



Atlas-rail: geo-referenced database on high-speed

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Abstract

The whole Atlas-Rail project has a very strong visual impact. On a methodological level, this feature can be noted, through the codification of available rail data in spreadsheet tables and after processing them for graphic outputs. Furthermore, it can be depicted in different format general information of the railway and technical characteristics of the rolling stock.

Keywords: Database, GIS, georeferencing, cartography, high-speed rail.

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1. Introduction

Atlas-Rail project is made up of a geographic database composed of information related to lines, sections and railway stations, of both European and Spanish high-speed railway services. All this information has positioning values, in other words, they are geographically located in the space.

Profits and appliances of Atlas-Rail project are multiple. The first one has mainly a visual component, and it refers to present geographic database elements in satellite platforms, for example Google Earth.

The variety of data depends on their accessibility and if they can be compared with the same data of other spatial units or not.

In particular, it has been possible to obtain and depict technical information related to track geometry and lines, sections and high-speed rail stations data, taking into account that this information can be updated according to the activities or actions undertaken.

Cartography is another appliance to be highlighted. If the variety of data increases, the possibilities to present information in a map also increase. For instance, it can be elaborated cartography both topological and choropleth map type, in different formats (raster and vector) and in different geographical base map (physical and political units).

To complement this, Atlas-Rail project can be considered a very interesting tool as a basis for future research in the area of high-speed railways.

2. Atlas-rail project elements

Atlas-Rail Project has two different types of elements, depending on the nature of the content offered. On the one hand, there are the database components. On the other hand, the elements which make up the GIS or Geographic Information System.

2.1 Database components

Regarding database components, there are line-type elements and point-type elements, but both of them are including inside feature-type or vector-type elements.

In the first case, it refers mostly to high-speed railway lines or, falling this, sections which have a certain length that, due to their technical characteristics, are capable of hosting high-speed traffic. Furthermore, it refers to sections that differ from adjacent lines in, at least, one of its characteristics.

As to point-type elements, they are identified with stations that currently offer high-speed railway services or cities that will be part of the high-speed network in the future because there is a high-speed line under construction near or across it.

In the case of lines or sections, each reference point has two coordinate values X and Y. It would be useful to have a Z value too, but if it is not possible, the height above ground level value is taken.

The reference points whose X, Y and Z coordinates refer to high-speed railway sections are located on the track axis. In particular, in the case of being a single track, it is placed among both lanes. If it is a double-track, the reference point will be marked among both tracks. If the value exceeds the double-track or junctions, high-speed lines are digitized according to highspeed rails traffic system. Every reference points are geo-referenced.

The lengthwise separation between two consecutive reference points depends on the scale

values used. A larger scale is recommended to digitize sections with small-radius curves, in order to improve the accuracy about the real track. As a general idea, interval between consecutive points from 50 to 200 meters will be considered.

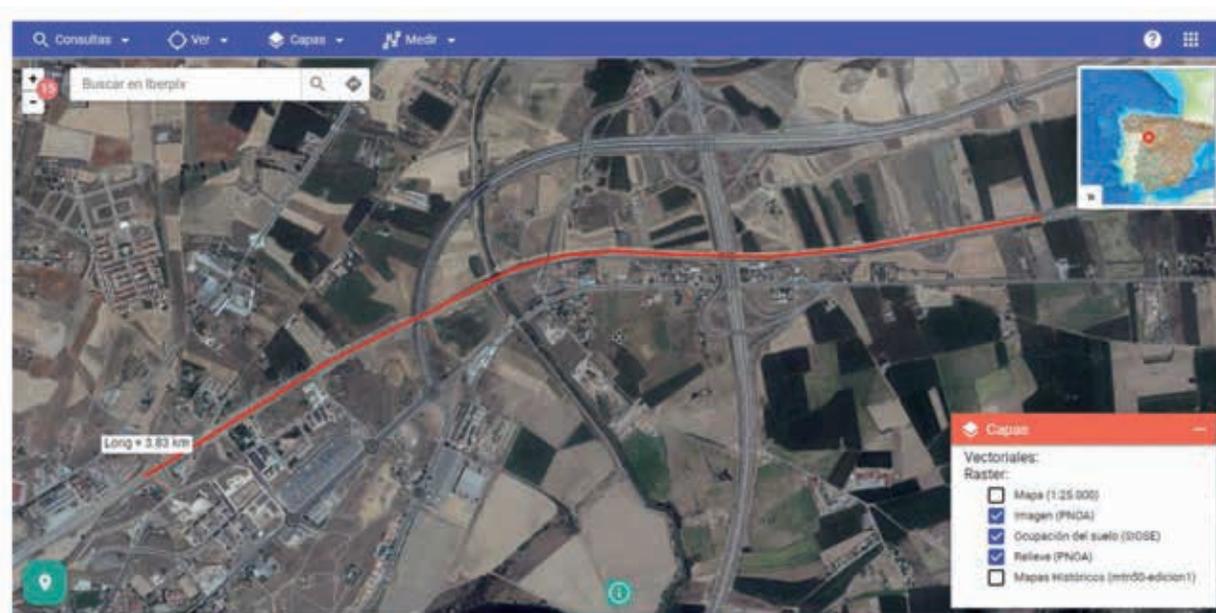
Sections are line segments of variable length with homogeneous technical and service characteristics, and they can have intermediate nodes. Both lines/sections in service and under construction are included in Atlas-Rail project.

The characteristics of the sections are called attributes, and they are shown in tables or databases through fields (columns). Each field has a number of specific characteristics, relating to accepted data format, interval of values, limited digits or text characters, and so on.

Each line or section is identified with a single code. This code must have unless one digit and it can be used to join or relate several tables or databases. This issue will be explained in detail in the following section.

In the case of nodes, the station reference point is always fixed with X, Y and Z coordinate values, and it is placed in the location of the passengers building. If no passengers building is found, reference point must be fixed close to the high-speed station.

Figure 1: Example of high-speed line scanning. Olmedo-Zamora HSR (Spain)



Source: Independently produced. Satellite image provided by IBERPIX
(<http://www.ign.es/iberpix2/visor/>)

2.2 GIS components

GIS can be defined as software with specific capabilities, which are summarized in the following functions:

In first place, the functions for inputting data. These are the procedures that allow the conversion of geographic information from analogical (the traditional format in Geography, especially paper maps) to digital format. This conversion has to keep the baseline features of the spatial data through data entry procedures (digitizing or similars).



These functions also have to consider procedures to remove mistakes and bugs in the information to be included in the GIS. Previously, information has to be compiled and prepared, in order to be edited and converted into digital format.

In second place, functions for graphic and cartographic output of information. In particular, it refers to the activities that show the user the own data included in GIS database, and the results of the analytical operations performed on them. These functions make it possible to obtain maps, graphics, tables and other sort of results in different mediums: paper, digital images, data files, and so on.

In third place, spatial information management functions. Data required are selected from database, and these functions facilitate to reorganize all information and integrate it into the database in several different ways. GIS softwares are able to launch searches by spatial or geographic criterias. For instance: Which lines are in construction in this year? What countries have in a given year with unless one high-speed line? What are the stations through which the "x" line runs?

In fourth place, there are analytical functions. They make easier the processing of the data included in the GIS, so that it is possible to hold more information and to improve knowledges with respect to initial situation. In addition, these functions make GIS a simulator of territorial reality. This way, it is possible to build "cartographic models" and to solve a large number of issues in the spatial scope of application. In this case, regional planners and the rest of agents involved can observe which could be the result of a specific action in the territory and it can influence in the decision making process.

2.2.1 Obtaining the geographic data

Digital information can be collected through data layers (vector and raster). Raster files represent the territory in the form of pixels or cells, which can have a very varied resolution. Depending on this number of cells, quality and level of detail of the display also varies. An example of a raster layer is a satellite image.

On the other hand, vector files represent the territory through three spatial element types: points, lines and polygons. For instance, a road layer. In this second case, there are different procedures to gather information: observation of reality, indirect sources (analogue maps, which can be digitized and converted into digital format) and geo-referenced vector layers. In particular for Atlas-Rail project, this would mean railway line layers, train station layers, tunnels, and so on.

Georeferencing is the procedure by which the location of a spatial object in a given coordinate system and datum is defined. In order to standardise information, the ETRS89 (European Terrestrial Reference System 1989) is taken as the official reference system, replacing the ED50 (European Datum 1950).

The coordinate system used to develop Atlas-Rail project is the WGS (World Geodetic System), specifically WGS84. This is also suitable for systems that do not use gravity to locate the position, such as GPS (Global Positioning System).

Figure 2. Coordinate System selection in QGIS



Source: Independently produced

Therefore, both the railroad tracks of the Atlas-Rail Project and the high-speed stations will be referenced in these systems.

2.2.2 GIS geo-referenced layers

In Atlas-Rail project, information is organized in two layers (lines/sections and stations), independent of each other. This implies that a train station can act as a start or end of a highspeed line and start of another or be placed in an intermediate position within a line. Thus, to change a section or line, it is necessary, at least, one change in the value of one of the attributes of the line layer.

Regarding attributes, different fields have been included in line layer: an unique identification code, name of the line or section, state of implementation (in operation or under construction), year of opening, the country it belongs to, distance in kilometres and maximum speed.

For the latter attribute, kilometres per hour are used as a unit. Reference is made to the maximum commercial speed at which the fastest train traveling on that line or section can travel.

According to data available or accessible, more attributes can be added to the table, for example: gauge, electrification system, signalling, traffic type (passengers or mixed), maximum gradient...



Stations layer consists of a unique identification code, name and the country they belong to.

To process the geographic information, it has been used software ArcGis (10.3 version) and QuantumGIS (2.12. version). These Geographic Information Systems include spatial analysis tools, advanced processing of data and they allow performing complex digital mapping.

3. Methodology

The methodological process consists of several phases. The first step is to get information on the current situation of high-speed railway lines and sections worldwide. These data have been obtained through the "High-speed Lines in the World. Statistical Yearbook", published annually by the International Union of Railways (UIC). It is an "open access" report in MS Excel format that can be downloaded from its website www.uic.org.

This Excel database has been modified and edited so that it can be compatible with a Geographic Information System (GIS).

Afterwards, a geo-referenced database is established in a GIS, defining the same projection and coordinate system for all the information layers to be added so that they can be overlapped, edited and compared.

Once the layer is established, it is necessary to start the digitization of the high-speed lines in service and, as much as possible, under construction, with the support of satellite image display platforms (Google Satellite or comparables), trying to draw as closely as possible the railway lines. This platform operates as just another layer, and can be downloaded in the GIS itself. This layer will be the unique raster layer in the project.

Likewise, the location of the high-speed stations is referred by point layers, taking as reference the passenger building or, failing this, a nearby building, as mentioned above.

To complement the geographic information, other layers considered of interest are aggregated. For instance: administrative boundaries, country polygons, large bodies of water, and so on.

The result will be the creation of .shp type files, in vector format, that makes it possible to be exported to other types of format and to other softwares.

Once the digitization is carried out the next step is the aggregation of data to these geometries to enrich the geographic database and facilitate its subsequent cartography treatment. This aggregation can be done through contributions from the UIC Statistical Yearbook and/or other sources. This information can refer to multiple fields: state of implementation, total railway length, maximum speed, among others.

This data will be the attributes of lines/sections and train station layers. On the figures below we can see the structure of the tables.

Figure 3. High-speed lines/sections attribute table

	Name	VEL_MAX	YEAR	DISTANCIA	ESTADO	ID
3	Madrid-Sevilla	270	1992	471	IN OPERATION	1
2	La Sagra-Toledo	250	2005	21	IN OPERATION	2
10	Madrid-Valencia / Albacete	300	2010	432	IN OPERATION	3
4	Córdoba-Antequera	300	2006	100	IN OPERATION	4
14	Antequera-Málaga	300	2007	55	IN OPERATION	5
13	Albacete-Alicante	300	2013	239	IN OPERATION	6
5	Lleida-Camp de Tarragona	300	2006	82	IN OPERATION	7
7	Figueres-French Border	300	2010	20	IN OPERATION	8
16	Barcelona-Figueres	300	2013	132	IN OPERATION	9
12	Madrid-Lleida	300	2003	519	IN OPERATION	10
1	Bypass Madrid	200	2009	5	IN OPERATION	11
8	Zaragoza-Huesca	200	2003	79	IN OPERATION	12
15	Valladolid-León	200	2015	163	IN OPERATION	13
11	Madrid-Segovia-Valladolid	300	2007	184	IN OPERATION	14
0	Ourense-Santiago	250	2011	88	IN OPERATION	15
9	Olmedo-Zamora	200	2015	99	IN OPERATION	16
6	Camp de Tarragona-Barcelona	300	2008	88	IN OPERATION	17
17	Santiago-Vigo	250	2015	94	IN OPERATION	18
18	Santiago-A Coruña	200	2011	60	IN OPERATION	19
19	Utrera-Jerez	200	2015	72	IN OPERATION	20

Source: Independently produced

Figure 4. Stations with high-speed services attribute table

	Name	ID	COUNTRY
26	Graz	1	AUSTRIA
27	Klagenfurt	2	AUSTRIA
28	Sankt-Pölten	3	AUSTRIA
29	Vienna	4	AUSTRIA
30	Antwerp	5	BELGIUM
31	Bruxelles	6	BELGIUM
32	Leuven	7	BELGIUM
33	Liège	8	BELGIUM
70	Aix-en-Provence	9	FRANCE
71	Angoulême	10	FRANCE
72	Arrás	11	FRANCE
73	Avignon	12	FRANCE
74	Belfort-Montbéliard	13	FRANCE
75	Besançon	14	FRANCE
76	Bordeaux	15	FRANCE
77	Calais	16	FRANCE
78	Champagne-Ard...	17	FRANCE
79	Dijon	19	FRANCE
80	Est	20	FRANCE
81	Gare de Lyon	21	FRANCE
82	Haute-Picardie	22	FRANCE
83	Hendaye	23	FRANCE
84	Le Creusot	24	FRANCE
85	Le Mans	25	FRANCE

Source: Independently produced



Once these steps are completed, a variety of outcomes is obtained, although it would be more accurate to call them “products”, which will be explained in the following chapter.

4. Outcomes

4.1 Presentation of the product in google earth

The first result obtained from these processes has already been mentioned: the creation of a geo-referenced database, which serves as a starting point for later products.

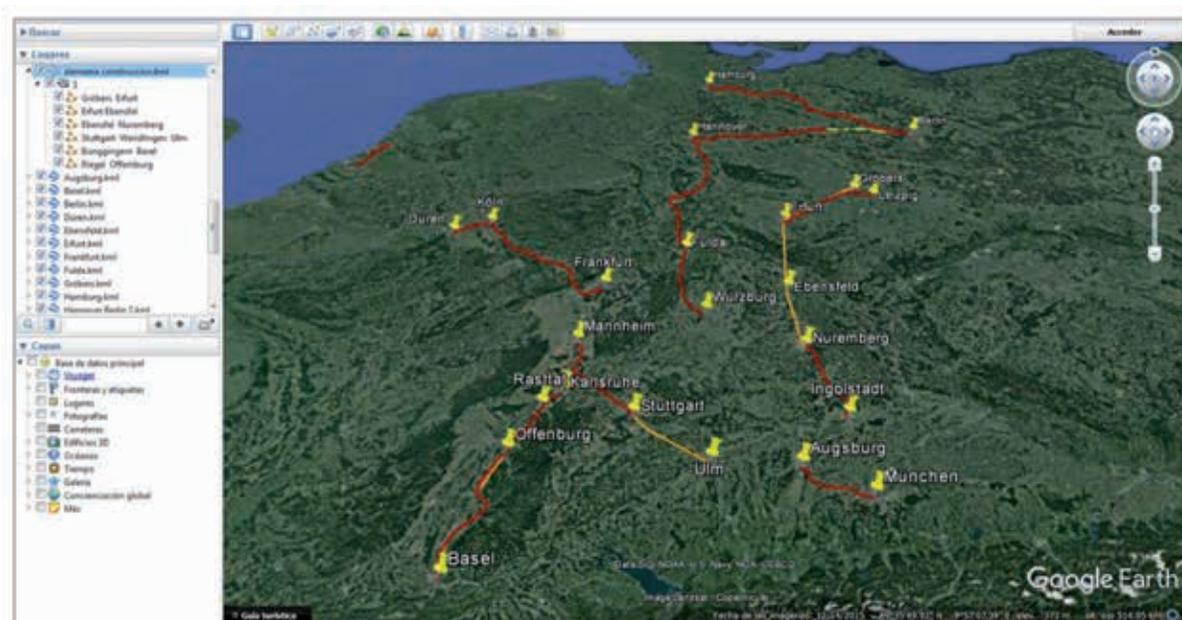
A first product developed has been the transposition of the geo-referenced database with lines and stations layers to the Google Earth platform. In other words, it means viewing the geometry of high-speed lines and their stations via satellite. So far, it has been made for European countries. In the future, it is expected that Atlas-Rail project will be implemented in countries of other continents that already have high-speed rail services.

For this, it has been necessary to transform the geospatial data, i. e. files with extension .shp created in the GIS to files type .kml (Keyhole Markup Language). In this way the identification and displaying of high-speed lines, sections, stations, connections between lines and neighbouring countries networks are possible using this online platform.

In Google Earth, users can customize the appearance of the railway lines giving different symbology depending on whether it is a line under construction or in operation, considering colour and thickness. It is also allowed editing the stations layer format, through the icon change.

Likewise, the platform enables users to select the items to display on the left side of the main screen and to obtain additional information by double-clicking in the corresponding geospatial element, either line/section or station. In the first case, clicking a high-speed line displays a table structure that looks like a GIS attribute table, offering the user the available data of that object. It is the same with stations layer.

Figure 5. Display of some high-speed lines and stations in Google Earth



Source: Own elaboration from the data provided by the Statistical Yearbook, UIC Passenger Department (2017)

In addition, it not only displays information relating to the object but also automatically approaches it until it is viewed perfectly framed on the screen on its full extent.

4.2 Atlas of high-speed rail in Spain

The second product to be highlighted is the elaboration and publication of the Atlas of Highspeed Rail in Spain, coinciding with the commemoration of the 25th anniversary of the commissioning of the Madrid-Seville high-speed line.

Atlas-Rail database and the International Railways Union's (UIC) Statistical Yearbook have been used as well as for the rest of the products.

The Atlas of High-speed Rail in Spain is a collection of detailed maps showing the past and present development of the Spanish high-speed rail network, along with other elements of the railway system, represented in the form of graphs, tables and photographs. The purpose is to supply the user an overview of high-speed in Spain through a detailed analysis of its components.

Map 1. Spanish High-speed rail network (2017)



Source: *Atlas of High-speed Rail in Spain*, Spanish Railways Foundation (2017)



In particular, a two-fold objective is sought. On the one hand, show the evolution of highspeed in Spain since its inauguration and its current situation. On the other hand, assess the work carried out by the Spanish Railways Foundation through the analysis and compilation of statistical and geo-referenced information of the country's rail network.

Information is provided at different spatial and time scales. In fact, a first part with data referring to the situation of high-speed worldwide is included, comparing the key data of each rail network.

Furthermore, the Atlas contains thematic maps with the characteristics of the Spanish highspeed network: types of lines, infrastructures as well as the most valuable tunnels and viaducts.

It also includes relevant information regarding traffic density by type of service and the demand for transport, as well as, the main high-speed routes, and data related to distances and travel times between different links, the characteristics of the lines (orography of the terrain, rail facilities, profiles...)

Finally, a more technical chapter is devoted to the rolling stock that has operated in the past and which currently is used in the Spanish high-speed network.

The Atlas has been published in Spanish language and has just been produced an English edition. In the Internet, the Spanish version can be downloaded by clicking on the following link: <http://www.ave-altavelocidad.es/atlas.asp>

A cartographic example of the aforementioned Atlas is shown in the next figure, and represents the high-speed rail tracks in Spain in 2017.

4.3 Cartographic models

Up to know, the third product has been the creation of customized cartography. The latter has already been applied partly to the second product exposed, offering a schematic representation of each of the proposed topics.

Map 2. Countries with high-speed railway services in the world (2017)



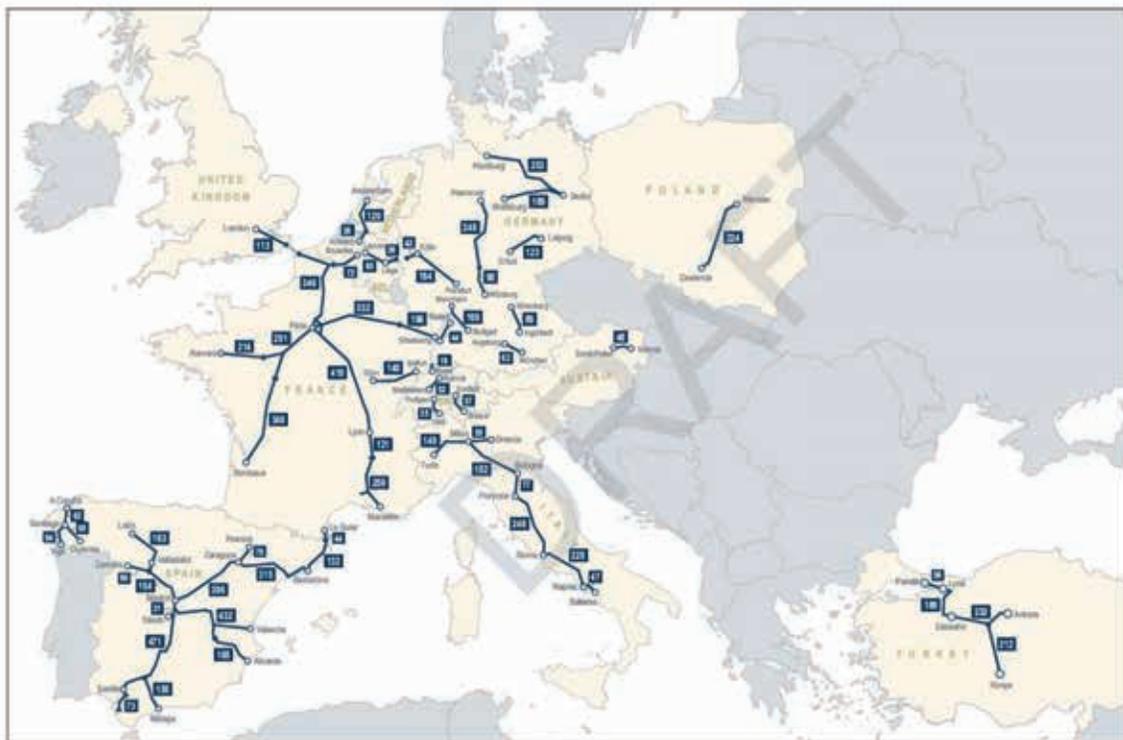
Source: Own elaboration from the data provided by the Statistical Yearbook, UIC (2017)

Atlas-Rail database, UIC Statistical Yearbook and the data that companies, operators or agencies wish to provide enable a very wide range of map contents as well as other supporting elements to illustrate the geographical reality of high-speed networks in the world, continents or even on a smaller scale.

All this depending on the data availability and the required level of detail to be depicted in the document.

The following are some examples of this cartographic typology. They are shown from small to large scale.

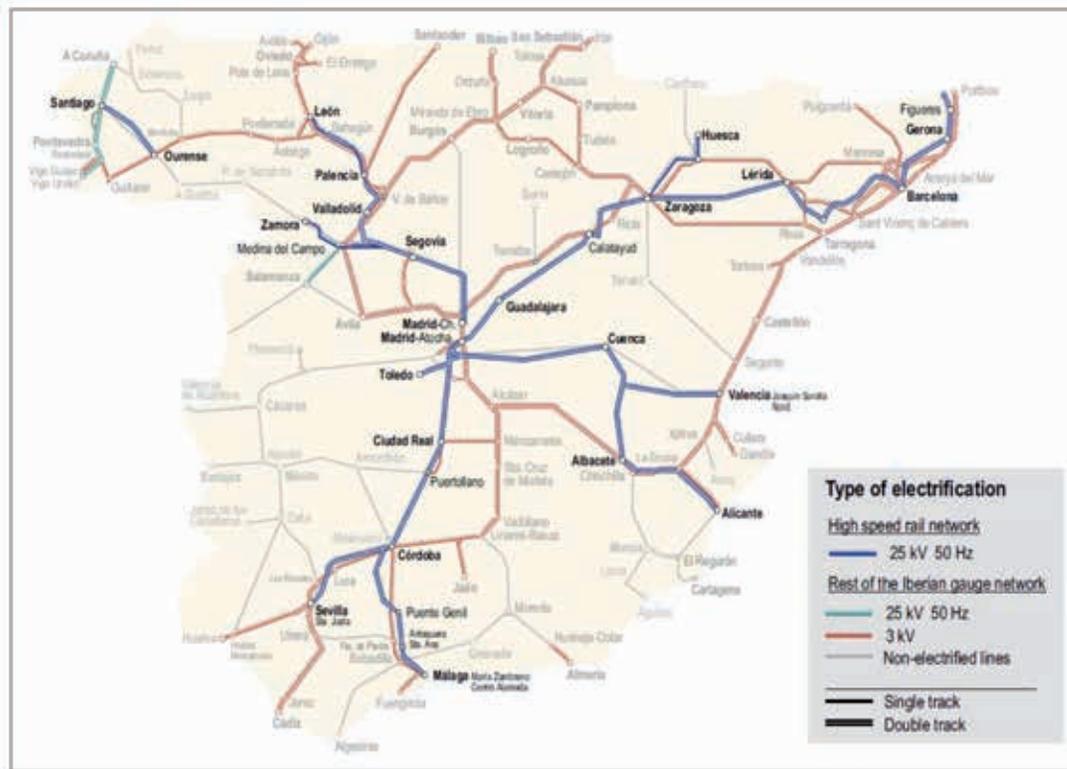
Map 3. Distances in kilometres of the European high-speed rail lines (2017)



Source: Own elaboration from the data provided by the Statistical Yearbook, UIC Passenger Department (2017)

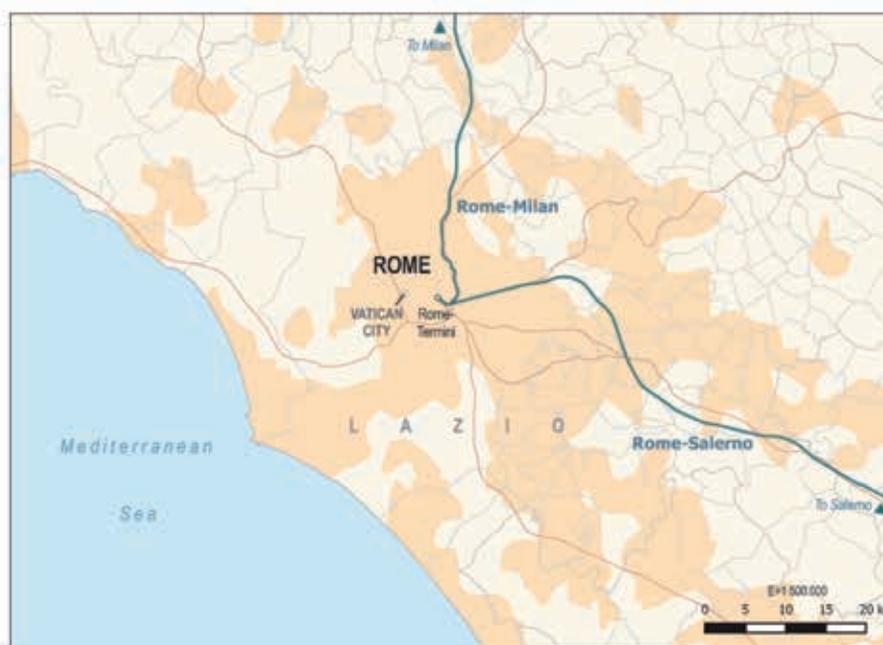
Note: Countries with at least one high-speed line are highlighted in another colour compared to those with no line

Map 4. Typology of electrification in the Spanish railway network (2017)



Source: Own elaboration from the data provided by Atlas-Rail database and the Statistical Yearbook, UIC Passenger Department (2017)

Map 5. High-speed railway lines in the Lazio Region (Italy) (2017)



Source: Independently produced

5. Conclusions

Atlas-Rail Project consists in a database composed of geo-referenced information relating to high-speed rail.

It includes data at different scales and years, allowing comparative and evolutionary analysis between regions, countries, continents and for varied attributes.

With the support of other tools (data sources, specific software), this database makes it possible carrying out research activities of a wide variety in the railway field. As a result of this, it is the display of lines and railway stations on the Google Earth platform, the publication of an Atlas on the 25th Anniversary of Spanish high-speed, or the customized cartography production.

In short, Atlas-Rail aims to be a tool that supports the dissemination of research at rail level and also becomes a support tool that promotes the right decision-making to maintain or improve as far as possible the different rail networks.

6. References

- INTERNATIONAL UNION OF RAILWAYS (UIC) (2017): High-speed Lines in the World. Statistical Yearbook. Union Internationale des Chemins de Fer, Passenger Department. Paris, 21 pp.
- MINISTERIO DE FOMENTO (2015): Observatorio del Ferrocarril en España. Fundación de los Ferrocarriles Españoles. Madrid, 231 pp.
- IBERPIX (Instituto Geográfico Nacional de España):
<http://www.ign.es/iberpix2/visor/>
- ADIF (Administrador de Infraestructuras Ferroviarias):
http://www.adif.es/es_ES/index.shtml
- SNCF (Société Nationale des Chemins de Fer):
<http://www.sncf.com/>
- DB (Deutsche Bahn):
<https://www.bahn.com/en/view/index.shtml>