - Sevilla is compared with those of the Shinkansen Shin Osaka - Hakata.

Based on this comparison the author proposes an upgrading of the AVE-Line Madrid - Sevilla for 300 km/h. A strict regular service for all AVE lines can be developed on the basis of a new travel time Madrid - Sevilla with 118 min together with a 142 min nonstop travel time Barcelona - Madrid. The cost-benefit analysis shows several results, above all nearly 100% more train kilometres as well as saving of running days from EMU's and track change constructions. These results could considerably improve the cost-benefit ratio of the AVE traffic.

Keywords: cost-benefit-ratio, use to capacity, regular service, comparison of travel times

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1. Introduction

High speed rail is a complex and expensive system. A continuos feedback between designing and constructing the new line as well as with the basic structure of future operation is urgently necessary to dimension the infrastructure in the right manner. Further a strict regular service is necessary to offer the passengers a timetable which can be easily remembered. A strict regular service is also an urgent condition to optimize the use of the EMU's. All these criteria have a great influence for the cost-benefit ratio of the high speed traffic.

In May 2013 the EU-commission wrote to the Spanish government to take care of the costbenefit ratio of the AVE traffic. In the same year the German newspaper "Die Welt" published a contribution "Spanien steckt Milliarden in unnütze Züge"[1]. The railway magazine "Eisenbahn Revue International" published a contribution "Schlecht ausgelastetes AVE-Netz in Spanien" in the issue from December 2013 [2]. The author uses all these information as an opportunity to scrutinize the present AVE traffic. He makes proposals to improve the present cost-benefit ratio of the AVE traffic. For this the author bases his research upon the present European Rail Timetable, summer 2017 edition, and on several publications about High speed rail in Spain.

2. Comparison of High-speed Rail systems

A comparison of High-speed rail systems can be made by using different criteria. A main criterion is the different way of operating high speed lines. For this we can distinguish between two different methods. The first method is marked by the fact that high speed trains run over exclusively dedicated high speed lines. No disturbing influences from outside must be taken into consideration for daily operation process. This advantage is mainly justified by the different gauges of the high speed network and the classic network in several countries. This is the case in Japan, Taiwan and in Spain. China is building a huge network only for high speed rail. Furthermore operation process on this separated network faces no disturbing influence from outside. Therefore from an operating view all these countries are comparable.

The second method of operating high speed trains is marked by the fact that high speed trains also run over classic lines in sections. This especially the case in France, where high speed trains use the classic lines when approaching or leaving the city centre stations of big cities. Germany faces the great disadvantage that high speed trains can only use isolated high speed lines with no high speed connection to each other. So both countries face the disadvantage of a mixture from high speed trains and classic trains in sections of the classic network for daily operation process.

3. Experimental analysis

3.1 High use to capacity

From an economic point of view a high use to capacity should be aimed at. This goal can be reached if the high speed trains run with the same speed on parallel train paths to each other given headway of at least 3 minutes in sections. But this is not the case in Spain. Spain is the only country in the world which carries out an operation with different speed on high speed lines. This criterion must be analysed intensely.

3.2 An example of the AVE traffic taken from the European Rail Timetable, valid from July 2017

Figure 1 shows an extract of the train diagram for the direction Madrid - Málaga. This figure shows impressively the problem of scheduling train paths with different speeds. AVE train 2152

running with a speed of 300 km/h is being delayed by 11 minutes to the in front running Alta train 9330, which runs only with a maximum speed of 200 km/h. This unsatisfactory timetable situation exists since December 2011. Absolute parallel train paths have a positive influence on the use to capacity and they are also a condition for an easier daily operation process. This unsatisfactory situation for the train diagram also applies for the mixture of AVE train paths (300 km/h) and Alvia train paths (250 km/h) respective Avant train paths (V_{max}=270 Km/h)

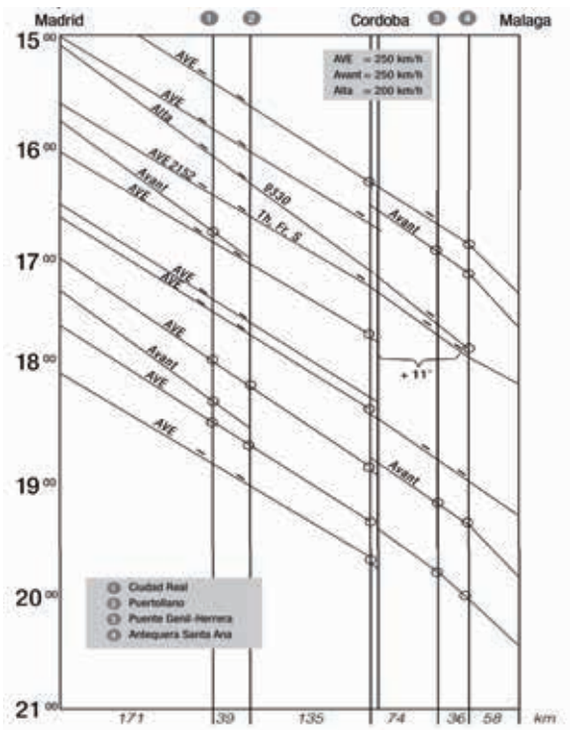


Figure 1. Extract from present train diagram Madrid - Málaga

A relative new unsatisfactory timetable situation exists since December 2016 on the Madrid - Sevilla AVE line. Since this date a nonstop AVE 2360 Madrid (16.00) - Sevilla (18.55) is affected by a 5 minutes delay approaching Sevilla. The in front running IC train 2364 Fr runs only 200 km/h.

3.3 Different travel times Madrid - Málaga

Although only 13 or less trains run daily Madrid - Málaga (Sunday to Wednesday = 12, Thursday and Friday = 13, Saturday = 10) nearly every AVE-train has a different travel time: 2082 + 2102 = 140 min; 2182 + 2212 = 143 min; 2152 = 151 min, 2162 = 152 min, 2112 = 162 min, 2143 = 163 min, 2072 = 165 min, 2092 = 167 min, 2192 = 168 min, 2172 = 170 min, 2122 + 2202 = 185 min). Such a divergence of travel times between two towns nowhere else can be found in a country with high speed traffic.

3.4 Scheduling the length of intermediate stops

Looking at the AVE Madrid - Barcelona timetable it can be noticed that an AVE-train with 4 intermediate stops needs a total travel time of 3h 10 min whereas a nonstop AVE train needs only 2 h 30 min. So the average length of an intermediate stop is about 10 min. This finding also applies for the stop in Córdoba although the AVE trains in this section at present only run with a maximum speed of 250 km/h.

This time should now be compared with a similar regulation in China. The Chinese Code for Design of High-sped railway formulates in chapter 4.2.3: *"Generally, the additional time for start of trains shall not be longer than 2,5 min, and that for stop of trains shall not be longer than 1,5 min."*[3]. With a length of 1 min for the stop we can calculate the whole amount of the stop to 5 min; with a length of stop with 2 min to 6 min. This is also the case in Japan. These amounts lie clearly below the amount of 10 min.

Travelling between Barcelona and Zaragoza Delicitas for the first time on Tuesday 03-10-2017 with train AVE 3122, the author could watch that the train was running relative slowly through the track leading from the main track to the platform track in the two stations Lleida and Zaragoza. Regarding this observation it should be possible that in total 24 min for the three intermediate stops at Zaragoza, Lleida and Camp de Tarragona should be enough. Concerning this assumption please have a look at the train diagram study at the end of the final paper at page 36.

Furthermore it is known that RENFE is proud of being absolutely punctual with the AVE traffic. From a certain amount of delay RENFE reimburses the costs for the tickets to their passengers. But it seems that this goal is achieved with a disproportionate prolongation of the stopping time in stations and in the running time. RENFE should give up this goal and take all effort to provide the highest possible commercial speed for a maximum of passengers. This goal always must have the highest priority in high speed rail traffic.

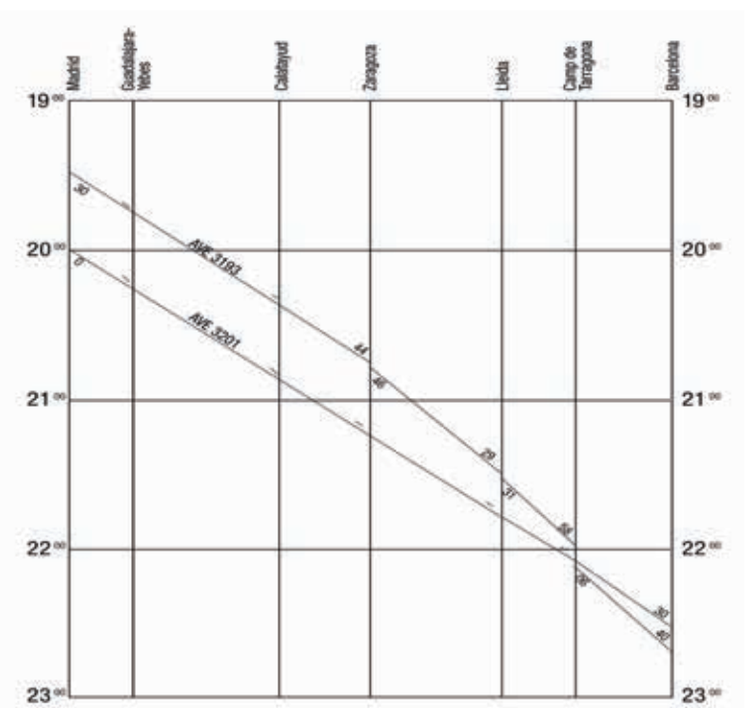


Figure 2. Extract from present train diagram Madrid - Barcelona

Figure 2, taken from the current timetable Madrid - Barcelona, proves this finding impressively. In the end AVE train 3193 needs additional 40 minutes for only 3 additional stops, including a surely unproductive waiting time in the intermediate station Camp de Tarragona. The insufficient infrastructure in this station doesn't allow a quick overtaking.

3.5 Comment on the present AVE timetable

With the present more or less irregular timetable including such different travel times between two cities as demonstrated for the Madrid - Málaga direction RENFE never will be able to receive sufficient revenues from the AVE traffic, which are necessary to justify the huge investment costs for this traffic.

3.6 Comparison of travel times

It is necessary to compare the fastest AVE travel times between Madrid and Barcelona respective Sevilla with those of some other countries that carry out high speed rail. For this step it is important that the distances of the connections are nearly the same as Madrid - Barcelona and Madrid - Sevilla.

3.6.1 Direction Madrid - Barcelona

The comparison shows the data for a nonstop train in this connection. All data are taken from the timetable effective from July 2017.

Table 1. Travel time comparison of two railway connections in Spain and China

Connection	Country	distance (km)	train number	running speed (km/h)	travel time (min)
Madrid P.d.A. - Barcelona	Spain	621	several	300	150
Guangzhou South - Changsha South	China	618	G 66	300	137

The figures in the last column require an explanation. RENFE puts too much recovery time into the running time in order to be punctual. A Swiss countryman, who travelled with a nonstop AVE Barcelona - Madrid, once told the author that he had watched an earlier arrival of almost 8 minutes at Madrid P.d.A. This observation proves that the present nonstop travel time Barcelona - Madrid contains too much recovery time.

For this detail a comparison with daily operation process on the Tokaido Shinkansen Tokyo - Osaka in Japan is useful. In the Annual Report 2016 JR Central informs about the daily operating performance: number of services per day: 358, average delay time pro train: 0,2 minutes [4]. And opposite to RENFE JR Central reaches this goal without any prolongation of running time and lengths of stop in stations. And on top of it from the fastest train category, the Nozomi train, 4 trains per hour and direction run during day time and 6 trains per hour and direction run during normal peak time. And all these Nozomi trains have to take into account 2 or even 3 overtakings of slower trains on their running between Tokyo and Shin Osaka.

3.6.2 Direction Madrid - Sevilla

The comparison of the travel times is shown in the table below. The data for Spain and China are taken from a timetable, effective from July 2017, those from Japan effective from March 2017.

Table 2. Travel time comparison of three railway connections in Spain, China and Japan

Connection	Country	distance (km)	number of trains	inter-mediate stop(s)	running speed (km/h)	travel time (min)	commercial speed (km/h)
Madrid - Sevilla	Spain	472	7	1	250 - 270	150	188,8
Zhengzhou East-Wuhan	China	472	2 6	1 2	300 300	112 119	252,8 238,0
Kokura Shin Kobe	Japan	465	2 29	2 3	300 300	113 119	246,9 234,4

The figures in this table raise the question if the Madrid - Sevilla AVE-line couldn't be upgraded to a speed of 300 km/h, because the line is designed for an operating speed of 300 km/h.

3.7 Upgrading the AVE line Madrid - Sevilla to a speed of 300 km/h

The profile of the speed of the line proves that it is mainly designed for a speed of 300 km/h [5]. When high speed rail started to become an important topic on the agenda of several countries in the last century no experiences existed between constructing and operating a high speed line. When a new line is built daily operation has to deal with the design criteria. Under this finding several countries now try to gain the highest speed from the infrastructure. In this way a comparison between the routing data of the Sanyo-Shinkansen line Shin Osaka - Hakata in West Japan and the AVE line Madrid - Sevilla in Spain could be very informative for Spain.

Table 3. This comparison is carried out in table 3.

Route	Country	minimum radius (m)	maximum gradient (‰)	tunnel cross section (m^2)	distance between tracks (m)	vehicle width (m)	distance between passing trains (m)	passing speed between trains (km/h)
Madrid -Sevilla	Spain	4000	12,5	75	4,30	2,96	1,34	500
Madrid -Sevilla in a section south of Puertollano	Spain	3250	12,5	75	4,30	2,96 (Talgo 350)	1,34	430
Shin Osaka - Hakata	Japan	4000 3500 = excep-tion	15,0	63,4	4,30	3,38 (N 700)	0,92	600

Comparison of routing data between Madrid - Sevilla in Spain and Shin Osaka - Hakata in Japan.

The routing data for the Sanyo Shinkansen are taken from source [6]. The minimum radius and the distance between tracks are the same in Japan and Spain, in all other criteria the routing data of the Madrid - Sevilla line are more convenient for a higher speed than those of Shin Osaka - Hakata line. But the trains between Kokura and Shin Kobe on the Sanyo-Shinkansen run with a speed of 300 km/h, as shown in table 2. This fact raises the question how a travel time Madrid - Sevilla would look like based upon a running speed of 300 km/h. For this step at first the travel time prolongation in the section south of Puertollano has to be calculated, where the minimum radius falls below an amount of 4000 m. This calculation is carried out in

Table 4. Calculation of travel time prolongation Puertollano - Sevilla

radius (m)	running speed (km/h)	length of the section (km)	travel time (min)	travel time prolongation (min)
4000	300	72	14,4	
3200	270	72	16,0	1,6
2300	270	28	6,2	
2300	215	28	7,8	1,6

The technical data were taken from source [7].

A new travel time Madrid - Sevilla with one intermediate stop at Córdoba can be calculated as follows :

Basic travel time: 112 min analogous to Zhengzhou East - Wuhan in China. This amount takes into account a 2 min stop at one intermediate station,

Travel time prolongation: 3,2 min

reserve: 2,8 min

total = 118 min.

A new travel time Madrid - Sevilla based upon a running speed of 300 km/h can be calculated to an amount of 118 min. This means a travel time reduce of 32 min (= -21,3%) compared to 150 min at present.

Additional remark: on his return trip from Ciudad Real on Saturday 07-10-2017 the author took train AVE 3993+3943. In the section before Madrid the author could watch that in a car of this train for a very short moment an amount of 298 km/h was shown.

3.8 Some basic statements for optimizing the AVE traffic

Some basic statements for the AVE traffic must be presented before an improvement for the AVE traffic shall be developed.

1. Compared with other countries (Japan, China) we must always bear in mind that very few trains will run over the tracks of the AVE lines,
2. these very few trains must run with the same speed over the tracks of the high speed line,

3. it is necessary to adjust the technical standards of all AVE lines to each other,
4. it is in the same manner urgent necessary, to adjust also the standards of the use of the EMU's to each other. Only one EMU type should be used on the AVE lines. The optimization proposal will be based on these statements.

3.9 Elimination of Alta, Alvia and Avant trains from AVE lines operated with a speed of 300 km/h

Because these trains run only 200/250 or 270 km/h train paths of these trains come into conflict with AVE train paths scheduled with a speed of 300 km/h. This topic now must be scrutinized.

Alta trains

The speed difference is too high. An Alta train does never delay an AVE train as figure 1 proves. The present Alta trains Madrid - Algericas must be replaced by AVE trains in the section Madrid - Antequera Santa Ana and by MD-trains in the section Antequera Santa Ana - Algericas. Passengers bound for Algaricas (= always the minority in the AVE trains) have to change trains in Antequera Santa Ana.

Alvia trains

This topic can be scrutinized by three train diagram studies. The first example refers to the AVE line Madrid - Barcelona. It is shown in figure 3.

Figure 3. Train diagram study for AVE line Madrid - Zaragoza - Barcelona

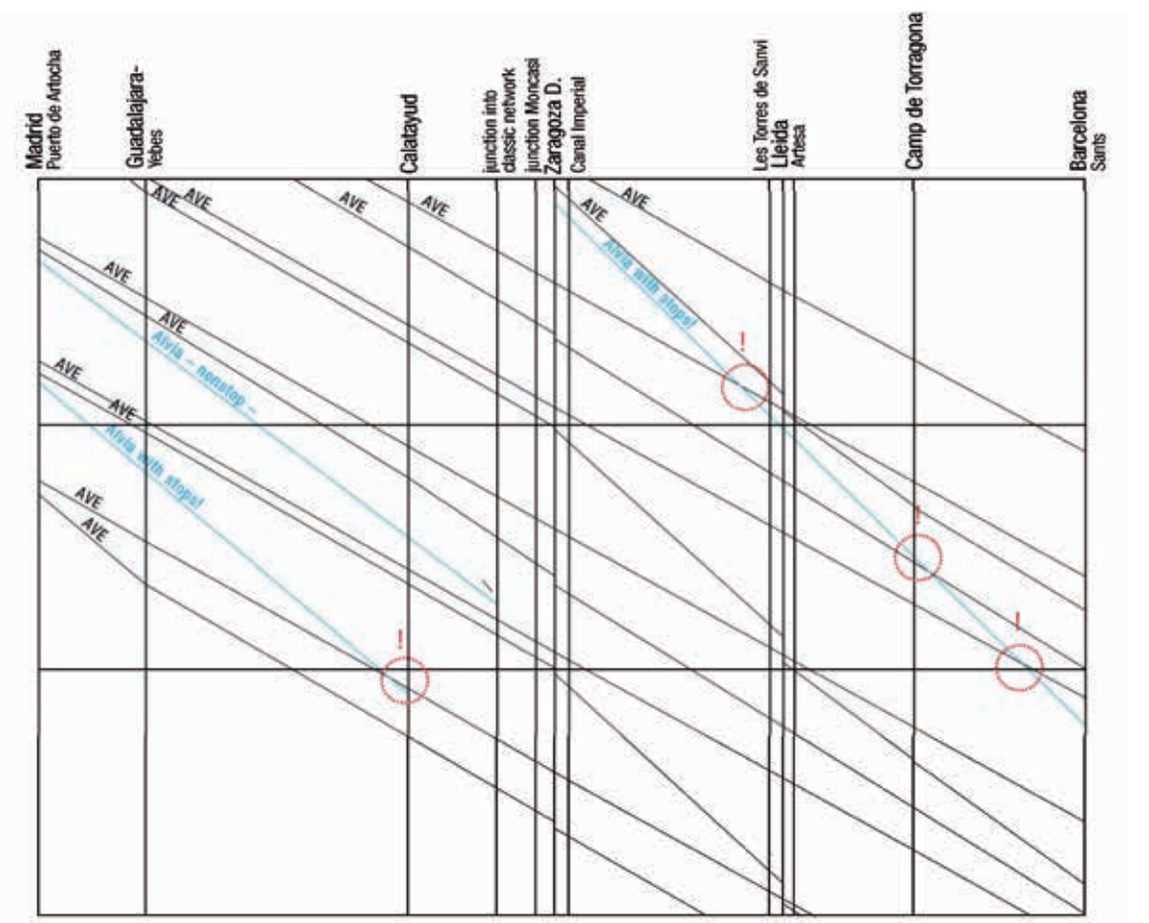


Figure 3 proves that an Alvia train West Spain - Barcelona, which also calls at Lleida and Camp de Tarragona, would be intersected by 3 AVE trains in the section Zaragoza - Barcelona .Such an Alvia train should be cancelled in the section Zaragoza - Barcelona. When such a train terminates in Zaragoza measures must be taken to improve the interchange modes in Zaragoza. For this refer to topic 3.10.3. Keeping up a through service Barcelona - West Spain would require an EMU, which is capable of running 300 km/h between Barcelona and Zaragoza on European track gauge (1435 mm) and than running on the Iberian gauge (1668 mm) beyond Zaragoza. This seems not to be an economic solution for RENFE, because this train must run additional to the proposed regular service and only very few special EMU's would be required for this through service.

The situation in the section Madrid - Zaragoza is a little bit less complicated. Given the possibility of departing three trains in a headway of 3 minutes to each other every hour only one train path with the fixed departure at minute /.20 o'clock would remain for an Alvia nonstop service Madrid - Pamplona. If the existing signalling system only allows a headway of 5 minutes, as by the present timetable may be assumed, no Alvia train path without any intersection can be scheduled. A target for the train diagram between Madrid and Barcelona is presented on page 36.

Figure 4. Train diagram study for AVE line Madrid - Sevilla

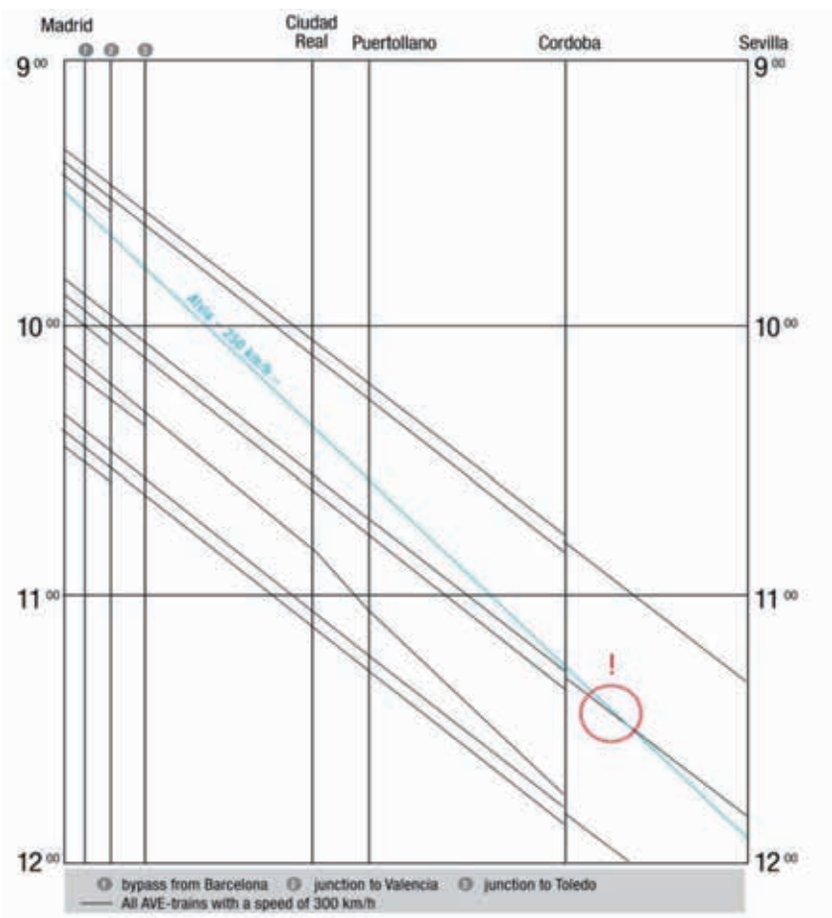
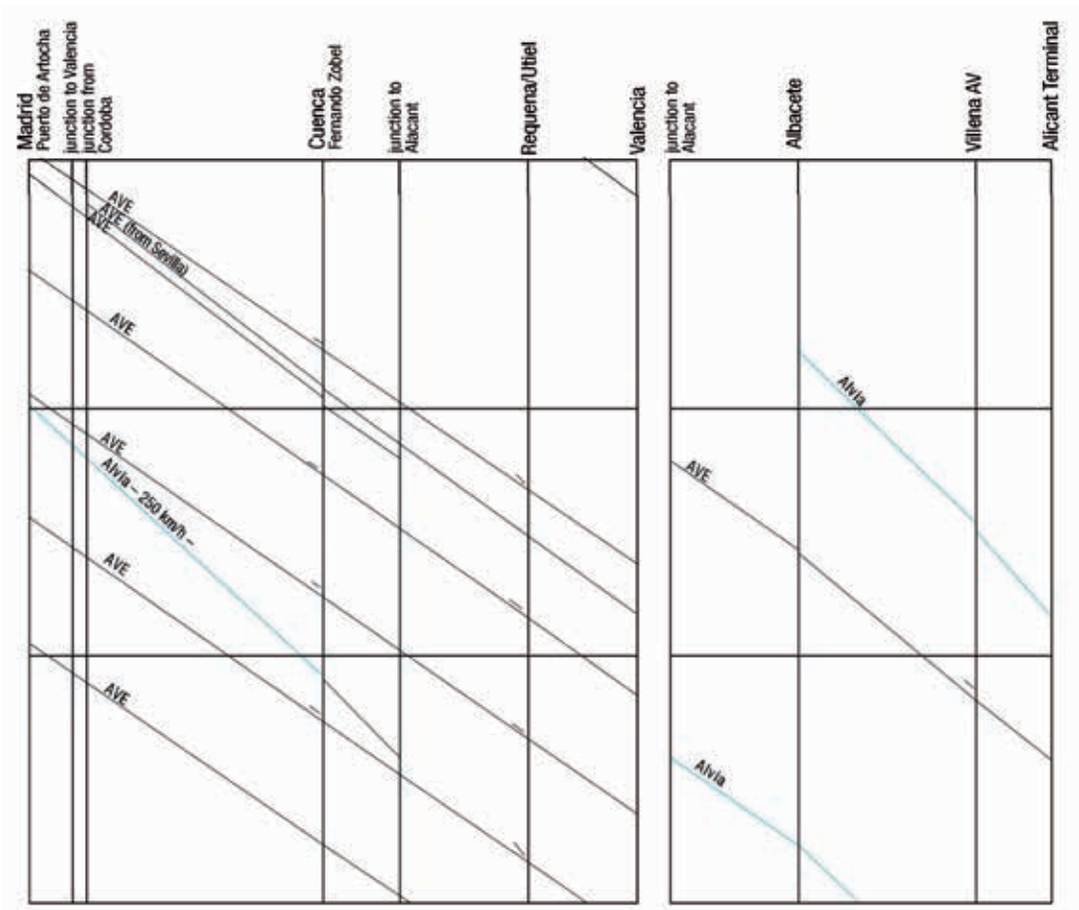


Figure 4 demonstrates the same problem for the Madrid - Sevilla route. A nonstop Alvia train path Madrid - Sevilla can't be scheduled without any intersection by an AVE train path, if the latter run in a 30 min space to each other. So an economic solution can only be that passengers from Madrid bound for Cadiz or Huelva use the AVE train until Sevilla and there change trains for their final destination, if possible at the same platform (see topic 3.10.3)

Figure 5 explains the situation for the Madrid - Valencia resp Alacant AVE line. If a nonstop travel time of 101 min is utilized for a nonstop travel time Madrid - Valencia an Alvia train path Madrid - Alacant may be scheduled exactly between two nonstop train paths Madrid - Valencia running in a space of 30 min to each other, if the Alvia train leaves the main AVE line at the junction splitting off to Alacant. But when the author travelled on 2016-04-21 with AVE train 5141 from Valencia (14.10) to Madrid (15.45) the travel time amounted to only 95 min. The train was absolute punctually. The presented train diagram situation may therefore be checked by RENFE again, if the in figure 5 described situation works, given a nonstop travel time Madrid - Valencia of 95 min.

Figure 5. Train diagram study for AVE line Madrid - Valencia resp. Alacant



Avant trains

The idea of running Avant trains (classes 104 and 114) with a maximum speed of only 250 km/h on AVE-Lines with a speed of 300 km/h, because there is surplus capacity (via libre special issue *"25 years of Spanish high speed rail"*, page 58) is a **wrong** conclusion. As already mentioned on page 2 it must always be a goal to run trains on parallel train paths in order to reach a high use to capacity. The demand for absolute parallel train paths refers also to the daily operations control. It is much easier to carry out operations control with trains running the same speed rather than with different speeds. Therefore it shall be checked, if the present Avant services Puertollano - Madrid, Toledo - Madrid and Sevilla - Málaga can be integrated in an economic manner in the rolling stock roster for the 300 km/h fast EMU's. For this see topics 3.10.4 and 3.10.5.

3.10 Developing of a regular service concept for the AVE traffic in Spain

A strict regular service concept shall be developed for the AVE traffic. The backbone for this concept shall be a half-hourly concept of express AVE-trains between Barcelona and Sevilla only calling at Madrid P.d.A. and Córdoba on their running. The nonstop travel time Barcelona - Madrid P.d.A. can be assumed to an amount of 142 min. This amount is in line with the data in table 1. The timetables for a strict regular service presented in the following statement are developed in a continous feedback with the available number of EMU's capable of running 300 km/h.

3.10.11 Sevilla/Málaga/Granada - Madrid - Barcelona - Figueres Vilafant

Table 5. Hourly AVE-Concept Málaga/Granada/Sevilla - Madrid - Barcelona - Figueres-Vilafant first hour

Hourly AVE-train concept direction south - north ***first*** hour

train number	5071	2171	AVE	3061	3253		AVE	2171	5073	AVE	3161	3255		3981		AVE
Malaga dep.							**06.29**									**06.59**
Granada arr.							07.19									07.49
Granada dep.							**07.41**									**08.11**
Malaga arr.							08.31									09.01
Malaga dep.		**06.08**		**06.16**						**06.42**						
Granada dep.			**06.02**								**06.36**					
Antequ.S.A. arr.		06.29	06.33	06.37						07.03	07.07					
Antequ.S.A. ep..		06.30	06.34	06.38						07.04	07.08					
Puento G.-H. arr.		06.42	↓	↓						↓	↓					
Puente G.-H. dep.			↓	↓				06.54		↓	↓					
Sevilla arr.			**07.29**							07.59						
Sevilla dep.					**06.41**							**07.11**		**07.14**		
Cordoba arr.				07.09	07.12			07.15			07.39	07.42		07.45		
Cordoba dep.				**07.11**	**07.14**			**07.17**			**07.41**	**07.44**		**07.47**		
Puertollano dep.				↓	↓			07.56			↓	↓		08.26		
Ciudad R. dep.				↓	↓			08.10			↓	↓		08.40		
Cuenca F. dep														09.56		
Valencia arr														**10.50**		
Valencia dep.	**06.52**						AVE		**07.22**					every	AVE	
Cuenca F. dep.	↓						8091							two	8093	
Toledo dep.							**08.18**							hours	**08.48**	
Madrid P.d. At arr.	**08.33**			**08.36**	**08.39**		**08.47**	**08.54**	**09.03**		**09.06**	**09.09**			**09.17**	
train number					↓	3061			↓			↓	3161		↓	
Madrid P.d.At. dep.	**08.39**				**08.44**	**08.47**	**08.57**	**09.03**	**09.09**			**09.14**	**09.17**		**09.27**	
Guadj. Yebes dep.	rever-				↓	↓	rever-	rever-	rever-			↓	↓		rever-	
Calatayud dep.	sal to				↓	↓	sal to	sal to	sal to			↓	10.13		sal to	
Zaragossa D. arr.	Toledo				↓	**09.59**	Valen-	Alacant	Toledo			↓	10.34		Valen-	
Zaragossa D. dep.					↓	**10.01**	cia					↓	**10.36**		cia	
Lleida dep.					↓	10.47						↓	↓			
Camp de Tarr. dep.					↓	11.13						↓	↓			
Barcelona S. arr.					**11.06**	11.46						**11.36**	**12.00**			
Barcelona S. dep.												11.38				
Girona dep.												12.18				
Figueres V. arr.												12.33				

Important remarks: A.) The exact new travel times Sevilla - Madrid and Madrid - Barcelona for trains with intermediate stops must be calculated from RENFE analogous to the new non-stop travel times. B.)The travel time Granada - Antequera Santa Ana for an AVE-train is calculated as follows: 621 km: 142 min = 123 km: x x = 142 x 123: 621 = 28,1 rounded up = 31 min.

Table 6. Hourly AVE-Concept Figueres-Vilafant - Barcelona - Madrid - Sevilla/ Granada/Málaga first hour

Hourly AVE-train concept direction north - south **first** hour

train number	3254			3062	3256		3270					3162	3258				
Figueres V. dep.							**Mo -**						06.27				
Girona dep.							**Th**						06.42				
Barcelona S. arr.													07.22				
Barcelona S. dep.	**06.24**			**06.14**	**06.54**		**07.00**					**07.06**	**07.24**				
Camp de Tarr. dep	↓			06.47	↓		↓					↓	↓				
Lleida dep.	↓	rever-	rever-	07.13	↓		↓			rever-	rever-	↓	↓				rever-
Zaragossa D. arr.	↓	sal	sal	07.59	↓		↓			sal	sal	08.30	↓				sal
Zaragossa D. dep.	↓	from	from	08.01	↓		↓			from	from	08.31	↓				from
Calatayud dep.	↓	Alacant	Valen-	↓	↓		↓			Toledo	Valen-	↓	↓				Toledo
Guadj. Yebes dep.	↓		cia	↓	↓		↓				cia	↓	↓				
Madrid P.d.At. arr.	**08.46**	**08.57**	**09.03**	**09.13**	**09.16**		**09.22**			**09.17**	**09.33**	**09.43**	**09.46**				**09.47**
train number		2176	8292			3062	AVE	AVE	2176	5012	8294			3162	AVE	AVE	5014
Madrid P.d.At dep.	**08.51**	**09.06**	**09.09**		**09.21**	**09.24**				**09.27**	**09.39**		**09.51**	**09.54**			**09.57**
Toledo arr.			**09.38**								**10.08**						
Cuenca F. dep																	
Valencia arr.										**11.08**							**11.38**
Valencia dep.																	
Cuenca F. dep.																	
Ciudad Real dep.	↓	09.50			↓	↓							↓	↓			
Puertollano dep.	↓	10.04			↓	↓							↓	↓			
Cordoba arr.	10.16	10.43			10.46	10.49							11.16	11.19			
Cordoba dep.	**10.18**	10.45			**10.48**	**10.51**							**11.18**	**11.21**			
Sevilla arr.	**10.49**				**11.19**								**11.49**				
Sevilla dep.								**10.31**							**11.01**		
Puento G.-H. arr.		11.06				↓		↓						↓	↓		
Puente G.-H. dep.						↓		↓	11.18					↓	↓		
Antequ.S.A. arr.						11.22		11.26	11.30					11.52	11.56		
Antequ.S.A. dep.						11.23		11.27	11.31					11.53	11.57		
Granada arr.								**11.58**						**12.24**			
Malaga arr.						**11.44**			**11.52**						**12.18**		
Malaga dep.							**11.59**									**12.29**	
Granada arr.							12.49									13.19	
Granada dep.							**13.11**									**13.41**	
Malaga arr.							14.01									14.31	

All trains assumed with a running speed of 300 km/h !

Some explanation must be given to tables 5 and 6.

The whole regular service system is fixed on the exact meeting of a train Madrid - Barcelona containing the service pattern of train 3061 with a train Barcelona - Madrid containing the service pattern of train 3062, exactly every hour at minute.59/.01 o'clock, at Zaragoza. By this optimal conditions for connecting services are given in Zaragoza (see page 36 for this purpose!) A nearly half hourly connection with the capital Madrid is also given for the Andalusian cities Málaga and Granada. Both cities have one hourly direct service (Málaga departure at minute /.16 o'clock; Granada departure at minute /.36 o'clock) and one hourly connecting service with the train bound for Sevilla (Málaga departure at minute /.42 o'clock, Granada departure at minute /.02 o'clock). This train shall provide a connecting service within a time space of 5 minutes at the same platform at Antequera Santa Ana (see also topic 3.10.3)

The smaller intermediate stations Puenta Genil Herera, Puertollano and Ciudad Real shall be served hourly by a special service Málaga - Madrid, train 2173 and in reverse direction train 2176. We can assume that the capacity of these trains is primarily used for passengers bound for these stations or for passengers, who want to get in these trains from these stations. The train, departing Madrid every hour at minute /.17 o'clock towards Barcelona, shall provide alternately a stop every two hours at Calatayud or Guadalajara-Yebes

Table 7. Hourly AVE-Concept Málaga/Granada/Sevilla - Madrid - Barcelona - Figueres-Vilafant second hour

Hourly AVE-train concept direction south - north ***second*** hour

train number	5075	AVE	2173	AVE	2073	2085		AVE	2173	5077	AVE	2063	2087	
Malaga dep.		**07.29**						**07.59**						
Granada arr.		08.19						08.49						
Granada dep.		**08.41**						**09.11**						
Malaga arr.		09.31						10.01						
Malaga dep.			**07.08**		**07.16**						**07.42**			
Granada dep.				**07.02**								**07.36**		
Antequ.S.A. arr.			07.29	07.33	07.37						08.03	08.07		
Antequ.S.A. ep..			07.30	07.34	07.38						08.04	08.08		
Puento G.-H. arr.			07.42	↓	↓						↓	↓		
Puente G.-H. dep.				↓	↓				07.54		↓	↓		
Sevilla arr.				**08.29**							**08.59**			
Sevilla dep.						**07.41**							**08.11**	
Cordoba arr.					08.09	08.12			08.15			08.39	08.42	
Cordoba dep.					**08.11**	**08.14**			**08.17**			**08.40**	**08.43**	
Puertollano dep.					↓	↓			08.56			↓	↓	
Ciudad R. dep.					↓	↓			09.10			↓	↓	
Cuenca F. dep														
Valencia arr														
Alicant dep.														
Valencia dep.	**07.52**						AVE			**08.22**				AVE
Cuenca F. dep.	↓						8095			↓				8097
Toledo dep.							**09.18**							**09.48**
Madrid P.d. At arr.	**09.33**				**09.36**	**09.39**	**09.47**		**09.54**	**10.03**		**10.06**	**10.09**	**10.17**
train number					↓	↓						↓	↓	
Madrid P.d.At. dep.	**09.39**				**09.44**	**09.47**	**09.57**		**10.00**	**10.09**		**10.14**	**10.17**	**10.27**
Guadj. Yebes dep.	rever-				↓	↓	rever-		rever-	rever-		↓	10.39	rever-
Calatayud dep.	sal to				↓	↓	sal to		sal to	sal to		↓	↓	sal to
Zaragossa D. arr.	Toledo				↓	**10.59**	Valen-		Alacant	Toledo		↓	**11.34**	Valen-
Zaragossa D. dep.					↓	**11.01**	cia					↓	**11.36**	cia
Lleida dep.					↓	11.47						↓	↓	
Camp de Tarr. dep.					↓	12.17						↓	↓	
Barcelona S. arr.					**12.06**	12.45						**12.36**	**13.00**	
Barcelona S. dep.												12.38		
Girona dep.												13.18		
Figueres V. arr.												13.33		

All trains assumed with a running speed of 300 km/h !

In every second hour a modified turning shall be carried out in Madrid P.d.A. Train 2073 from Málaga turns into the nonstop service towards Barcelona (09.36/.44 o'clock) thus providing a fast service Málaga - Barcelona. Train 2085 from Sevilla turns into the stopping service towards Barcelona. By this a direct service from Sevilla towards Zaragoza, Lleida and Camp de Tarragona ca be provided (see also topic 3.10.3). Half hour later the same modification applies for the trains 2063 and 2087.

Table 8. Hourly AVE-Concept Figueres-Vilafant - Barcelona - Madrid - Sevilla/ Granada/Málaga second hour

Hourly AVE-train concept direction North - south ***second*** hour

train number			2072	2084						3272	2062	2086			
Figueres V. dep.										from		07.27			
Girona dep.										Hu-		07.42			
Barcelona S. arr.										esca		08.22			
Barcelona S. dep.			**07.15**	**07.54**							**08.00**	**08.24**			
Camp de Tarr. dep			07.43	↓							↓	↓			
Lleida dep.	rever-	rever-	08.13	↓					rever-		↓	↓			
Zaragossa D. arr.	sal	sal	**08.59**	↓				rever-	sal		**09.24**	↓			rever-
Zaragossa D. dep.	from	from	**09.01**	↓				sal	from	**09.23**	**09.26**	↓			sal
Calatayud dep.	Mala-	Valen-	↓	↓				from	Valen-	↓	09.47	↓			from
Guadj. Yebes dep.	ga	cia	↓	↓				Toledo	cia	10.15	↓	↓			Toledo
Madrid P.d.At. arr.	**09.54**	**10.03**	**10.13**	**10.16**				**10.17**	**10.33**	**10.40**	**10.43**	**10.46**			**10.47**
train number	2170	8296			AVE	2170	AVE	5070	8298				AVE	AVE	
Madrid P.d.At dep.	**10.06**	**10.09**	**10.21**	**10.24**				**10.27**	**10.39**		**10.51**	**10.54**			**10.57**
Toledo arr.		**10.38**							**11.08**						
Cuenca F. dep								↓							↓
Valencia arr..								**12.08**							**12.38**
Valencia dep.															
Cuenca F. dep.															
Ciudad Real dep.	10.50		↓	↓							↓	↓			
Puertollano dep.	11.04		↓	↓							↓	↓			
Cordoba arr.	11.43		11.46	11.49							12.16	12.19			
Cordoba dep.	**11.45**		**11.48**	**11.51**							**12.18**	**12.21**			
Sevilla arr.			**12.19**								**12.49**				
Sevilla dep..					**11.31**								**12.01**		
Puento G.-H. arr.	12.06			↓	↓							↓	↓		
Puente G.-H. dep.				↓	↓	12.18						↓	↓		
Antequ.S.A. arr.				12.22	12.26	12.30						12.52	12.56		
Antequ.S.A. dep..				12.23	12.27	12.31						12.53	12.57		
Granada arr..					**12.44**							**13.24**			
Malaga arr..				**12.44**		**12.52**							**13.18**		
Malaga dep.							**12.59**							**13.29**	
Granada arr.							13.49							14.19	
Granada dep.							**14.11**							**14.41**	
Malaga arr.							15.01							15.31	

All trains assumed with a running speed of 300 km/h

Table 8 shows the modifications of turnings in Madrid P.d.A in the reverse direction.

For reversal times less than 10 minutes it is assumed that a new train driver takes over the departing train. This procedure applies only for the reversals in Madrid P.d.A. with one exception in Málaga (minute .01/.08).

The timetable proposal is based upon three minutes headway also between Madrid and Barcelona. If the present installed signalling system doesn't allow this timetable, than the following modifications must be carried out: The reversals of the express trains Sevilla - Barcelona in Madrid must be shortened from 5 to 4 minutes and the following train departs a minute later. For example train 3252 at minute 08.39/.43 at Madrid and train 3061 at minutes 08.36/.48 at Madrid. The whole timetable in the section Madrid - Barcelona must be adapted according to this modification. It must be mentioned that a reversai of 4 min, where a new train driver takes over the departing train, is carried out every hour in Frankfurt(Main)-Flughafen.

At last the author wants to point out that according to the practice in China the stopping

time for a stop at an intermediate station should be reduced to 6 - 7 minutes. Than a train with 3 intermediate stops leaves Madrid 5 minutes later than the express train and arrives Barcelona 5 minutes before the next express train arrives at Barcelona. This scheduling would provide an amount of 20 minutes for the three intermediate stops at Zaragoza, Lleida and Camp de Tarragona. In this the stops at Zaragoza und Lleida can be scheduled with an amount of 7 minutes due to a short longer distance of running compared with the nonstop train on the main line.

3.10.12 Toledo - Madrid - Valencia

Table 9. Hourly AVE-Concept Toledo - Madrid - Valencia

train number				AVE	AVE		AVE	AVE	AVE	AVE	AVE	AVE	AVE	AVE
Toledo dep.					06.18		18.18	18.48	19.18	19.48	20.18	21.18	22.18	23.18
Madrid Puerta de Atocha arr.					06.47		18.47	19.17	19.47	20.17	20.47	21.47	22.47	23.47
Madrid Purta.de Atocha dep.				06.27	06.57		18.57	19.27	19.57	20.36	20.57	21.57		
Cuenca Fernando Zobel arr.		every		↓	↓	every	↓	↓	↓	to	↓	↓		
Cuenca Fernando Zobel dep.		30		↓	↓	30	↓	↓	↓	Cor-	↓	↓		
Valencia Joaquin Sorolla arr.		mi-		08.08	08.38	mi-	20.38	21.08	21.38	doba	22.38	23.38		
train number		nutes	4.)			nutes				4.)				
Valencia Joaquin Sorolla dep.		until	from	06.22	06.52	until	20.52		21.52					
Cuenca Fernando Zobel arr.			Cor-	↓	↓		↓		↓					
Cuenca Fernando Zobel dep.			doba	↓	↓		↓		↓					
Madrid Puerta de Atocha arr.			07.24	08.03	08.33		22.33		23.33					
Madrid Puerta de Atocha dep.	05.39		07.39	08.09	08.39		22.39							
Toledo arr.	06.08		08.08	08.38	09.08		23.08							

Remarks: 1.) The station Requena/Utiel should be cancelled due to a too low passenger demand
2.) Cuenca Fernando Zobel - Madrid P.d.A. will be served hourly by the trains from Alacant towards Madrid P.d.A.
3.) Cuenca Fernando Zobel - Valencia will be served every two hours by the Sevilla - Valencia trains
4.) Train also calls at Villanueva de CLP

Because all present Avant services shall be integrated in the service of the 300 km/h fast EMU's the idea was created, to combine the Valencia - Madrid service with the Madrid - Toledo service. With a speed of 300 km/h in the 50 km long section Madrid - overtaking station La Sagra a travel time Madrid - Toledo of 29 min can be calculated. For the section Madrid - Valencia a travel time of 101 min is fixed according to the present timetable.

But it should be checked, if this time could be to an amount of only 95 min. This travel time he author experienced on his travel on 2016-04-21 with train AVE 5141

3.10.13 Madrid - Alacant

Table 10. Hourly AVE-Concept Madrid - Alacant

										a.)			
train number		AVE	Alvia	AVE	3981	AVE	AVE	3983	AVE	Alvia	3985	AVE	AVE
Madrid Puerto de At.	dep	06.00	07.00	08.00		09.03	10.00		11.03	12.00		13.03	14.00
Sevilla	dep.				07.14			09.14			11.14		
Cuenca Fernando Zobel	arr.	06.52	08.05	08.52	09.55	09.58	10.52	11.55	11.58	13.05	13.55	13.58	14.52
Cuenca Fernando Zobel	dep..	06.53	08.06	08.53	09.56	09.59	10.53	11.56	11.59	13.06	13.56	13.59	14.53
Valencia Joaquin Sor.	arr.				10.50			12.50			14.50		
Albacete	arr.	07.28	08.45	09.28		10.34	11.28		12.34	13.45		14.34	15.28
Albacete	dep.	07.29	08.46	09.29		10.35	11.29		12.35	13.46		14.35	15.29
Villena AV	arr.	↓	09.28	↓		↓	12.03		↓	14.28		↓	16.03
Villena AV	dep.	↓	09.29	↓		↓	12.04		↓	14.29		↓	16.04
Alacant Terminal	arr.	08.19	09.51	10.25		11.25	12.25		13.25	14.51		15.25	16.25
		Mo-Fr						a.)					
train number		AVE	AVE	3980	AVE	AVE	3982	Alvia	AVE	3984	AVE	AVE	3986
Alacant Terminal	dep.	05.35	06.30		07.35	08.35		09.09	10.35		11.35	12.35	
Villena AV	arr.	05.56	06.51		07.56	↓		09.31	↓		11.56	↓	
Villena AV	dep.	05.57	06.52		07.57	↓		09.32	↓		11.57	↓	
Albacete	arr.	06.31	07.25		08.31	09.25		10.14	11.25		12.31	13.25	
Albacete	dep.	06.32	07.26		08.32	09.26		10.15	11.26		12.32	13.26	
Valencia Joaquin Sor.	dep.			07.10			09.10			11.10			13.10
Cuenca Fernando Zobel	arr.	07.07	08.01	08.04	09.07	10.01	10.04	10.54	12.01	12.04	13.07	14.01	14.04
Cuenca Fernando Zobel	dep..	07.08	08.02	08.05	09.08	10.02	10.05	10.55	12.02	12.05	13.08	14.02	14.05
Sevilla	arr.			10.46			12.46			14.46			16.46
Madrid Puerta de At.	arr.	08.00	08.57		10.00	10.57		12.00	12.57		14.00	14.57	

Remarks: a.) from/to Santander

						b.)							
train number		3987	AVE	AVE	3989	Alvia	AVE	3991	AVE	AVE	3993	AVE	AVE
Madrid Puerto de At	dep		15.03	16.00		17.00	18.00		19.03	20.00		21.03	22.00
Sevilla	dep.	13.14			15.14			17.14			19.14		
Cuenca Fernando Zobel	arr.	15.55	15.58	16.52	17.55	18.05	18.52	19.55	19.58	20.52	21.55	21.58	22.52
Cuenca Fernando Zobel	dep..	15.56	15.59	16.53	17.56	18.06	18.53	19.56	19.59	20.53	21.56	21.59	22.53
Valencia Joaquin Sor.	arr.	16.50			18.50			20.50			22.50		
Albacete	arr.		16.34	17.28		18.45	19.28		20.34	21.28		22.34	23.28
Albacete	dep.		16.35	17.29		18.46	19.29		20.35	21.29		22.35	23.29
Villena AV	arr.		↓	18.03		19.28	20.03		↓	22.03		23.08	↓
Villena AV	dep.		↓	18.04		19.29	20.04		↓	22.04		23.09	↓
Alicant Terminal	arr.		17.25	18.25		19.51	20.25		21.25	22.25		23.30	00.19
			b.)										c.)
train number		AVE	Alvia	3988	AVE	AVE	3990	AVE	AVE	3992	Alvia	AVE	AVE
Alicant Terminal	dep.	13.41	14.09		15.35	16.35		17.35	18.35		19.09	20.41	21.35
Villena AV	arr.	↓	14.31		15.56	↓		17.56	↓		19.31	↓	↓
Villena AV	dep.	↓	14.32		15.57	↓		17.57	↓		19.32	↓	↓
Albacete	arr.	14.31	15.14		16.31	17.25		18.31	19.25		20.14	21.25	↓
Albacete	dep.	14.32	15.15		16.32	17.26		18.32	19.26		20.15	21.26	↓
Valencia Joaquin Sor.	dep.			15.10			17.10			19.10			
Cuenca Fernando Zobel	arr.	15.07	15.54	16.04	17.07	18.01	18.04	19.07	20.01	20.04	20.54	22.01	↓
Cuenca Fernando Zobel	dep..	15.08	15.55	16.05	17.08	18.02	18.05	19.08	20.02	20.05	20.55	22.02	↓
Sevilla	arr.			18.46			20.46			22.46			
Madrid Puerta de At.	arr.	16.00	17.00		18.00	18.57		20.00	20.57		22.00	23.00	23.43

Remarks. b) from/to Gijón, c.) train runs Fr, Sa, S

This timetable is based upon the train diagram already presented in figure 5. At present there run two Alvia train pairs from Northwest-Spain to Alacant via the high speed line (Aivia 4072/4092 and 4143 respective Alvia 4110 and 4181/4381). If this through service shall remain in the future, these trains should run in that manner via the high speed line that they can replace one AVE running day.

Due to the running of Alvia trains with lower speed and due to the fact of changing trains every two hours in Cuenca Fernando Zobel coming from Sevilla towards Alacant the modifications for the hourly service shown in the timetable must be accepted.

3.10.14 Sevilla - Valencia

Table 11. Algeciras-Antequera Santa Ana Córdoba -Valencia - Barcelona

km			MD	MD	MD	MD	MD	MD	MD
0	dep, Algericas	arr.	06.22	08.22	10.22	12.22	14.22	16.22	18.22
12	dep. San Roque-La Linea	dep.	06.37	08.37	10.37	12.37	14.37	16.37	18.37
104	dep. Ronda	dep.	08.00	10.00	12.00	14.00	16.00	18.00	20.00
176	dep. Bobadilla	dep.	08.49	10.49	12.49	14.49	16.49	18.49	20.49
(185)	arr.. Ant equera Santa Ana	dep.	08.59	10.59	12.59	14.59	16.59	18.59	20.59
	dep. Antequera Santa Ana	arr.,	*09.08*	*11.08*	*13.08*	*15.08*	*17.08*	*19.08*	*21.08*
	arr. Madrid Puerto.de Atocha	dep...	*11.06*	*13.06*	*15.06*	*17.06*	*19.06*	*21.06*	*23.06*

Present travel times of direct services Algericas - Madrid: Alta 9367 5 h 22 min, Alta 9331 5 h 32 min

train number		3979	3981	3983	3985	3987	3989	3991	3993
dep. Sevilla	**arr.**		**07.14**	**09.14**	**11.14**	**13.14**	**15.14**	**17.14**	**19.14.**
arr. **Cordoba**	dep.		07.45	09.45	11.45	13.45	15.45	17.45	19.45
der. **Cordoba**	arr..	05.47	07.47	09.47	11.47	13.47	15.47	17.47	19.47
dep. Puertollano	dep.	06.26	08.26	10.26	12.26	14.26	16.26	18.26	20.26
dep. Ciudad Real	dep.	06.40	08.40	10.40	12.40	14.40	16.40	18.40	20.40
arr. Cuenca Fernando Zobel	dep..	07.55	09.55	11.55	13.55	15.55	17.55	19.55	21.55
dep. Cuenca Fernando Zobel	*arr..*	*08.06*	*09.59*	*11.59*	*13.59*	*15.59*	*18.06*	*19.59*	*21.59*
arr. Alacant	*dep..*	*09.51*	*11.25*	*13.25*	*15.25*	*17.25*	*19.51*	*21.25*	*23.25*
dep. Cuenca Fernando Zobel	arr...	07.56	09.56	11.56	13.56	15.56	17.56	19.56	21.56
arr. Valencia Joaqin Sorolla	**dep...**	**08.50**	**10.50**	**12.50**	**14.50**	**16.50**	**18.50**	**20.50**	**22.50**
train number		*Em*	*Em*	*Em*	*Em*	*Em*	*Em*	*Em*	
dep. Valencia Joaqin Sorolla	**arr...**	**08.58**	**10.58**	**12.58**	**14.58**	**16.58**	**18.58**	**20.58**	
dep. Castello de la Plana	dep.	09.38	11.38	13.38	15.38	17.38	19.38	21.38	
dep. L'Aldea - Amposta	dep.	10.23	12.23	14.23	16.23	18.23	20.23	22.23	
dep.. Tarragona	dep.	11.09	13.09	15.09	17.09	19.09	21.09	23.09	
arr. Barcelona Sants	**dep.**	**12.14**	**14.14**	**16.14**	**18.14**	**20.14**	**22.14**		

Overview about the regular connecting service Algericas - Antequera Santa Ana - Cordoba - Valencia - Barcelona

Table 11 shows in the upper part the situation for the travel time Algericas - Madrid. Although passengers from Algericas bound for Madrid have to change trains in Antequera Santa Ana the overall travel time Algericas - Madrid amounts to only 4 h 44 min, which is Ø 43 min shorter than the Ø travel time with trains Alta 9367 or Alta 9331. A same situation applies for the reverse direction.

In the part below the proposed AVE service in the direction Sevilla - Valencia is shown by the train numbers 3979 - 3993. This service doesn't run via the capital Madrid. Therefore there is no travel connection to be seen, in which many people want to travel. For this service is assumed that passengers in many possible railway connections can use this service, For example: the departure stations could lie in the area Cadiz - Sevilla, Algericas- Antequera Santa Ana, Málaga and Granada and the destinations could be Córdoba, Puertollano, Ciudad Real, Cuenca Fernando Zobel, Valencia, Castello de la Plana, L'Aldea-Amposta, Tarragona, Barcelona, Albacete and Alacant. The blue underlined times prove this concept exemplary. A passenger may in the morning travel from Ronda towards Castello de la Plana. At present he must start at07.53 o'clock and he arrives at Castello de la Plana at 16.30 o'clock. Given a regular service he could start at 08.00 o'clock and arrive at Castello de la Plana at 13.38 o'clock. This is a travel time reduce of 179 min or = - 34,6%. And this described travel possibility exists every two hours during the day from 08.00 o'clock until 16.00 o'clock.

3.10.15 Future possible train service concept in Andalusia

Table 12. Future possible train service concept in Andalusia

train	MD	MD	MD	MD	MD	MD	AVE	AVE		AVE	AVE	
Sevilla dep.	06.06	07.06	08.06	09.06	11.06	12.06	07.01			06.31		
Dos Hermanas d.)							b.)			b.)		
via	a.)	a.)	a.)	a.)	a.)	a.)	c.)			c.)		
Antequera S.A. arr.	07.45	08.45	09.45	10.45	12.45	13.45	07.56			07.26		
Madrid P.d. A. dep	*05,54*	*06.54*	*07.54*	*08.54*	*10.54*	*11.54*						
Antequera S.A. arr	*07.52*	*08.52*	*09.52*	*10.52*	*12.52*	*13.52*			**and**			**and**
Antequera S.A. dep.		09.01		11.01	13.01				**so**			**so**
Bobadilla		09.09		11.09	13.09				**on**			**on**
Ronda		10.00		12.00	14.00				**every**			**every**
San Roque-La Linea		11.23		13.23	15.23				**hour**			**hour**
Algericas		11.38		13.38	15.38							
Antequera S.A. dep	07.57		09.57			13.57	07.57				08.23	
via	a.)		a.)			a.)	c.)				c.)	
Malaga arr.	08.56		10.56			14.56	08.18				08.44	
Antequera S.A. dep								07.53		07.27		
via								c.)		c.)		
Granada arr.								08.24		07.58		

train	MD	MD	MD	MD	MD	MD	AVE	AVE	AVE	AVE	AVE
Sevilla dep.	13.06	15.06	17.06	18.06	19.06	21.06			22.01		22.31
Dos Hermanas d.)									b.)		b.)
via	a.)	a.)	a.)	a.)	a.)	a.)	→		c.)		c.)
Antequera S.A. arr.	14.45	16.45	18.45	19.45	20.45	22.45	**last**		22.56		23.26
Madrid P.d. A. dep	*12.54*	*14.54*	*16.54*	*17.54*	*18.54*	*20.54*	**ser-**				
Antequera S.A. arr	*14.52*	*16.52*	*18.52*	*19.52*	*20.52*	*22.52*	**vices**		-		-
Antequera S.A. dep.	15.01	17.01	19.01		21.01		→				
Bobadilla	15.09	17.09	19.09		21.09						
Ronda	16.00	18.00	20.00		22.00						
San Roque-La Linea	17.23	19.23	21.23		23.23						
Algericas	17.38	19.38	21.38		23.38						
Antequera S.A. dep				19.57		22.57			22.57	23.23	
via				a.)		a.)			c.)	c.)	
Malaga arr.				20.56		23.56			23.18	23.44	
Antequera S.A. dep								22.53			23.27
via								c.)			c.)
Granada arr.								23.24			23.58

Remarks: a.) via classic line, b.) via a new high speed connecting line in the area SW from Cordoba allowing a direct Sevilla - Antequera S.A. running of high speed trains, c.) via AVE-high speed line, d.) It is assumed that an upgrading of the classic line (passing loops!) may provide a travel time of 1 h 39 min between Sevilla and Antequera Santa Ana.

Antequera Santa Ana could become an interesting interchange station not only for the AVE services Málaga - Madrid and Granada - Madrid and the MD/AVE service Algericas - Madrid but also for MD/AVE services coming from Sevilla via the classic line towards Málaga and Granada. Passengers living in the area of the classic stations between Sevilla and Antequera Santa Ana and between Antequera Santa Ana and Málaga can gain the advantages of high speed rail in Andalusia. And once more the advice shall be made to construct a short high speed connecting line in the area southwest from Córdoba allowing a fast direct service between Sevilla and Antequera Santa Ana. For the latter a travel time of 55 min is calculated in this study.

3.10.16 Comparison of train kilometre expense

Table 13. Comparison of train kilometres expense

The proposal for a regular service contains more train kilometres than the present timetable the increase of the train kilometre expense must be estimated. This detail has an important effect on the cost-benefit-ratio. The change of train kilometre expense is shown in table 13.

Direction	Train-kilometre 12/2016 per week	Train-kilometre in the timetable study per week	Percentage
Barcelona - Madrid	154 496	267 538	+73,1%
Madrid -Sevilla resp. Málaga	134 079	279 634	+108,5%
Madrid - Valencia	37 145	73 117	+ 96,8%
Madrid - Toledo	7 125	16 615	+133,2 %
Madrid - Alacant	29 160	54 432	+86,6 %
Sevilla - Valencia	8 120	43 238	+432,4 %
Total	**370 125**	**734 574**	**+98,4 %**

3.10.2 Connecting services in Sevilla and Zaragoza

A regular service must also take into account the connecting service in important interchange stations. A regular service must also be scheduled on connecting lines in order to pass on the travel time reduce from the 300 km/h fast EMU's into destinations of the classic network. This fact must be explained by the interchange station Sevilla, because MD trains on the classic routes towards Cadiz and Huelva shall replace present Alvia services in the last section towards Cadiz or Huelva.

3.10.2.1 Sevilla

Table 14. Proposal for regular service Sevilla - Cadiz

MD		MD	MD	MD	km			MD	MD	MD	MD		MD
05.19	and	19.19	20.19	21.19	0	dep, Cadiz	arr.	07.38	08.38	09.38	10.38	and	23.38
05.30	so on	19.30	20.30	21.30	15	dep. San Fernando- Bahia Sur	dep.	07.26	08.26	09.26	10.26	so on	23.26
05.45	every	19.45	20.45	21.45	34	dep.Puero de Santa Maria	dep.	07.10	08.10	09.10	10.10	every	23.10
05.54	hour	19.54	20.54	21.54	49	dep. Jerez de la Frontera	dep.	07.01	08.01	09.01	10.01	hour	23.01
06.02	until	20.02	21.02	22.02	61	dep. Aeroporto de Jerez	dep.	06.54	07.54	08.54	09.54	until	22.54
06.40		20.40	21.40	22.40	123	dep. Utrera	dep,	06.19	07.19	08.19	09.19		22.19
06.50		20.50	21.50	22.50	140	dep. Dos Hermanos	dep.	06.08	07.08	08.08	09.08		22.08
07.05		21.05	22.05	23.05	156	arr. Sevilla	dep.	05.55	06.55	07.55	08.55		21.55
07.11		*21.11*				dep. Sevilla	arr.				*08.49*		*21.49*
09.09		23.09				arr. Madrid P.d.A.	dep.				*06.51*		*19.51*

At present the shortest travel time Madrid - Cadiz with an Alvia through service amounts to 3 h 55 min (Alvia 2164). The average travel time for daily services Madrid - Cadiz amounts to 4 h 4 min. This amount lies 17 min above the travel time of 3 h 47 min, which can be provided

in the regular service concept. In the reverse direction the shortest travel time Cadiz - Madrid amounts to 3 h 59 min (Alvia 2175). The average travel time for daily services Cadiz - Madrid amounts to 4 h 15 min. This amount lies 25 min above the travel time of 3 h 50 min, which can be provided in the regular service concept.

Table 15. Proposal for a service concept Sevilla - Huelva

km			MD	MD	MD	MD	MD	MD	MD	MD	MD	MD
0	Huelva	dep.	07.05	08.05	10.05	11.05	13.05	14.05	16.05	17.05	19.05	20.05
40	La Palma del Condado	dep.	07.45	08.45	10.45	11.45	13.45	14.45	16.45	17.45	19.45	20.45
115	Sevilla	arr.	08.35	09.35	11.35	12.35	14.35	15.35	17.35	18.35	20.35	21.35
	Sevilla	*dep.*	*08.41*	*09.41*	*11.41*	*12.41*	*14.41*	*15.41*	*17.41*	*18.41*	*20.41*	*21.41*
	Madrid P.d.A.	*arr.*	*10.39*	*11.39*	*13.39*	*14.39*	*16.39*	*17.39*	*19.39*	*20.39*	*22.39*	*23.39*

km			MD	MD	MD	MD	MD	MD	MD	MD	MD	MD
	Madrid P.d.A.	*dep.*	*06.21*	*07.21*	*09.21*	*10.21*	*12.21*	*13.21*	*15.21*	*16.21*	*18.21*	*19.21*
	Sevilla	*arr.*	*08.19*	*09.19*	*11.19*	*12.19*	*14.19*	*15.19*	*17.19*	*18.19*	*20.19*	*21.19*
0	Sevilla	dep.	08.25	09.25	11.25	12.25	14.25	15.25	17.25	18.25	20.25	21.25
75	La Palma del Condado	dep.	09.23	10.23	12.23	13.23	15.23	16.23	18.23	19.23	21.23	22.23
115	Huelva	arr.	09.53	10.53	12.53	13.53	15.53	16.53	18.53	19.53	21.53	22.53

In the service concept with changing trains in Sevilla a travel time Madrid- Huelva of 3 h 32 min can be reached. The two services, which run daily except Saturdays need 3 h 40 in (Alvia 2384) or even 4 h 7 min (IC 2494). A similar situation is given for the reverse direction.

3.10.2.2 Zaragoza

Table 16. Proposal for a regular service Pamplona - Zaragoza

train category		IC	Alvia	Alvia	IC	Alvia	IC		IC	IC	Alvia	IC	Alvia	IC	IC y)
Logroño	dep.			07.25											
San Seb./Don.	dep				x06.24	07.12					S 13.54			Sa16.24	
Pamplona	arr				x08.02	08.58					S 15.35			Sa18.02	
Pamplona	dep.	06.04	06.30		08.04	09.00	10.04		12.04	14.04	15.37	16.04	17.24	18.04	y.) 20.04
Castejon	arr.	06.57	07.19		08.57	↓	10.57		12.57	14.57		16.57		18.57	y.)20.57
de Ebro	dep.	06.59	07.20		08.59	↓	10.59		12.59	14.59		16.59		18.59	y.) 20.59
Zaragoza	arr.	07.53			09.53	10.53	11.53		13.53	15.53		17.53	19.23	19.53	y.) 21.53
Zaragoza	*dep.*	*08.01*			*10.01*	*11.01*	*12.01*	*13.01*	*14.01*	*16.01*		*18.01*		*20.01*	*22.01*
Madrid	*arr.*	*09.13*	09.40	10.40	*11.13*	*12.13*	*13.13*	*14.13*	*15.13*	*17.13*	18.40	*19.13*		*21.13*	*23.13*
Zaragoza	*dep.*	*08.01*			*10.01*	*11.01*	*12.01*	*13.01*	*14.01*	*16.01*		*18.01*	*19.36*	*20.01*	*22.01*
Barcelona	*arr.*	*09.44*			*11.44*	*12.44*	*13.44*	*14.44*	*15.44*	*17.44*		*19.44*	*21.00*	*21.44*	*23.44*

Remarks : x= only Fr and Mo y.) not on Thursdays. There runs train 16111 Vitoria - Zaragoza in this time

train category						Alvia				Alvia			Alvia	
Madrid	*dep*	*06.47*	*08.47*		*10.47*	11.20	*12.47*	*14.47*	*16.47*	18.20	*18.17*	*18.47*	19.20	*20.47*
Zaragoza	*arr*	*07.59*	*09.59*		*11.59*		*13.59*	*15.59*	*17.59*		*19.34*	*19.59*		*21.59*
Barcelona	*dep*	*06.16*	*08.16*	*10.00*	*10.16*		*12.16*	*14.16*	*16.16*		*18.00*	*18.16*		*20.16*
Zaragoza	*arr*	*07.59*	*09.59*	*11.24*	*11.59*		*13.59*	*15.59*	*17.59*		*19.24*	*19.59*		*21.59*
		IC	IC	Alvia	IC		IC	IC	IC			IC		IC
Zaragoza	dep.	08.07	10.07	11.37	12.07		14.07	16.07	18.07			20.07		22.07
Catejon	arr	09.01	11.01	12.31	13.01		15.01	17.01	19.01			21.01		23.01
de Ebro	dep	09.03	11.03	12.33	13.03		15.03	17.03	19.03			21.03		23.03
Pamplona	arr.	09.53	11.53		13.53	14.25	15.53	17.53	19.53			21.53	22.25	23.53
Pamplona	dep				Sa 13.54				Th 19.54			S 21.54		
San Seb./Don.	dep				Sa 15.11				Th 21.11			S 23.11		
Logroño	arr.									21.35				

The Ø travel time Madrid - Pamplona of the 4 Alvia trains 601/605/613/801 amounts to 3 h 5,5 min. Alvia 609 needs 3 h 21 min
The Ø travel time Pamplona - Madrid of the 4 Alvia trains 802/602/606/610 amounts to 3 h 10 min
The Ø travel time Barcelona - Pamplona of the 4 Alvia-trains 534/622/654/530 amounts to 3 h 50 min; IC 562 needs 4 h 4 min
The Ø travel time Pamplona - Barcelona of the 4 Alvia-trains 533/661/621/537 amounts to 4 h 6 min; IC 635 needs 3 h 45 min

As already mentioned in chapter 3.10.11 Zaragoza shall become an important interchange station. This fact shall be explained by table 16. A regular connecting service with IC trains every two hours from Pamplona towards Zaragoza shall provide attractive connecting services towards Madrid as well as to Barcelona always with the same train. For this proposed service is assumed that it can be carried out with the equipment expenses currently used in the IC trains

635/10657/562/10560/10655.The connecting AVE train from Zaragoza to Madrid is always a nonstop train whereas the connecting AVE train from Zaragoza towards Barcelona is always a AVE-stopping train.

In the direction Pamplona - Madrid the travel time is the same as with a present Alvia service. In the direction Pamplona - Barcelona the average travel time of the 5 direct services with trains 635/533/661/621/537 amounts to exact 4 hours whereas the travel time Pamplona - Barcelona with changing trains at Zaragoza in the regular service would amount to only 3 h 40 min. For the role of Zaragoza Delicitas of being an important interchange station in the Spanish network see also page 36.

3.10.3 Discussing of the track diagram for several interchange stations

If a changing of trains is required for a service than all measures should be taken into account, to make the changing as convenient as possible for the passengers. This situation shall be briefly discussed by the regarding situation in the five stations Antequera Santa Ana, Sevilla, Córdoba, Zaragoza and Madrid P.d.A.

Antequera Santa Ana

Antequera Santa Ana could become an interchange station for several railway connections They are listed in table 17.

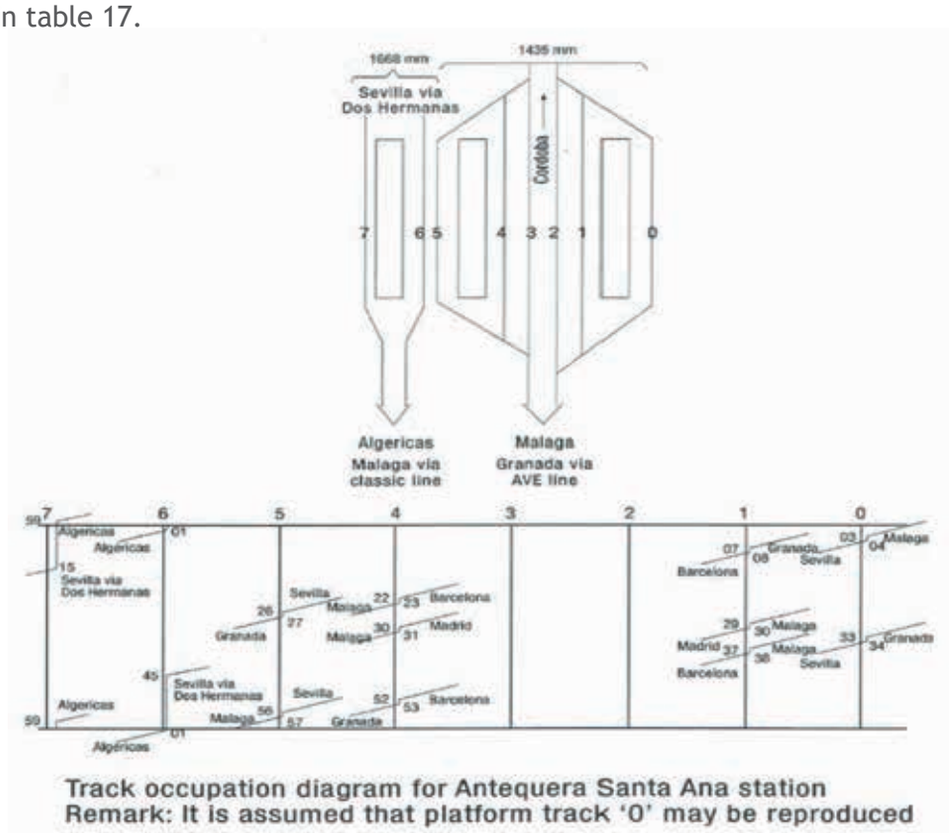


Figure 6

Table 17. Possibility of changing platform tracks in Antequera Santa Ana Interchange station

Interchange connection	Changing time in Antequera Santa Ana	Platform tracks	Remarks
Algericas - Madrid	minute 59 →08	7 →1	
Málaga - Madrid	minute 03 →08	0 →1	same platform
Málaga - Sevilla via classic line	minute 03 →15	0 →7	
Granada - Sevilla via classic line	minute 07 →15	1 →7	
Madrid - Granada	minute 22 →27	4 →5	same platform
Sevilla - Málaga	minute 26 →31	5 →4	same platform
Málaga - Sevilla	minute 29 →34	1 →0	same platform
Granada - Madrid	minute 33 →38	0 →1	same platform
Sevilla via classic line - Granada	minute 45 →53	6 →4	
Sevilla via classic line - Málaga	minute 45 →57	6 →5	
Madrid - Málaga	minute 52 →57	4 →5	same platform
Madrid - Algericas	minute 52 →01	4 →6	

The more the network grows the more the need grows to change trains at interchange stations. It is impossible to provide direct services in every connection. Concerning Antequera Santa Ana the consequence reads to take all measures to make convenient the interchange procedure for the passengers as far as possible.

Sevilla

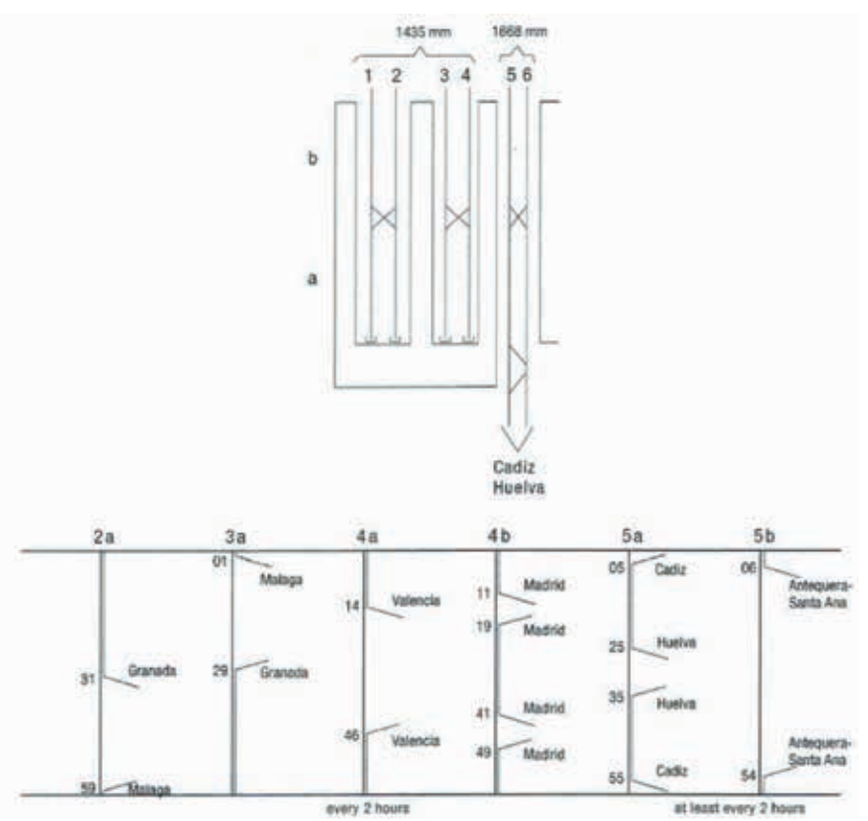


Figure 7. Track occupation diagram for Sevilla station

The interchange conditions for Sevilla could be optimized, if a platform with an European standard track at the one side (track 4) and a track with Iberian gauge at the other side (track 5) could be realized. This idea is shown in figure 7. This sketch was designed before seeing Sevilla station in practice. The platform between track 6 (1435 mm gauge) and track 7 (1668 mm gauge is the most important platform in Sevilla station.

Córdoba

The interchange situation in Córdoba is very convenient for passenger change. It is assumed that the third train can run in the track of the first train. A 4 minutes space between these two trains contains already 1 minute recovery time.

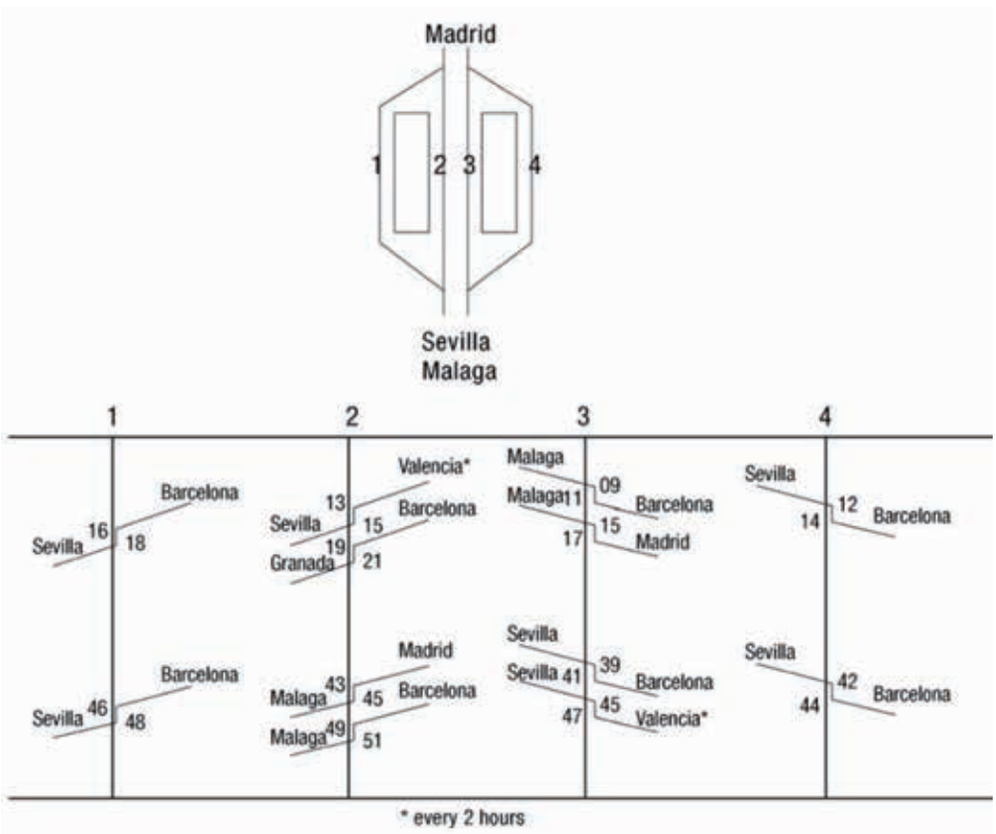


Figure 8. Track occupation diagram for Córdoba station

Zaragoza

In Zaragoza a connecting service from Pamplona with AVE trains bound for Madrid as well as bound for Barcelona shall be provided. This manoeuvre will never be possible, to carry out at the same platform. To make passenger change convenient it may be checked to build a passenger bridge between two neighbouring platform as it is shown in figure9.

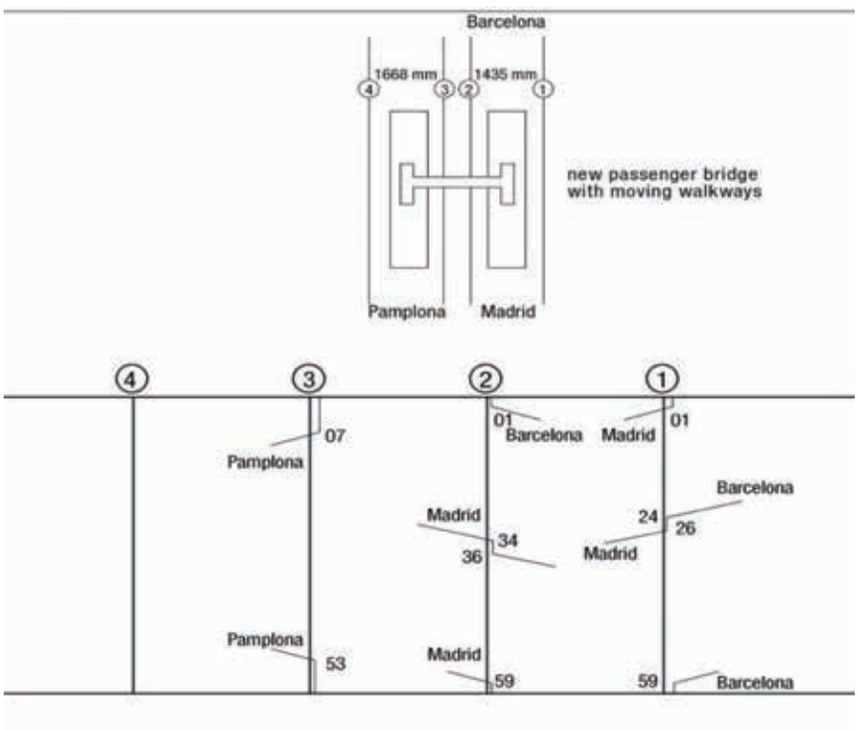


Figure 9. Track occupation diagram for Zaragoza station

Madrid Puerta de Atocha

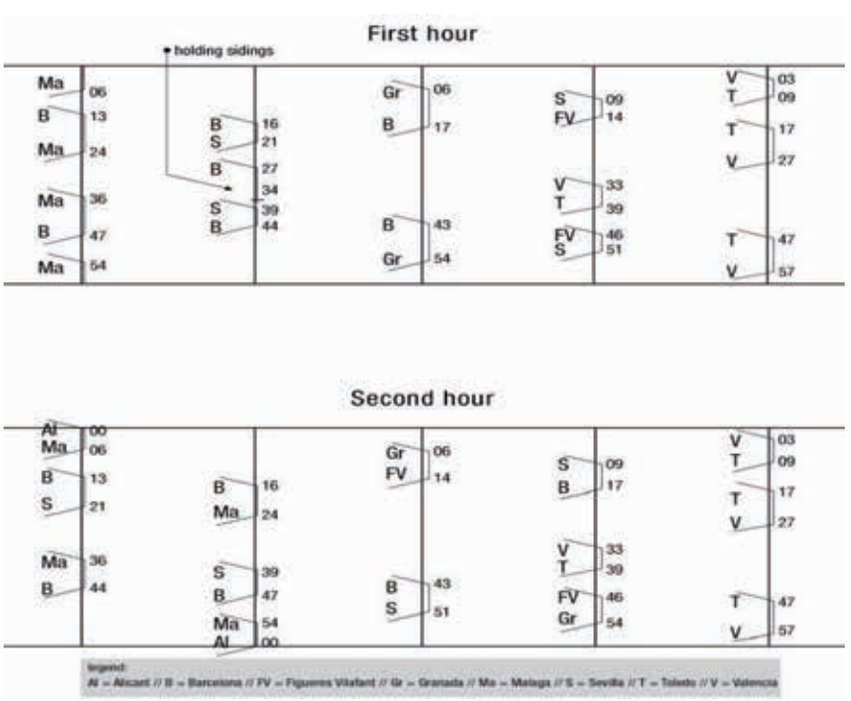


Figure 10. Track occupation diagram for Madrid Puerta de Atocha station

Madrid Puerta de Atocha The track occupation diagram for Madrid Puerta de Atocha proves that a combing of services, in which Puerta de Atocha will become an intermediate station, considerably reduces the need of platform tracks. And for this it must be mentioned that every platform track in Madrid Puerta de Atocha is 450 m long with a double crossover in the middle. So it should be possible to run four trains into two platform tracks in different sections. So in the end in total 4 trains could stand opposite to each other thus providing a changing of trains at the same platform in several directions.

It must be stressed that it is much more important to make possible the above designed track occupation diagram in Madrid P.d.A. rather than provide 15 platform tracks in this station.

3.10.4 Rolling stock roster study for regular service concept

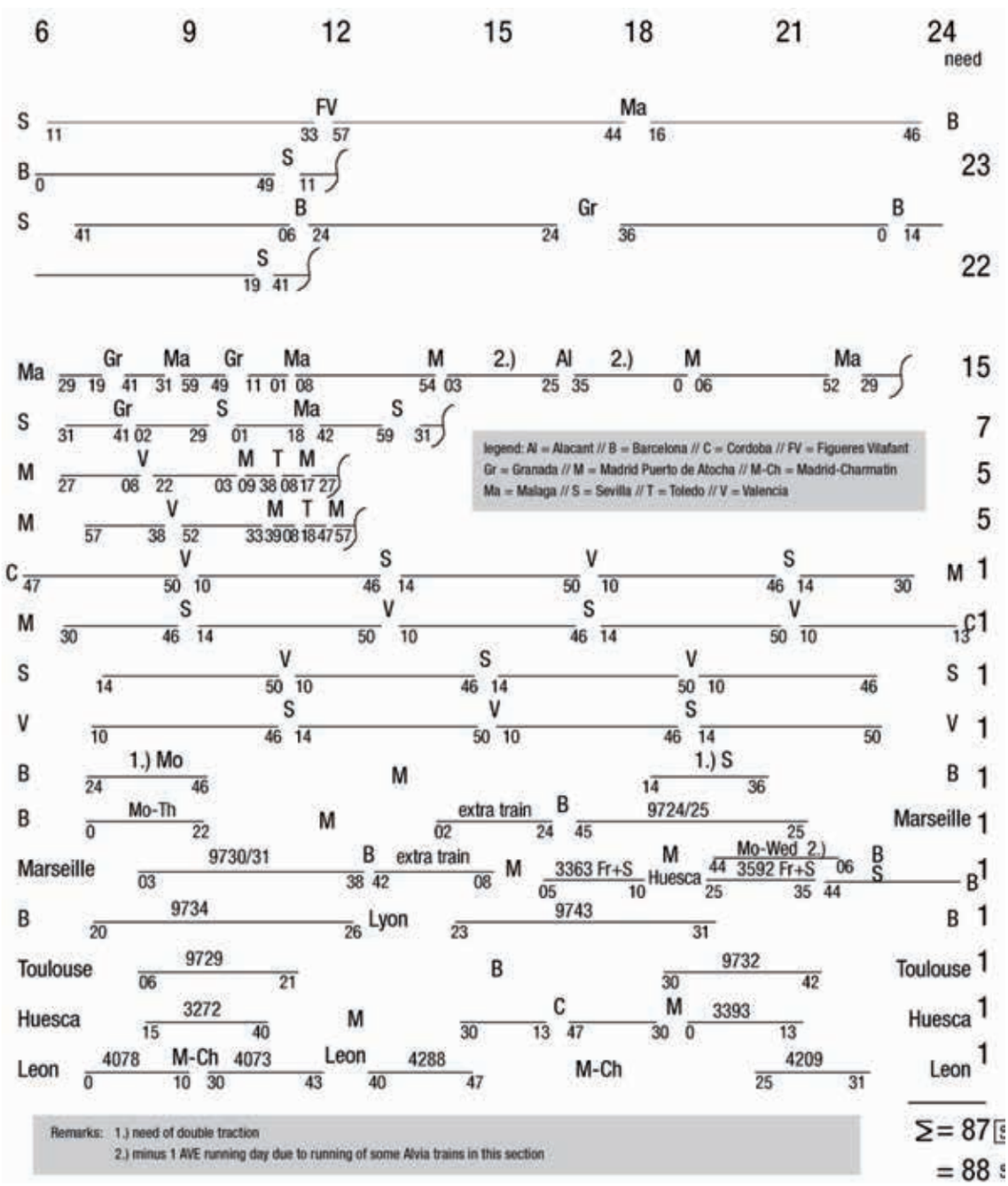


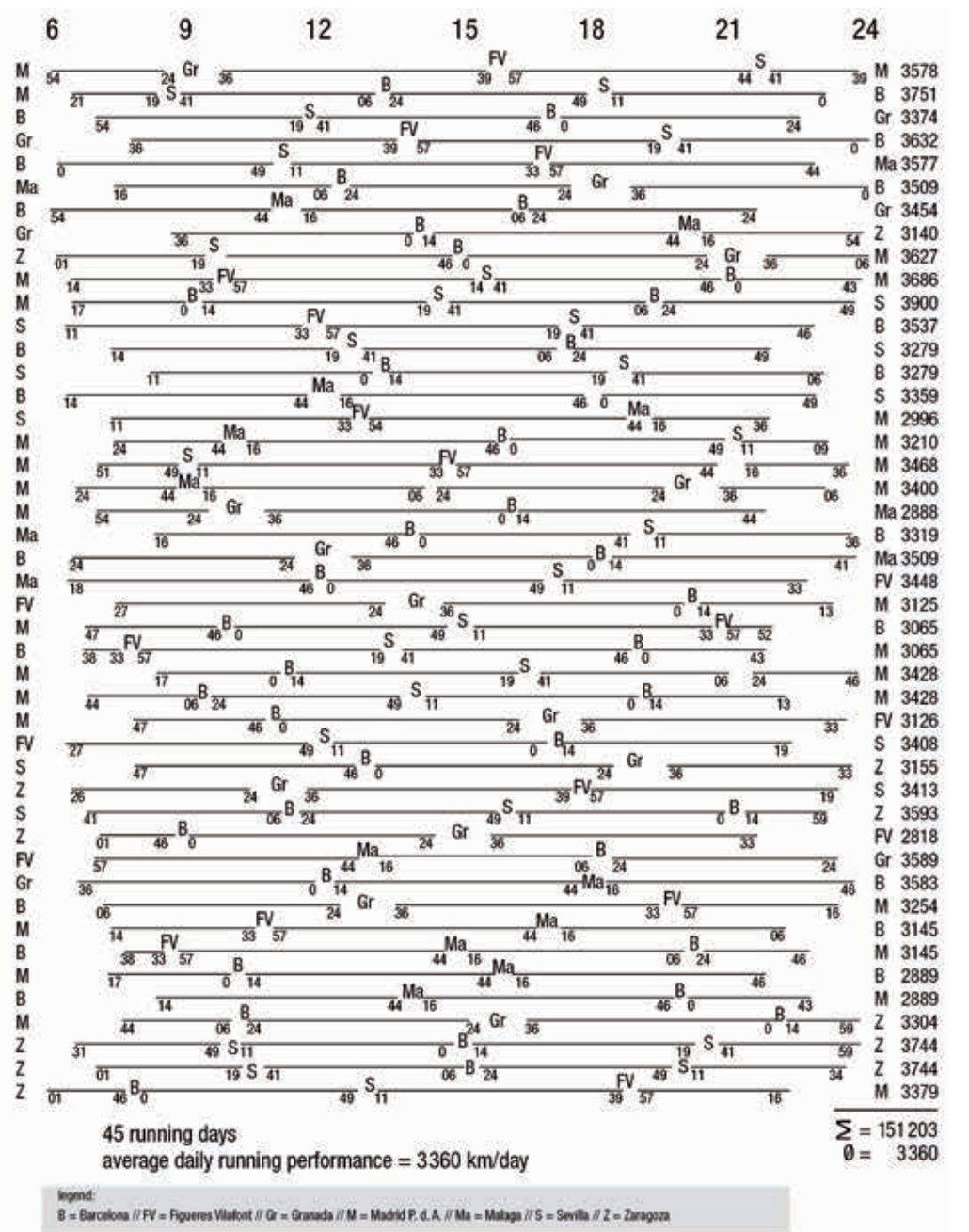
Figure 11. Principal overview about the rolling stock roster for the whole regular service concept

The change in rolling stock roster presents an important influence on the cost-benefit ratio. Therefore a rolling stock roster must be developed in order to assess the consequences. This step will be carried out in figure 11.

Principal overview about the rolling stock roster for the whole regular service concept

The overall need is calculated to 87 running days with an exception of 88 units for the short time period Sunday evening to Monday morning.. On Monday morning the train from Barcelona arriving at Madrid P.d.A. at 08.46 o'clock needs double traction.

In the first 4 rows the need of running days for the direction Sevilla/Málaga/Granada - Madrid - Barcelona - Figueres Vilafant is shown. This relation presents the backbone of the whole service. The complete rolling stock roster of these 4 rows is shown in figure 12.



Overview about the rolling stock roster for EMU's running over the core section Córdoba - Barcelona

Figure 12 presents a very intensively used rolling stock roster with an average daily running performance of almost 3360 km per day. The high daily running performance may require a level one maintenance (bogie inspection) after every running day. It is assumed that equipment for this step is available at every station, where an EMU stands overnight.

Generally it is assumed that maintenance is exclusively carried out only during night. For this topic the author wants to point out to the new strategy of SNCF in this manner, which is explained up-to-date in source [8].

When the CEO of SNCF Voyages, Rachel Picard, points out that in future trains will be in service for 13 hours per day, it may be stated that the rolling stock roster presented in figure 12 is in line with this rule. RENFE isn't affected with the disadvantage of running AVE trains in section on classic lines like in France. And in Spain the EMU's don't have to take into account an overtaking of one in front running EMU in an intermediate station like in Japan and China. At least it must be mentioned that source [3] reads in topic 4.2.5 "The turn-back time of immediate turn-back multiple units should not be longer than 20 min" ([3] p.11)

The overall need of the rolling stock roster amounts to 87 running days. Only during Sunday evening to Monday morning 88 running days are needed. The real amount needed for the service must refer to the expense for maintenance. For this purpose a referring percentage must be calculated. This percentage refers to several criteria. If the percentage is assessed to 15 % than the overall need calculates to 87 x 1,15=100,05 respective 88 x 1,15 = 101,2 ≈101 EMU's. This means in practice 101-87=14 EMU's are available for daily maintenance and repair.

The present RENFE fleet of EMU's capable of running 300 km/h consists of 86 units (via libre "25 years of Spanish high speed rail", English version page 68, series 100R, 102, 112 and 103). Currently RENFE is buying an additionally part of 15 EMU's capable of running 300 km/h. In near future EMU fleet capable of running 300 km/h consist of 86 + 15 = 101 units.

3.10.5 Saving of rolling stock and gauge changing constructions.

As already mentioned the strict regular service concept is aimed to use only one EMU category on the 300 km/h fast Ave lines. The Avant, Alvia and Alta train sets, which can be saved, are listed in two figures.

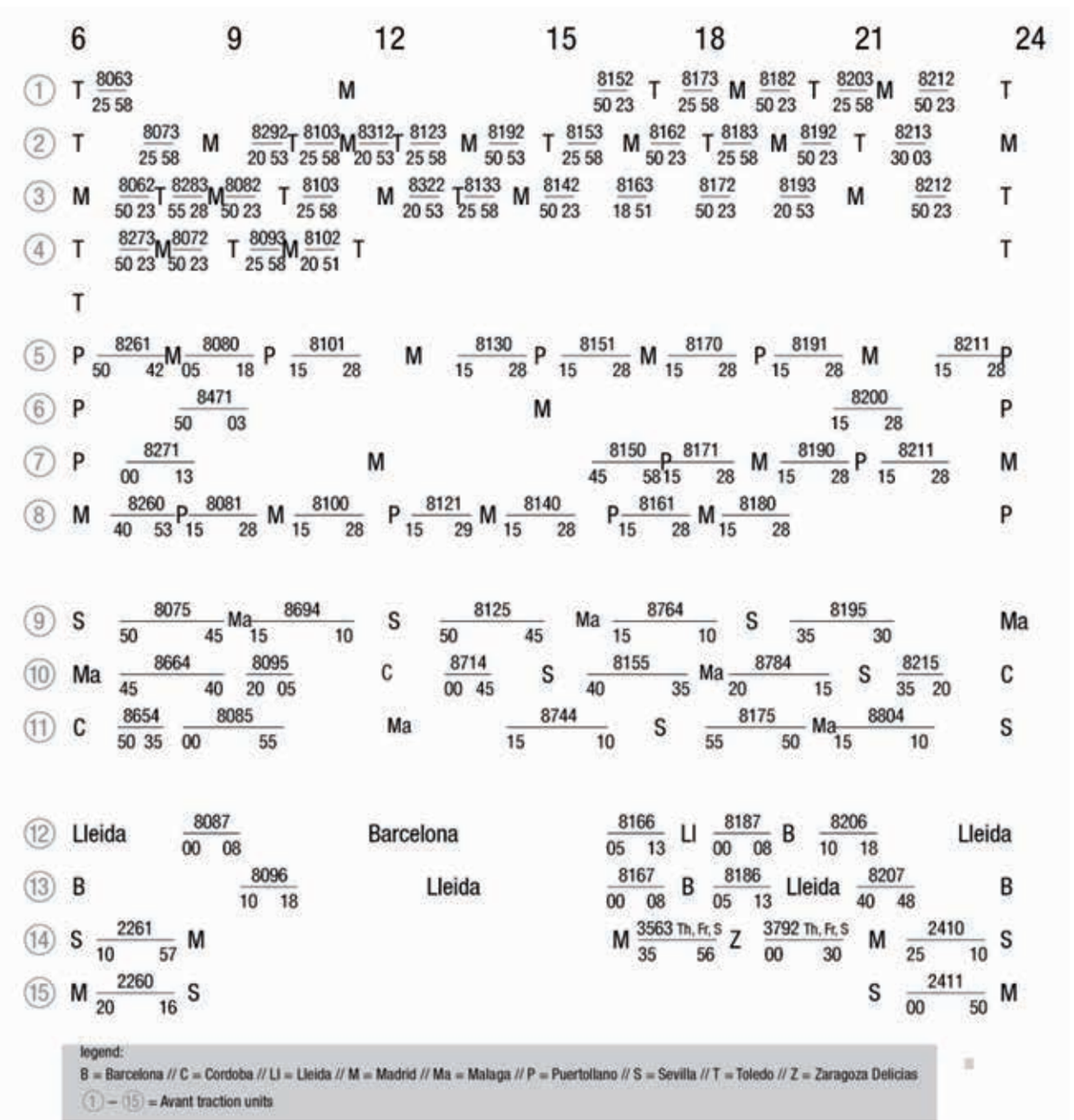


Figure 13. Overview about the Avant running days, which can be saved in a regular service concept

In figure 13 the number of Avant running days is shown, which shall be saved by an intensive use of the 300 km/h fast EMU's.

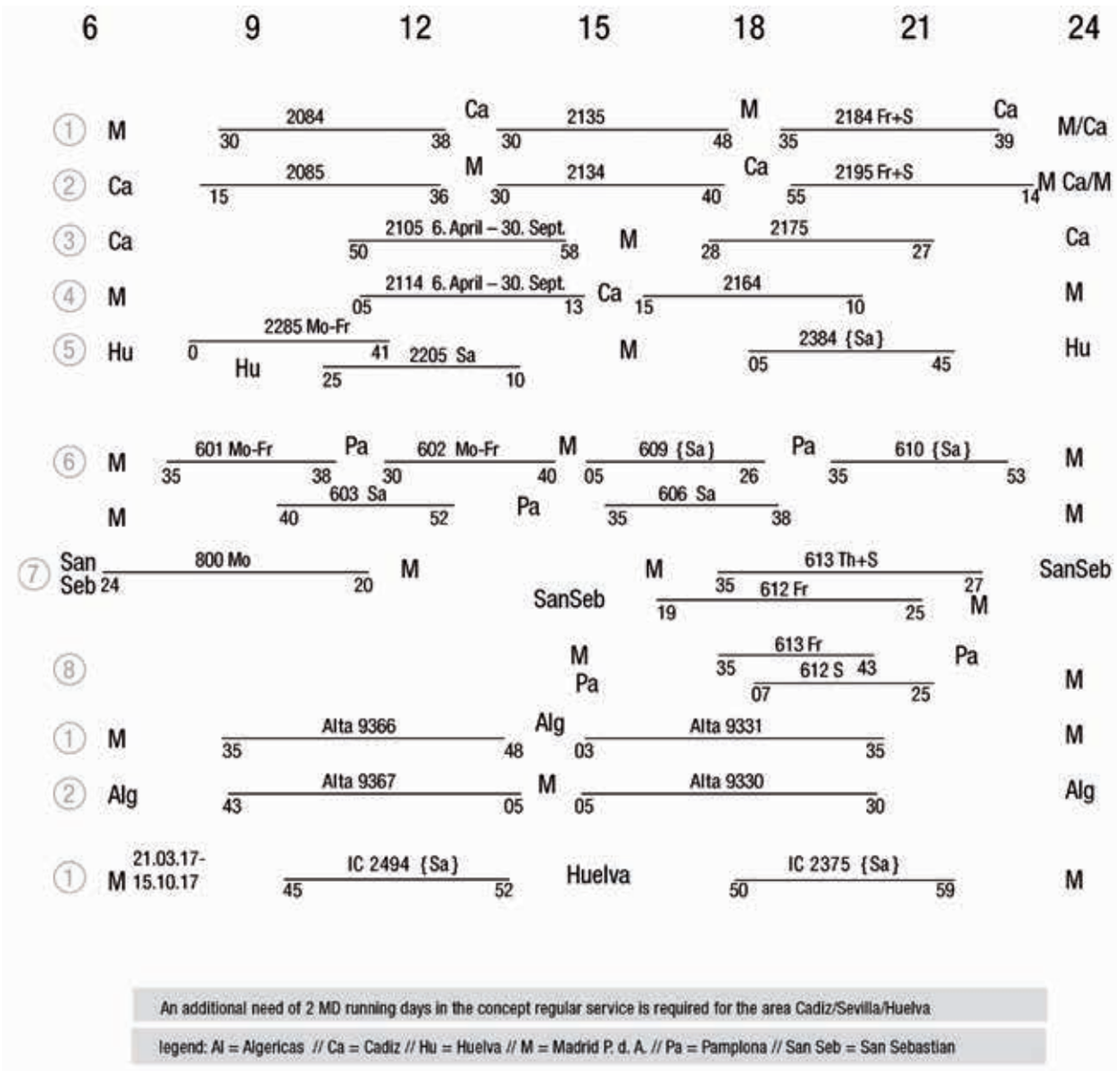


Figure 14. Overview about the Alvia- and Alta running days, which can be saved in a regular service concept

Figure 14 presents the number of Alvia and Alta train sets, which shall be saved by an intensive use of the 300 km/h fast EMU's. Because these EMU's run also beyond the 1435 mm AVE network the replacement of these EMU's must refer the new need of the MD running days in this area. Two additional MD running days are needed in the area Cadiz/Sevilla/ Huelva.

3.10.6 Survey about all additional infrastructure facilities needed for a strict regular service

All measures, which are necessary to upgrade the infrastructure of the Madrid - Sevilla AVE line from 250 km/h to 300 km/h, come first. When the author returned on Saturday 07.10,2017 from Ciudad Real with train AVE 3993+3943 he could watch that the train for a very short time was running 298 km/h in the section between Ciudad Real and Madrid. Secondly the signalling system on the different AVE lines and the maintenance facilities must allow a rolling stock roster presented in figure 11. Thirdly the infrastructure approaching Madrid P.d.A, must allow a track occupation diagram presented in figure 10. Fourthly a short new high speed connecting line in the area SW of Córdoba is necessary, to allow a fast direct travel Sevilla - Antequera Santa. At least an upgrading of the infrastructure in some interchange stations is necessary, in order to make more convenient the changing procedure.

3.10.7 Overview about the main results with influence on cost-benefit ratio

A strict regular service with at least a service every hour allowing a high commercial speed for a maximum of passengers shall boost passenger demand. For this an increase of 98% for the train kilometres is designed. Although this goal is envisaged the alteration of the train sets needed for the proposed regular service reads as follows: an additional need of 15 running days capable of running 300 km/h and two MD running days is faced to a reduced demand of in total 15 Avant, 8 Alvia, 2 Alta and 1 IC train sets. Further the 3 gauge changing constructions facilities in Antequera Santa Ana, Sevilla-Majarabique and Zaragoza could be saved. All these criteria together could decisive improve the cost-benefit ratio of the AVE traffic.

4. Conclusion

The present AVE timetable contains too much recovery time in the running time of the AVE trains as well as in the stopping time at the stations. RENFE should give up the strategy to reimburse the passengers for the tickets if an AVE-train arrives with a certain delay at the final destination. RENFE should rather make all efforts to shorten the travel times. The top most goal of high speed rail is to provide the highest possible commercial speed for a maximum of passengers. This goal includes a strict regular service and leads to a lower load factor beyond peak times. For this RENFE should use the Market pricing strategy in order to raise demand in these times and maximize revenues [9]. By of all these criteria RENFE should be able to improve the cost-benefit ratio of the AVE traffic considerably.

5. Brief

Brief comment to the AVE network (important comment: this chapter is upgraded and completed **after** attending the high speed congress in Ciudad Real)

This brief addendum belongs to this research. In figure 15 the present AVE network development is shown. At present the extension of the AVE network gears to the Northwest region of Spain. But for this strategy we must state the following statements:

Madrid - junction Olmiedo will be the trunk section for all trains from NW Spain bound for the capital Madrid.

1. In the European Railway Timetable, valid from June 2017, in the three tables 679, 679a and 680 in total 39 trains per direction could be counted out departing on Friday from Madrid Charmartin to this junction. This number of 39 trains now must be distributed to

the different destinations Salamanca, Santiago de Compostela, Gijon, Santander, Bilbao and San Sebastian. The result reads 39:6 =7 trains per day and direction. Although a future higher traffic demand can be expected we can surely assume that during a 14 hour service not even every hour a high speed train will be running per hour and direction.

2. And from these 39 trains at present only two are high speed trains capable of running 300 km/hand more (AVE 4099 and 4209); all the other trains (Alvia, Avant and IC) are only running max 250 km/h or less (IC). But the high speed lines in Galicia are all designed for a speed of 350 km/h.
3. Due to this expected very low use to capacity the new AVE line Palencia to Léon it is built as a single track line in sections, The 162,7 long AVE line from Valladolid to Léon comprises 78,7 km of double track and two single track sections totalling 84 km[10]. The line is designed for a speed of 350 km/h. By these results and all other new AVE lines in Northwest Spain someone only can come to conclusion that these measures never will receive a positive costbenefit ratio for the AVE traffic.

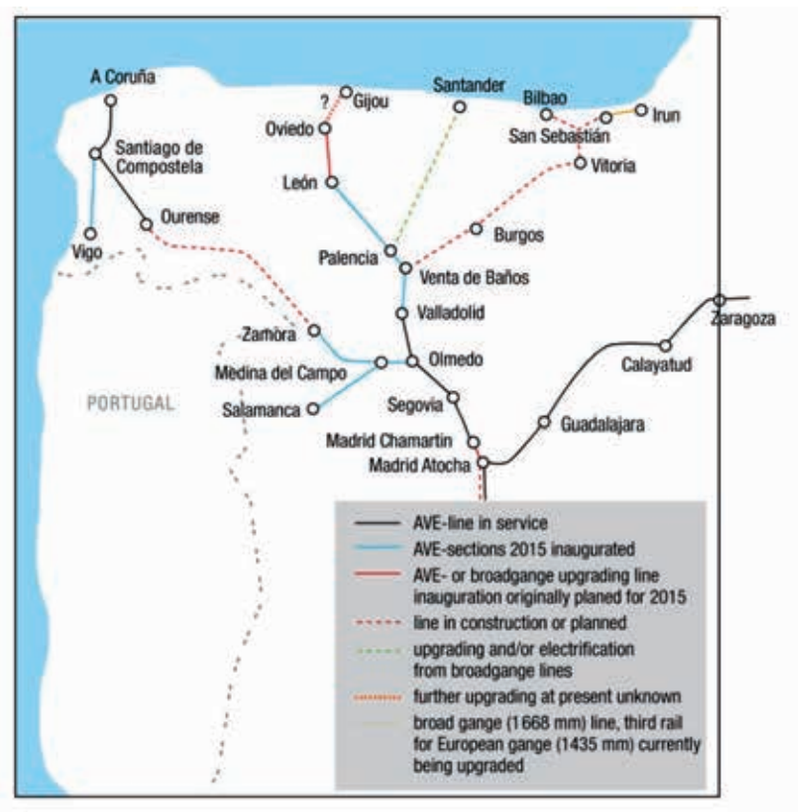


Figure 15

When a foreign expert looks at the Spanish high speed network he is wondering about the subject that no high speed line is planned between the second largest city in Spain, Barcelona, and the third largest city, Valencia. This becomes clear, when someone studies the information given on page 32 of the brochure "25 years of Spanish high speed rail" (in English) which was published from the *Spanish Railway Journal Vía Libre*. The criteria normally given for constructing a new high speed lines as improvement in quantity and quality for the passenger service by switching from the classic line to the new high speed line and making free capacity for the freight traffic on the classic line are obviously not given - at least in a necessary scope - on all high speed lines currently under construction in Spain. But these criteria would apply to a new high speed line between Barcelona and Valencia, exactly between Camp de Tarragona and Valencia. So a foreign expert can only agree with with Catalan and Valencian businessmen,

when they urge Spanish Government to build Mediterranean Railway Corridor. When a Spanish countryman argues: *"This situation occurs in a country with the second-longest High Speed network in the world, 80% of which is useless."* [11] so should every Spanish railway expert this statement making thinking even if he disagrees with this opinion.

In the author's opinion upgrading of Madrid - Sevilla high speed line to a speed of 300 km/h gains highest priority concerning the development of Spanish High Speed network. The introduction of a strict regular service belongs together with this step as described.

After this the introduction of a strict regular on all AVE lines gets highest priority. This important goal shall finally be demonstrated by the train diagram of the Madrid - Barcelona high speed line, see figure 16. Zaragoza Delicitas could become an important interchange station in the Spanish network, where train from direction and reverse direction meet each other every two hours at minute "0". Someone should imagine that also the trains in the classic network from Huesca and Logroño or even Teruel could arrive every two hours about minute /.50 o'clock and leave the station about minute /.10 o'clock. By such a timetable scheduling optimal connections in all possible directions in the interchange station Zaragoza Delicitas could be provided.

And last but not least the signalling system must provide 3 minutes headway. 3 minutes headway is an international standard for all highs peed lines in the world. A signalling system, which doesn't allow a departure of two trains in a 3 minute space, doesn't fulfil its purpose. And a departure of two trains in a 3 minutes space or arrival or the main terminus station is even urgent necessary as figure 16 proves.RENFE should make all effort to reach the timetable train diagram goal as demonstrated in figure 16.

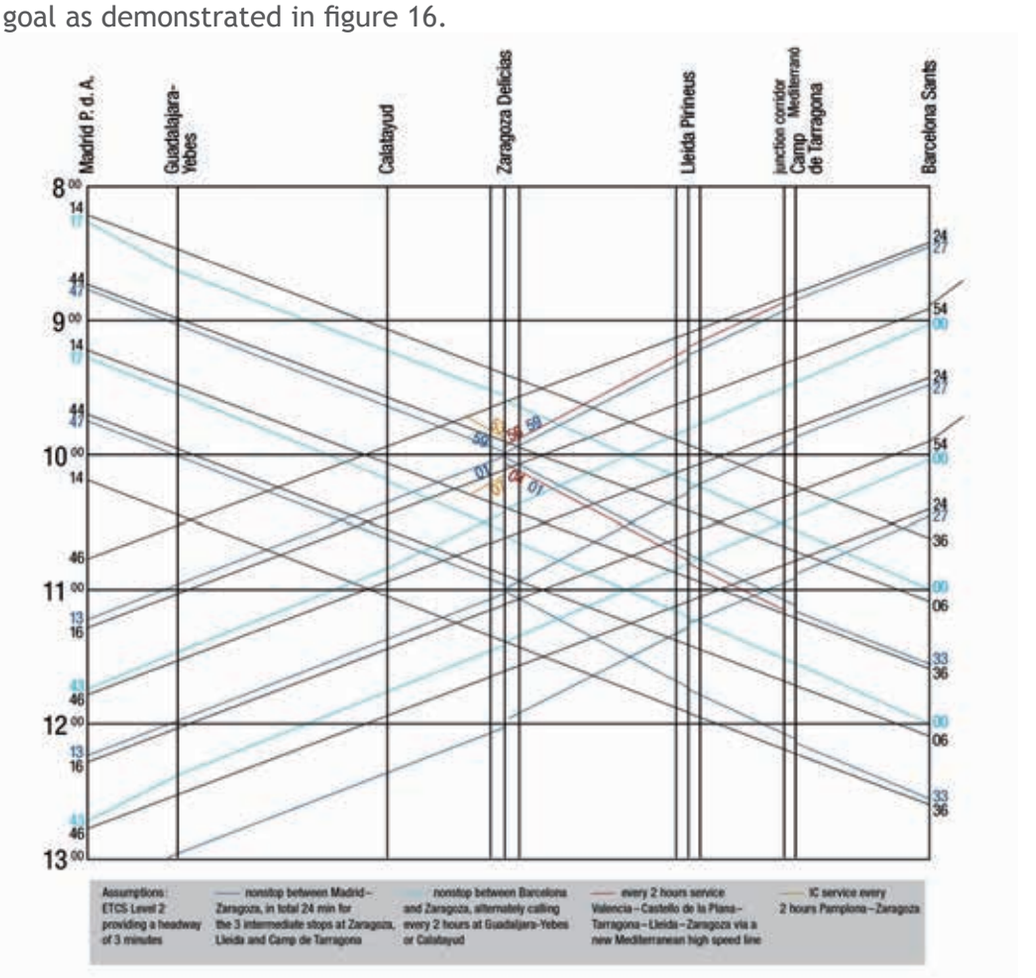


Figure 16. Train diagram goal for the Madrid - Barcelona AVE line

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