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High Speed Rail commuting:

Efficiency analysis of the Spanish HSR links

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Abstract

This paper is centred on the analysis of the commuting High Speed Rail (HSR) links that are possible nowadays in the Spanish network. The large development of the network multiplies the possibilities of travelling for commuting. However, not only the feasibility but also the characteristics of the trip, in terms of ticket cost and time spent on the travel, become essential factors when considering HSR commuting links. This paper presents a person-based methodology focused on travellers' needs and working schedules constraints, which allow differentiating among connections and identifying those intervals of time spent and costs that are affordable for commuting.

1. Introduction

This paper is focused on the commuting trips' analysis that are feasible nowadays thanks to the expansion of the High Speed Rail (HSR) network in Spain. The development of new HSR lines and especially the high increase of the services supply opens a wide range of opportunities for travelling, facilitating in many cases the commuting relations between cities.

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Commuting patterns analyses have been widely carried out in the literature, especially in an urban and metropolitan scale. Studies are mainly centred on the influence of the urban pattern and land-uses in the commuting mode choice (Cervero, 1996), but also on the effects of the urban sprawl and suburbanisation on travel behaviour and commuting patterns (Sakanishi, 2006; Sultana & Weber, 2007).

In the last decades, commuting patterns are changing due to the variations on working conditions and job accessibility. First, many enterprises and administrations offer nowadays flexitime conditions to their workers, as a way to increase their job quality perception (Kelliher & Anderson, 2008). It is stated that working schedules' flexibility favours labour productivity and work-life integration, enhancing workers' ability to balance competing demands at work and at home (McMenamin, 2007). Secondly, flexible arrival times to work are favouring job accessibility and, therefore, commuting relations. Departure time decisions become more adaptable to both working and household-related responsibilities, and will be conditioned by the travel time needed to commute. Studies on the matter identify travel time as a key factor on job accessibility (Wang, 2000; Hu, 2015) and show differences on commuters' value of time depending on this commute time (Asensio & Matas, 2008).

In this sense, the development and improvement of transportation infrastructures are clearly influencing workers' daily mobility, allowing reaching longer distances in a reasonable travel time (Sandow, 2008). Especially, the HSR system constitutes an interesting alternative for medium and long distance commuting (Garmendia, et al., 2011), as it allows a significant reduction of travel times in comparison to road transportation. The accessibility provided by HSR opens nowadays new labour markets that were unreachable for many cities in the network, and favour different kind of relations between regions (Fröidh, 2005; Vickerman, 2015). Therefore, travel time has been considered in the literature on HSR as a key element in journey-to-work analyses. Many studies have established different travel time limits where the HSR is competitive depending on the travel purpose. For commuting trips, the limit of one-hour travel time is quite extended (Chen & Hall, 2012) as a reasonable time to invest every day in working travelling. Some other studies establish a wider range of travel time, between 30 and 90 minutes, where HSR can be consider as an interesting alternative to the private vehicle for commuting trips (Menéndez, et al., 2002; Ureña, et al., 2009). When the travel time is over 2 hours, HSR is competitive for business or personal purposes, because more than 2 hours is considered an excessive time to be invested in daily working trips (Ureña, et al., 2009).

Apart from travel time, commuting-oriented transport policies are taken into consideration in the main HSR networks, which are offering HSR services to connect smaller cities to large metropolitan areas with a commuting perspective (Garmendia, et al., 2012; Vickerman, 2015). In the Spanish case, regional HSR services (commercially named AVANTs) were implemented between the cities of Madrid, Ciudad Real and Puertollano. These services present more economic fares than the classical long-distance HSR trains in Spain, the AVE services. Thereafter, commuting trips in these links have become very relevant, and the number of commuters reached the 26% of the travellers 10 years after their implementation (Menéndez, et al., 2002). Some years later, the AVANT services were implemented in many other links in the network, generally involving a large metropolitan area, and they became an interesting alternative for commuting trips (Garmendia, et al., 2012; Guirao, 2013) as they offer an important reduction of travel times in comparison to road transportation and more reasonable ticket prices in relation to long-distance HSR services. In addition, the Spanish rail operator RENFE offers nowadays different commuting-oriented ticket passes for these kinds of services (Guirao, 2013).

In this panorama, it is obvious that commuting trips are very conditioned by travel times and associated costs, but they also depends on adequate timetables offered by HSR services, which should be convenient for travellers and adapted to their working timetable flexibility in order to make commuting between HSR cities feasible. Precisely, the present paper is centred on the analysis of commuting links that are possible thanks to the HSR system in Spain and proposes a person-based method, which includes workers' temporal constraints with the aim of assessing the real efficiency of these connections in terms of ticket costs and time spent in the trip.

2. Methodology

The main objective of this paper is to analyse the efficiency of all the commuting connections feasible nowadays through the Spanish HSR network (Fig. 1).

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It is composed by six main lines and encompasses 30 HSR cities, but in this study, the 3 cities located in the Galician corridor (Coruña, Santiago and Ourense) are not considered as they are not already linked by HSR lines to the whole network.

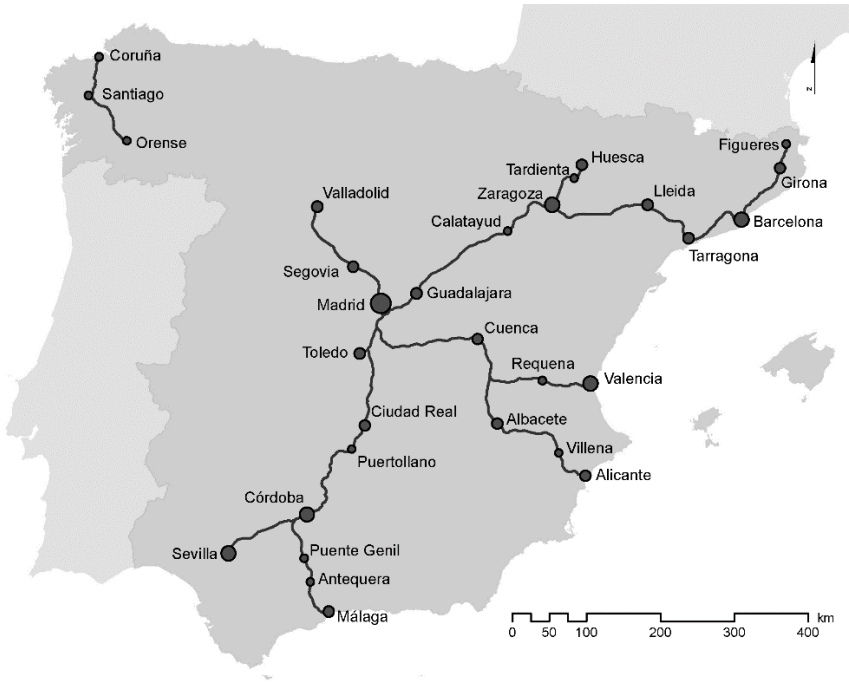

Fig. 1 – Spanish HSR network

To carry out this assessment, it is necessary to establish certain requisites that every commuting connection must guarantee. Generally, the commuting trip is conditioned by the following transport chain, which defines certain hypothesis and temporal constraints (Fig. 2):

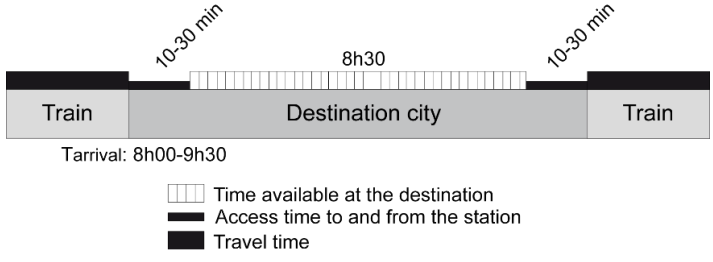

Fig. 2 – Commuting trip transportation chain. Source: Adapted from L'Hostis and Leysens (2012)

The labour schedule consists in 7.5 daily working hours (37.5 hours per week) and one hour for lunch that is 8.5 hours of total time available at the destination. In addition, a range between 10 and 30 min for access to and from the HSR station must be included as a very general approximation. The arrival time limit to the destination city will depend on the timetable's flexibility in each job. This study will consider 4 scenarios that cover a wide range of working possibilities (Table 1):

Table 1 – Scenarios of arrival times to the destination city

Scenario	**1**	**2**	**3**	**4**
Max. arrival time to the destination	8h00	8h30	9h00	9h30

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Once the scenarios are defined, the most suitable inbound and outbound trains are selected for every city-pair, through a computer algorithm that takes into account real timetables and ticket costs offered by the Spanish rail operator (data collected in October 2015). The selection is done minimising waiting times that is, it considers the HSR services that are better adapted to the working timetable.

This data allows the calculation of both associated costs and time invested on the trip:

- Costs related to ticket prices: the reduced fare offered by train passes is used. For AVANT trains, ticket passes of 40 trips with an up to 60% discount are considered. For AVE services, there are passes of 10 trips with a 35% discount.
- Total time invested: It is related to travel and waiting times

3. Results

3.1. Accessible cities for commuting trips

Nowadays, network configuration and HSR services allow a high number of links adapted to the temporal constraints established by different labour timetables. Fig. 2 shows all the feasible connections depending on the different scenarios outlined in the methodology section.

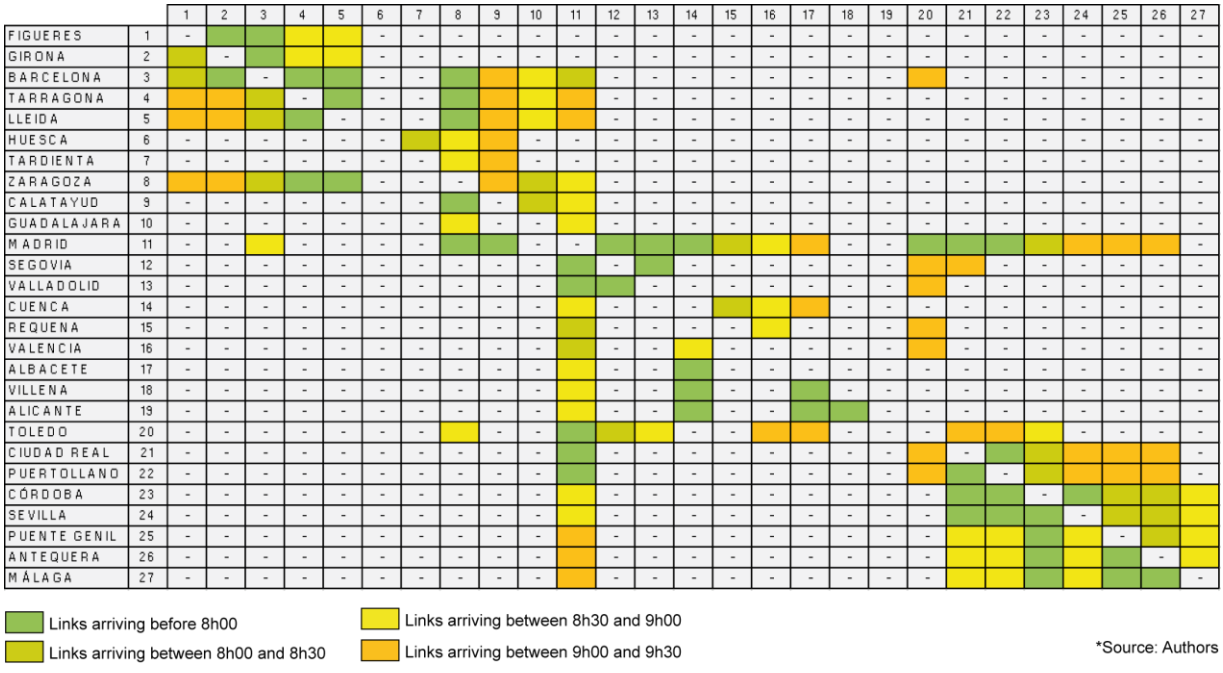

Fig. 2 – Possible commuting links depending on the arrival time limit

In the scenario 1 (arrival time at 8h00), 49 connections between cities are feasible, mainly those between close cities located generally in the same HSR line. Madrid is the origin with more accessible destinations (8), followed by Barcelona (4). In this scenario, the most distant connection is made between Barcelona and Zaragoza, two cities located 314 km away of rail distance. The number of commuting links increase to 71 links in the second scenario (arrival time at 8h30), including a few distant connections between Madrid and cities located at the end of HSR lines such as Barcelona (621 km) or Valencia (391 km), cities that benefit from good HSR services to the capital of the country. In the third scenario, the number of links reaches 111 connections, allowing almost all connections between cities located in the same line, independently of their distance. The arrival time limit at 9h00 allow reaching Madrid from 17 different origins, therefore, with a relatively flexible working schedule, most of the HSR cities can benefit from the wide labour market located in Madrid. In the last scenario, there are 151 links, making possible to connect cities that needed transferring between trains to be accessible (Barcelona-Toledo, where there are not direct trains and

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travellers need to transfer in Madrid). In this scenario, only 4 cities are not linked to Madrid and this is due to the low quality of the HSR services (Huesca and Tardienta, with only one train a day) or a very large rail distance (Figueres and Girona).

However, although in many cases the HSR services are adapted to working timetables allowing commuting relations between cities, the ticket costs and travel times may make these connections totally unfeasible or inefficient.

3.2. Time and money invested on commuting links

This section is only focused on the last scenario (arrival time before 9h30), as it allows analysing a higher number of connections (151). Fig. 3 shows the relation between ticket costs (expressed in total monthly expenses) and the rail distance between each city-pair. The graph clearly shows the differences between links with and without AVANT services, as they offered a more economic cost per km. For the same distance, AVANT services are much more efficient. On the other hand, Fig. 3a also shows a high number of very long-distance connections that are feasible thanks to the HSR services' timetables. However, for these distances, travel and waiting times may be key factors of travel efficiencies. In many cases, these times reach very high values that would make travellers to reject the commuting option. Fig. 3b shows the relation between these travel and waiting times and the rail distance. The graph is much more scattered because many connections presents low frequencies that make difficult to have suitable HSR services. For instance, for rail distances around 200 km, the time invested may oscillate between 40 hours/month (around 1h40 per day) and almost 120 hours (5h30 per day).

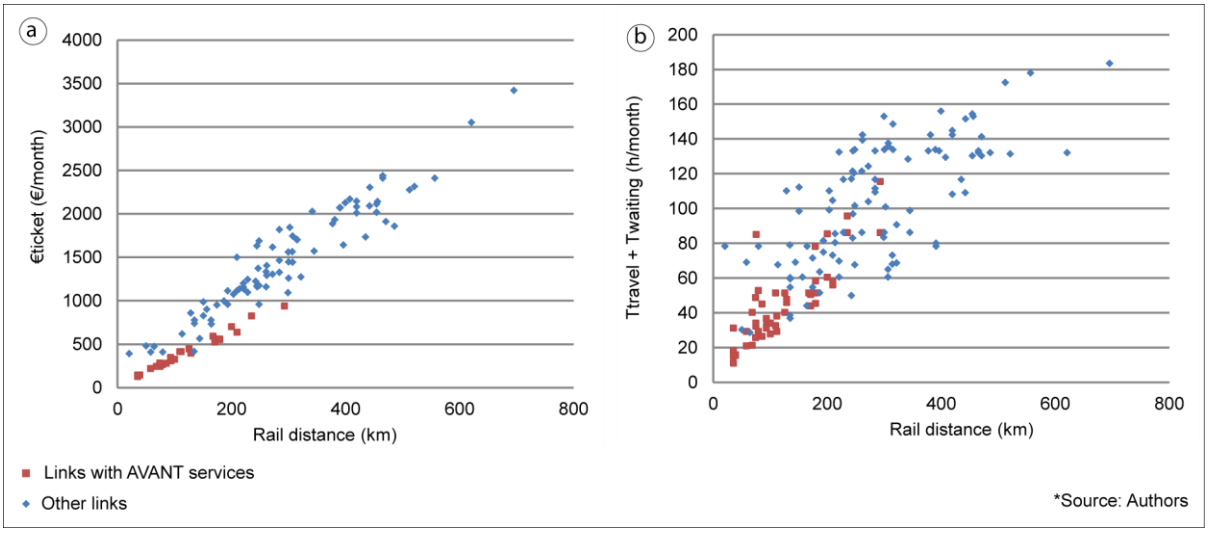

Fig. 3 – Dispersion graphs: a. rail distance – ticket cost; b. rail distance – time invested

Therefore, travel and waiting times could be decisive in the efficiency of commuting HSR links, as the existence of adequate timetables and the quality of the services play an important role.

Fig. 4 shows the relation between rail distance and time invested with more detail and precision, bringing to light not only the general trends but also the differences found depending on the direction considered in each city-pair.

In the graph it is shown that travel and waiting times can be very different when considering the trip from a city A to a city B, and on the opposite direction, because the possibilities of commuting are not the same due to services timetable's configuration.

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Being at the same rail distance (from A to B, or from B to A), the time needed for commuting in terms of travel and waiting time could be very different and this will be an important factor that conditioned the commuting trip feasibility.

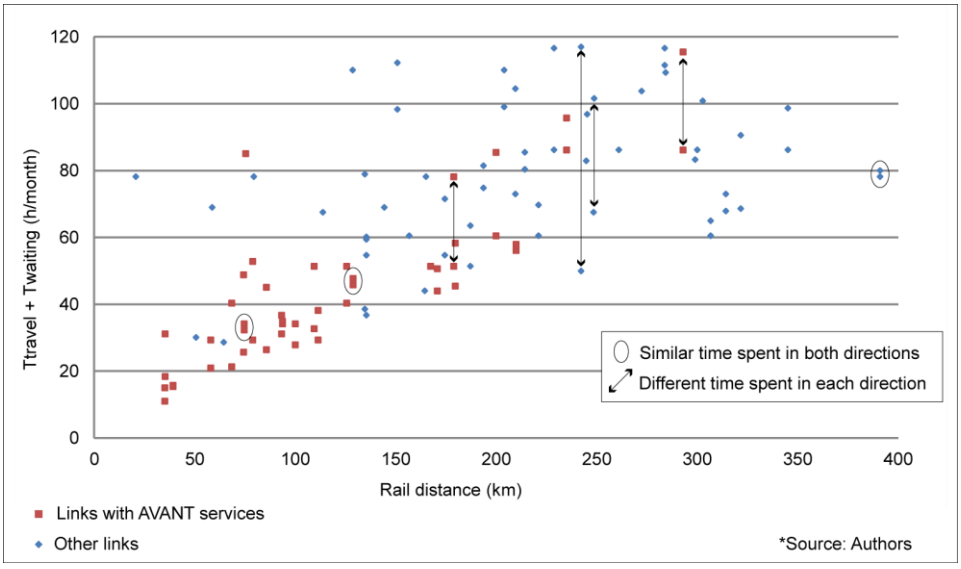
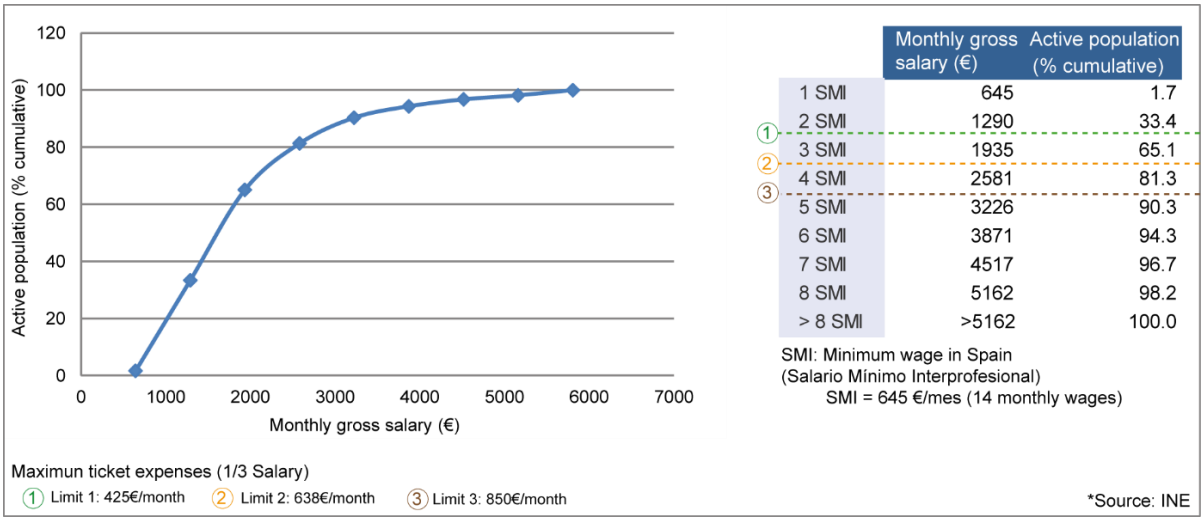


Fig. 4 – Dispersion graph: rail distance – time invested. Differences between directions in each city-pair links

3.3. Commuting links' feasibility

Once having analysed the HSR connections, an assessment of their feasibility, in terms of cost and time, depending on workers' salary is carried out. The salary will condition the maximum amount of money that workers can invest in travelling. According to the Salary Structure Survey of the Spanish Statistics National Institute (*Instituto Nacional de Estadística – INE*), the active population distribution depending on their gross salary is shown in fig. 5.



	Monthly gross salary (€)	Active population (% cumulative)
1 SMI	645	1.7
2 SMI	1290	33.4
① 3 SMI	1935	65.1
② 4 SMI	2581	81.3
③ 5 SMI	3226	90.3
6 SMI	3871	94.3
7 SMI	4517	96.7
8 SMI	5162	98.2
> 8 SMI	>5162	100.0

SMI: Minimum wage in Spain
(Salario Mínimo Interprofesional)
SMI = 645 €/mes (14 monthly wages)

Fig. 5 – Cumulative population distribution depending on gross salary

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Considering for the assessment that workers would use, as maximum, a third of their salary in travel expenses (which it is a very high amount of money in some cases), three limits are established:

- Limit 1: maximum monthly expenses of 425€. If the associated travel costs are higher than this value, a 33.4% of the population would be excluded.
- Limit 2: 638€ of total expenses. In this case, if the costs are higher, the 65% of the active population would be excluded.
- Limit 3: 850€ of total expenses. It would be affordable by only the 19% of the active population.

Total time (h/day) / Monthly expenses (€)	<1h (<22 h/month)	1h-2h (22-44 h/month)	2h-3h (44-66 h/month)	3h-4h (66-88 h/month)	>4h (>88 h/month)	Total
<425	7	18	6	5	0	**36**
425-638	0	4	9	3	0	**16**
638-850	0	2	4	3	2	**11**
>850	0	0	8	20	60	**88**
Total	**7**	**24**	**27**	**31**	**62**	

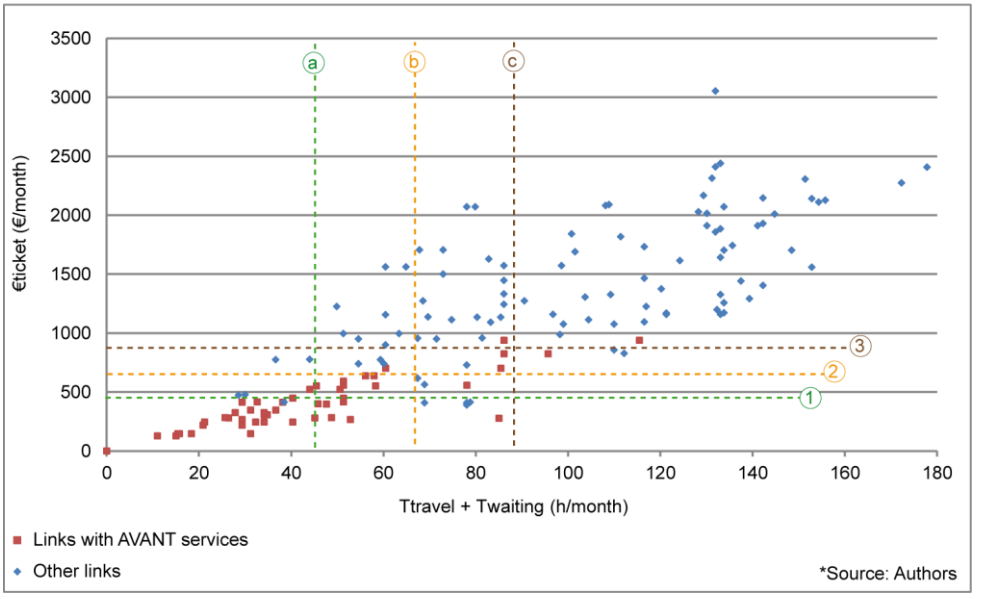

Fig. 6 – Links' distribution depending on time invested and monthly expenses

These limits allow assessing the commuting links depending on their associated costs and, therefore, their efficiency. Focusing exclusively on tickets costs (Fig.6), many links seem unaffordable for a high percentage of the active population. Only 36 out of 151 links can be paid by the 66.6% of the total workers (limit 1) while 88 out of 151 links are unaffordable for more than the 80% of the active population. When considering travel and waiting times, more than the 60% of the links (93 out of 151) need more than 3 hours per day that is considered in the literature as an excessive time spent for commuting. In this range, some connections with AVANT services can be found, showing that there are some of these services that could be the result of the addition of two commuting-oriented HSR services (For instance, the link between Sevilla and Malaga, stopping at Cordoba).

Besides, as it is shown in fig. 6, there are many links that present reasonable travel and waiting times, under 3 hours (1h30 in each trip), but they require important ticket expenses, higher than 850 € per month (limit 3).

4. Conclusions

This article is centred on the systematic analysis of commuting links that are possible nowadays in the Spanish HSR network. In a commuting relation is essential to have HSR services that allow workers to keep to working

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timetables. However, this is a necessary but not sufficient condition to guarantee an efficient commuting HSR connection, because the feasibility of commuting trips will be determined by both the ticket expenses and the time spent on the travel, which will play an important role in the efficiency of the trip. The methodology proposes a person-based assessment of all this connections, and takes into account real timetables and costs that allow identifying those feasible commuting connections from the travellers' perspective.

In many links analysed where the commute time is reasonable, the efficiency could be increased offering more economic ticket passes which will reduce significantly the total expenses for travellers. However, in other cases, the trip becomes unfeasible because of the deficient adaptation between HSR services and working timetables, increasing waiting times.

In summary, this paper brings to light the high potential of this person-based methodology in the analysis of the high variability existing nowadays in the Spanish HSR network, where certain connections benefit from more economic ticket prices or higher frequencies that favour timetables' coordination.

Acknowledgements

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