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Estimating radial railway network improvement with a CAS

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ABSTRACT

The Spanish railway network is very complex, with two different track gauges: the broad classic *Iberian* track gauge and the so called *international gauge*, the latter used in the extensive high speed network. All new lines have been built with double track and top technologies. But there are controversial opinions among experts regarding how the network should grow. We had developed what we called *isochrone circle graphs* and a *geometric index* for radial railway networks improvement estimation, that can be very useful for decision taking regarding the improvement of railway lines. The corresponding paper was illustrated with a sketch constructed with a dynamic geometry system that used sliders to change the input parameters (timing to each peripheral destination and population of these destinations). Although very comfortable to use, altering the number of peripheral destinations considered required to construct a complete new sketch. To avoid this problem and in order to be able to perform symbolic computations and solve equations with the data obtained, we have begun from scratch and have designed and implemented a complete new package in the computer algebra system CAS *Maple* that takes as input the lists of destinations, timings and populations and builds the corresponding *isochrone circle graphs* and performs all the corresponding calculations. An important advantage of working in symbolic mode (i.e., of introducing parameters in the computations) is the possibility to work with unknowns (that represent network improvement goals) and consequently obtain the time improvement required in a line in order to fulfil a network specific improvement goal.

1. Introduction

The Spanish railway network is very complex, with two different track gauges: the broad classic *Iberian* track gauge (1667 mm) and the so called *international gauge* (1435 mm), the later used in the extensive high speed network (Fig. 1) (there is also a small narrow gauge network). There are gauge changeovers [1] at several points that connect both subnetworks (a subset of the rolling stock is dual gauge).

Adif [2] company takes care of the infrastructure and *Renfe* [3] operates most trains. A detailed updated report of *Adif* facts can be found in their annual report [4].

Only China has nowadays a longer high speed railway network. Moreover, the longest high speed railway service in Europe is operated in Spain: the 1121 km Barcelona–Málaga, operated at an average speed of 204 km/h [5]. The high speed

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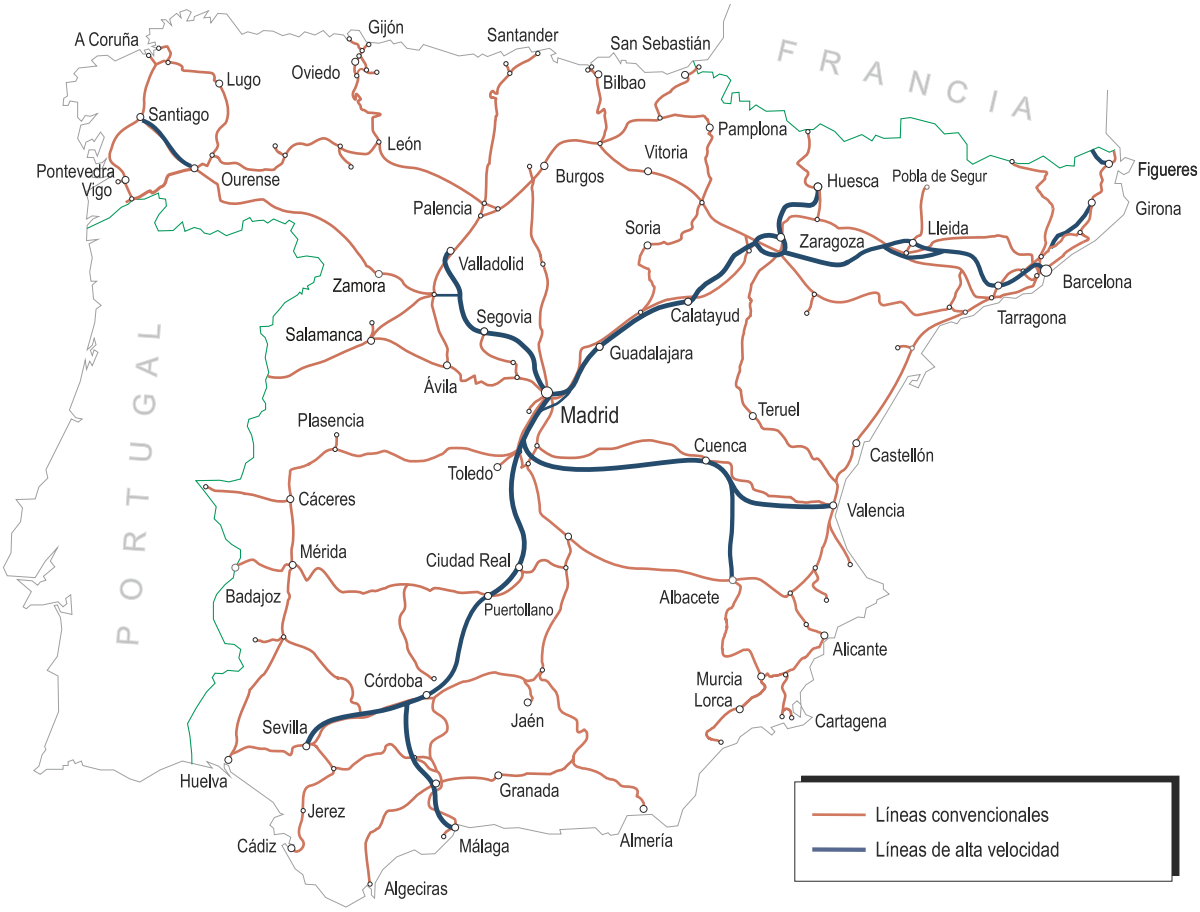

Fig. 1. Spanish railway network November 2012. The Iberian gauge conventional network is represented with thin red lines. The high speed international gauge network is represented with thick blue lines. (Courtesy of the Spanish Railway Foundation.)

railway network has grown very quickly, as the first line (Madrid–Seville) was opened only in 1992 for the *Expo'92 World Fair*. All new lines have been built with double track and top technologies ($\geq$300 km/h track design, *LZB* or *ERTMS* traffic management system, 25 000 V AC electrification, etc.) [6–8].

Renfe's rolling stock is very flexible, with some dual gauge trains and multiple units (using two different gauge change systems: *Talgo* and CAF) [9]. Many locomotives and multiple units can read different signalling systems (*ASFA*, *ASFA 200*, *LZB*, *EBICAB*, *ERTMS*), are multi-voltage and even hybrid rolling stock has been developed (730 series [10]).

There are controversial opinions among experts regarding how the network should grow, especially after the cuts due to the economic crisis (let us underline that the completion of the NW line, the N line, the Spanish side of Madrid–Lisbon line and the extensions of the SE line, are under work now).

An alternative could be to build very high speed trunks followed by *not so high speed* (for example 200 km/h) antennas. Although designed for high speed traffic, these antennas could be (initially) single track if the expected traffic was low. Moreover, the circulation of high speed trains in these antennas would not exclude the circulation of freight trains, regional trains or even commuter trains.

2. Previous works

Due to the controversy mentioned in Section 1, we performed some research in order to easily compare the different alternatives for routing trains and for building new infrastructures in the Spanish railway network. We followed two research lines.

On one hand, we developed a computer package that is able to calculate precise timings, consumptions, costs, emissions, best routes, etc., for each piece of *Renfe*'s rolling stock running on *Adif*'s lines [11,12].

On the other hand, we developed what we have called *isochrone circle graphs* and a *geometric index* for radial railway networks improvement estimation [13], that can be very useful for decision taking regarding the improvement of railway lines.