HGIS reconstruction of the urbanisation process in major Spanish cities.

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Summary

The present work aims to reconstruct and interpret the urban fabric of the main cities in Spain in order to understand their urbanisation processes during the 19th and 20th centuries. Using the technological innovations that took place during this period, these cities escaped the confines of their walls and spread outwards in a process that saw the sustained growth of transport networks and urban services. The main objective of this research is to interpret this phenomenon and to classify it in terms of its geographical, demographic, political and regional characteristics.

The approach followed is based on the compilation of historical urban maps, and also other documentary sources, which have allowed us to continuously map urban growth through Historical Geographic Information System (HGIS). The sources used are essentially primary and have been obtained from historical cartographic archives, map libraries and digital map collections. Vectorization tools have become an essential part of this work, as they allow us to obtain homogeneous and comparable shapefiles over periods of many years. They are used to describe the different techniques available and to justify the approach chosen based on the documentary sources available. This approach involves the construction of a homogeneous database for the whole of Spain, which it will also be possible to use for other studies and related applications.

The present research group has already carried out similar work focused on different regions of Spain. It also has experience of working with complementary data on population, GDP and transport infrastructure for the whole of Europe, with this undoubtedly providing a great incentive to continue developing this type of database. Adding new variables to the study should help to create increasingly comprehensive models and help us to understand the evolutionary dynamics of Spain, and Europe in future stages of the project.

Introduction

In recent years, urbanization phenomenon is gradually becoming such an important matter in terms of international policies and concerns. There are too many considerations to explain this phenomenon, but mainly depend on the definition of urbanization taken. Hall at al.(1973: 118) exposes two basic meanings: the use of land for urban purposes, in a physical sense, and the people and their activities, in a functional sense.

Assuming *urbanization* such as the percentage of urban population in relation to the total population of a region, measurement is quite clear. For instance, United Nations identify in 2007 a paradigm shift, when urban population surpassed rural population at global level for the first time in history (figure 1). World's population is growing exponentially and mostly concentred in cities and their respective metropolitan areas.

In terms of urban areas, urban footprints are changing constantly and new neighbourhoods are appearing extremely fast in the peripheries. New citizens are arriving from rural areas, but there is no

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more delimitation to country boundaries. Migrants scroll at regional, national or international level without distinction. Depending on the country and their specificities, a type of migration may be predominant but there are not common patterns. Just one issue tends to keep significance. Most of migrations are motivated by economic reasons and their integration on receiving city is usually complex. The magnitude of these phenomena does not allow governments, nor other agents; to plan, adapt and built proper housing for all these people. This way, suburbs and informal settlements are being creating gradually and mainly in an informal way.

The two approaches are relatively easy to quantify nowadays, thus we dispose enough tools to measure both phenomena, the portion of urban population and the urban area.

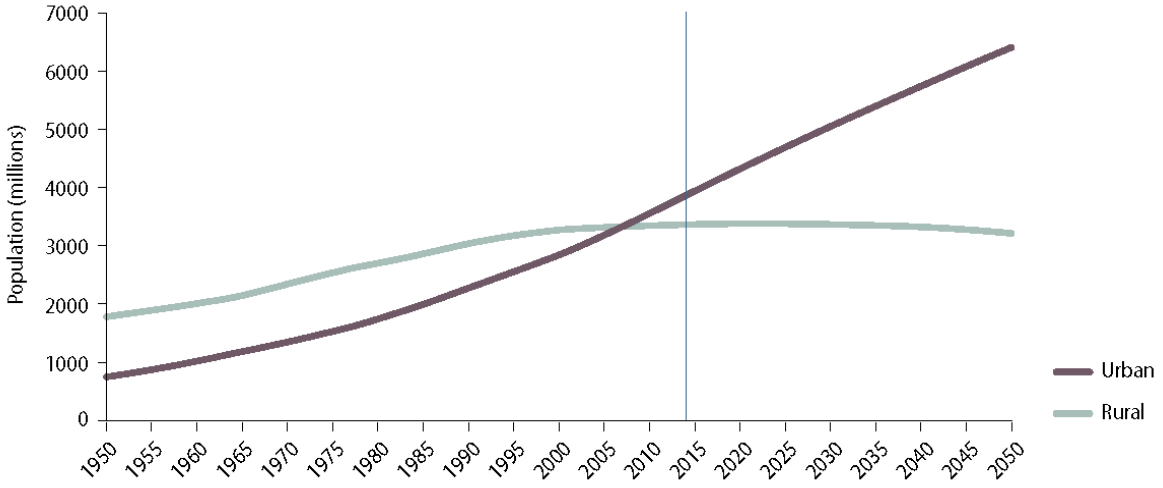

Figure 1: Urban and rural population of the world, 1950-2050.
Source: World Urbanization Prospects, United Nations (2014: 7).

The study of urbanization using an historical perspective is so more complex. Urban and rural areas have to be defined in an appropriate way to capture this phenomenon assuming the limitations of the data. In order to identify which population may be assigned to urban or rural sets, it is important to first define the *city*.

De Vries (1984:11) define cities using four criteria:

- Population size
- Density of settlement
- Share of non-agricultural occupations
- Diversity of non-agricultural occupations

However, by the fact of analysing historical data, he assumes only population size of cities (over 10,000 inhab.) in relation to the entire country as the main indicator to measure urbanisation. The existence of census with reliable information plays a key role. In the European case, for instance, countries start to collect this data by the middle of c.19th. But it is not enough to implement a global diagnostic. Some cities show unknown information in specific periods, and some countries start to compute quite late.

Nowadays, the emergence of new tools and instruments helps to develop other approaches, whether complementary or alternative. The Campop Group[3], headed by Shaw-Taylor, has recently obtained an

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HGIS for England and Wales with information about occupational structure since the c.17th. This database can help to seek other approaches in relation to the definition of cities, and consequently the national urbanization. At the same way, density of cities has started to be recalculate using urban footprints to limit the extension of the urban area.

This second approach is widely interesting for our study, since we are defining a method to reconstruct the second indicator of urbanization mentioned above: the growth of urban areas. It will allow us to contribute to the discipline in two different ways: measuring historical urbanization in terms urban areas and adjusting the definition of historical cities using more accurate estimates of the density of each settlement.

In the following try to synthetize the current project we are working on, data and methodology, some preliminary results and further applications.

Our project

Historical reconstruction of urban areas is a topic widely developed by urban planners at a local scale. Using different kinds of information (historical maps, cadastral information, local knowledge, etc.), several researchers have been creating evolutionary maps in their respective cities. And these databases tend to help explaining local history of the city and their region. However, generalisation of this process has not been performed at a national level and following comparable methodologies.

The project we are presenting here was targeted to create an HGIS with homogeneous information of urbanisation evolution of Spanish cities, initially province capitals. Temporal delimitation went from 1800s and until the present day and our main sources were historical urban maps.

In fact, a similar analysis was implemented on twenty-five Catalan county capitals, in a previous stage of the current project. There, the creation of the HGIS was not the main purpose, but it helped to explain urban changes because of the construction of railways and the further urban evolution (Solanas at al. 2015 and Alvarez et al. 2016). Methodology developed there was a first approach and allowed consequent tests to check our initial intuitions.

Data and methodology

In order to carry on the studio, we required two different sort of information. First, and most important, images of historical maps of each city. Second, the current georeferenced cartography in shapefile, or another compatible GIS format. Both kinds of data, historical maps and current cartography, were added into a GIS, properly vectorised and analysed following the adopted criteria.

At this stage, the project was focused in Spanish province's capitals from 1800s until the current period, setting 25-years intervals.

The methodology we carried out was divided in six steps:

1. Look for historical maps of each city.
   Our purpose was to create a complete database with eight historical maps of each Spanish province's capital, one every 25 years. So, we consulted different map collections, either physically or online. *ICGC cartoteca digital*[4], *Fondos Cartográficos del Instituto Geográfico*

[4] See: http://cartotecadigital.icc.cat/

Nacional of IGN[5] and the Spanish Military Archive are some examples. Urban maps, ortophotos, urban projects or digital cartography sources were accepted.

We also consulted atlas and books, such the *Atlas general de planos de las 49 capitales de España con industrias y comercio* (García 1905), *Ciudades Españolas. Su desarrollo y configuración urbanística* (Jürgens 1926), *Cartografia Històrica dels Països Catalans* (Rosselló 2008) and *Las ciudades españolas en el siglo XIX* (Quirós 2009).

At the moment, considering the 47 province capitals, we completed 20 cities, 21 were almost finished and only 6 needed three or four extra maps to complete the whole series of eight time periods (further information in appendix 1).

2. Get the current georeferenced cartography in a GIS format.
   In the era of knowledge, data is becoming available gradually. In the case of current cartography, almost all European countries provided open-access and free databases.

   In our case, we downloaded shapefiles for all the cities from IGN, specifically the *Base Topográfica Nacional* (BTN25v0). These databases disposed information of several geographical layers at a scale 1:25.000, using ETRS89 Geodesic Reference System and UTM projections.

   For our analysis, we isolated the polygon layer corresponding to urban parcels.

3. Scan and digitize historical maps.
   All the maps obtained from online sources were in digital format, normally raster files (jpg or tiff). Anyway, an important part of our sources were in paper, so we needed to scan them in order to get digital images.

4. Georeference digitised maps helped by the current cartography.
   Both sources digital or physical provided us with raster images, but just a few of them were georeferenced properly. It means they do not had geographical description and were not located properly in a map. That situation difficulted tasks of identification and digitalization of their attributes.

   We georeferenced the historical maps using GIS software. Following Roset & Ramos (2012) methodology, we decided to use a minimum of 20 control points, in order to minimize the spatial error.

5. Give attributes to the polygons of the current cartography depending of the historical evolution of the city.
   Having historical urban maps georeferenced in proper coordinates, we identified those urban parcels in the current cartography that were constructed in each period. As our current cartography was in shapefile format and our elements were polygons, we just added a new field in the attributes table and assigned the year of the map in which those parcels were built by first time.

6. Aggregate and homogenise the information, creating the HGIS.
   Even the previous database allowed us to show the urban fabric evolution for each city, we opted for adding a further step, looking for the homogenization of our output. Further on our

[5] See: http://www.ign.es/fondoscartograficos/

study, we adapted our databases according to Urban Morphological Zones (UMZ) defined by the European Environment Agency.

The community institution defined this system according to Corine Land Cover project, where they have been characterising land uses at European scale in 1996, 2000 and 2006. In fact, one of their layers is coincident with our purposes: European Urban Areas.

Corine Land Cover main characteristics were:

- Reference scale 1:100.000
- Geodesic Reference System ETRS89, projected using UTM.
- Photointerpretation using Lanstat TM (1990), Landstat7 (2000) and SPOT4 (2006).
- Minimal cartographical unit of 25 Ha.
- Hierarchy classification in 3 levels and 44 land uses.
- Minimal distance of 200 meters for aggregating elements.

In our case, two of these criteria are fundamental. The minimal cartographical unit of 25Ha might avoid the creation of some settlements, because some downtowns were not so much bigger at the beginning of the c.19th. And the minimal aggregation distance of 200m. might separate urban fabric of two cities when they are interrupted by a river, or other geographical phenomena.

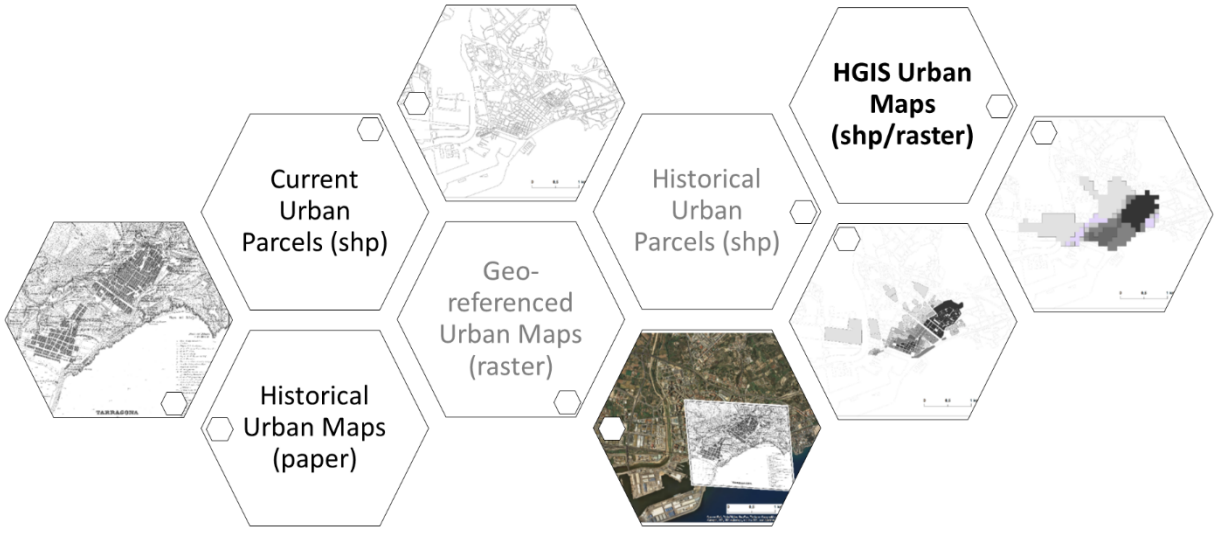

Figure 2: Methodological schema followed to create the urbanisation HGIS.

Preliminary results

As said in the previous section, we finished searching historical urban maps in 20 cities. And, having the maps and the methodology, we started creating our HGIS of Urban Maps.

Hereafter, we show preliminary results for some intermediate Catalan cities: Lleida, Girona and Tarragona. In graphical terms, figure 3 shows urban expansion of all of them according to the defined methodology cited above:

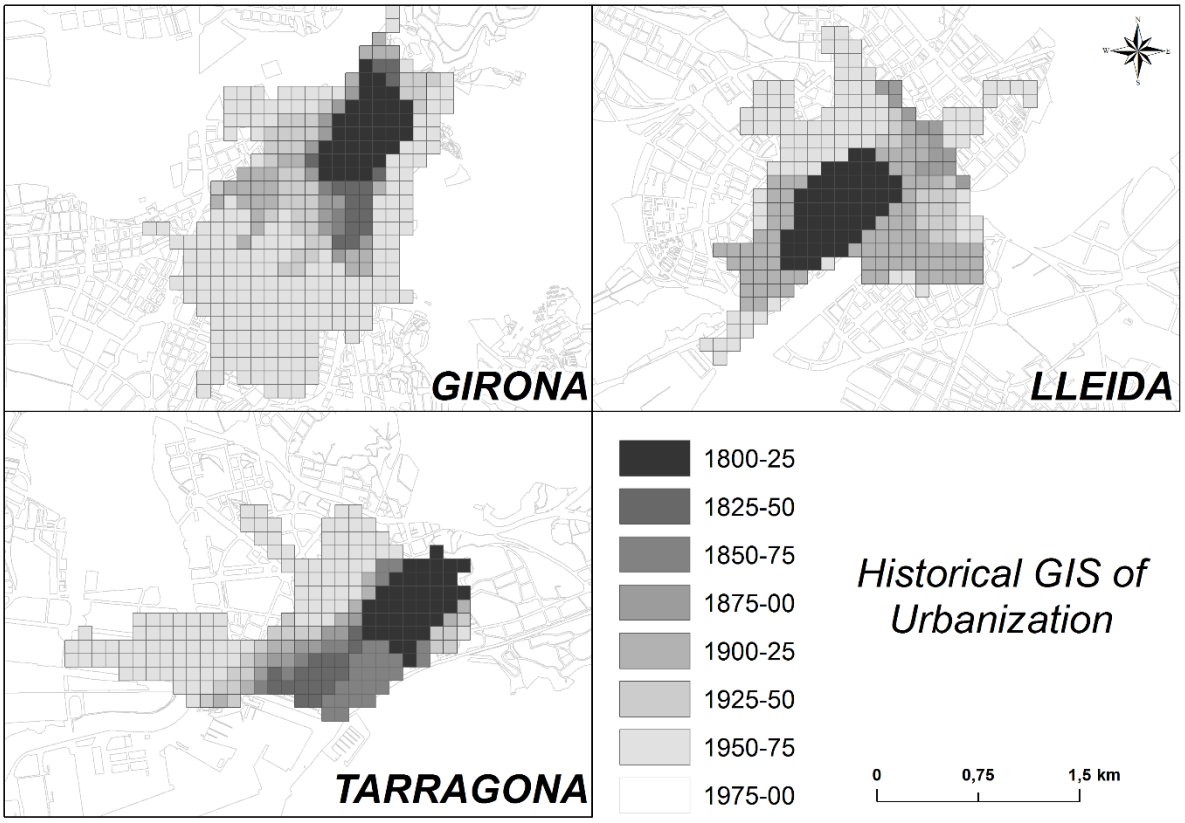

Figure 3: Historical GIS of Urbanization, showing the cases of Girona, Lleida and Tarragona, 1800-2000.

In analytical terms, we synthetized in the following graphs the evolution of population at municipal level in relation to the evolution of Urban Area.

Reading figure 4, we detected some clear tendencies. Cities population is growing constantly in the three capitals. Between 1877 and 1950 the annual rate was more or less constant and low. However, since 1950 we detected a tendency shift, increasing considerably annual rates of growth until 1981. After that, population were stabilised again.

The second graph was more surprising. Although there is a vigorous current debate about the accelerated evolution of urbanization in terms of cities growth, it is obvious that this phenomenon is even more surprising than expected. Since 1950 onwards, cities have been evolving fast and spreading out to new urban paradigms. The universalization of cars and the possibilities of commute between cities daily, helped to extend urban sprawl unconscionably.

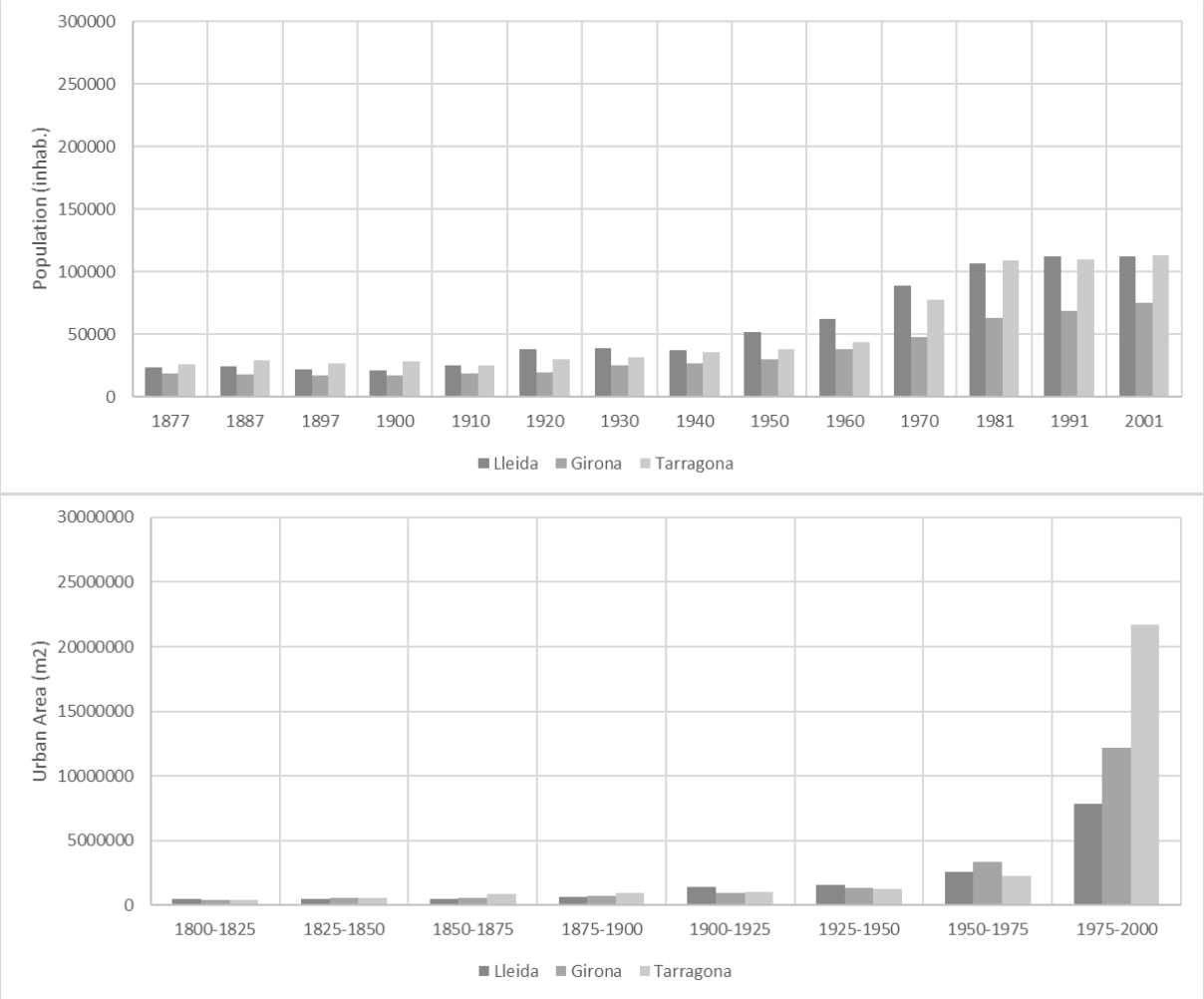

Figure 4: Evolution of Population (1877 – 2001) and Urban Area (1800 – 2000).

Further applications

The process of seeking and digitizing the historical sources is, in itself, enough important in terms of increasing to the availability of new Digital Humanities resources. Furthermore, the creation of the Urbanization-HGIS may contribute decisively to the evolution of the discipline. New Economic-Historians are seeking continuously for new geographical databases in order to improve their econometric models. Urban and Regional Planners are working in evolving models that help them to predict urban expansion (i. e. Cellular automata). Environmentalists are trying to understand the possible effects of urbanization on sustainability, etc.

Other more specific examples are cited below:

- Identify regional differences in terms of cities urbanization.
- Detect the emergence of new urban sectors.
- Correlate urban growth with the presence of production and geographical factors.
- Analyse the endogeneity of some policies in relation to urbanization (new infrastructures, land prices, land uses, etc.).
- Recalculate historical urban densities.
- Adjust calculations of urbanization, and provide complementary estimations.
- Etc.

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Appendix 1: Current list of historical maps

City	1800-1825	1825-1850	1850-1875	1875-1900	1900-1925	1925-1950	1950-1975	1975-2000
Albacete			1861	1876, 1892mtn50	1905, AlbMartin, 1920mtn50	1933	1954mtn50, vuelo56, 1965	1977, UMZ1990
Alicante	1812	1847	1853, 1859	1876	1915, AlbMartin	1937mtn50, 1940mtn50, 1945mtn50	Vuelo56, 1966mtn50	UMZ1990
Almeria	1800	1847	1855, 1858, 1864	1897	AlbMartin	Vuelo45	1951mtn50, Vuelo56, 1969	UMZ1990
Ávila			1864	1886, 1897	AlbMartin	1928, 1932, 193?, 1944mtn50, 1946	Vuelo56, 1960, 1974	UMZ1990
Badajoz	1800, 1811, 1812	1844	1873		AlbMartin	1941mtn50	Vuelo56	UMZ1990
Barcelona	1806, 1818	1840, 1847	1852, 1857, 1861, 1862	1878, 1885, 1888, 1892	1900, 1901, 1910, AlbMartin, 1911, 1913, 1915, 1922	1927mtn50, 1928, 1931, 1949	Vuelo56, 1957, 1958	UMZ1990
Bilbao	1813	1835	1857	1889	AlbMartin	1942mtn50	1952, Vuelo56, 1958mtn50	UMZ1990
Burgos	1812, 1820, 1823		1868	1877	AlbMartin	1939mtn50	Vuelo56	UMZ1990
Cáceres	1822	1845	1853		1900, AlbMartin	1936mtn50	Vuelo56	UMZ1990
Cádiz	1811, 1820	1836	1857, 1868	1880, 1890	1906, AlbMartin, 1917mtn50	Vuelo45	Vuelo56	UMZ1990
Castellón de la Plana			1852	1881	AlbMartin1920-1927	1942mtn50	Vuelo56	UMZ1990
Ciudad Real		1836	1857	1886	AlbMartin	Vuelo45	1954mtn50, Vuelo56	UMZ1990
Córdoba	1811	1840	1851, 1853	1884, 1896mtn50	1906, AlbMartin	1939mtn50	Vuelo56, 1969mtn50	UMZ1990, 1992mtn50
Cuenca	1811		1850	1875	AlbMartin	1942mtn50	Vuelo56	1987mtn50, UMZ1990
Girona	1809	1847	1851	1876	1910, AlbMartin	1930, 1934mtn50	Vuelo56	1986, UMZ1990
Granada	1819	1834, 1845	1857, 1868	1894	1906, AlbMartin	1932mtn50	Vuelo56	UMZ1990
Guadalajara		1849	1860		AlbMartin, 1919mtn50	1937mtn50	Vuelo56, 1972mtn50	UMZ1990

City	1800-1825	1825-1850	1850-1875	1875-1900	1900-1925	1925-1950	1950-1975	1975-2000
Huelva			1869	1885	AlbMartin	1946mtn50	Vuelo56	UMZ1990
Huesca			1861	1884, 1885	AlbMartin	1935mtn50	1952mtn50, Vuelo56	UMZ1990, 1999mtn50
Jaén					1906, 1907mtn50, AlbMartin	Vuelo45	Vuelo56, 1971mtn50	UMZ1990, 1999mtn50
La Coruña	1812	1845	1865	1884, 1886	AlbMartin	1933mtn50	Vuelo56, 1957mtn50	1985mtn50, UMZ1990
León	1825	1850	1862		AlbMartin	1928mtn50	Vuelo56	1987mtn50, UMZ1990
Lleida	1806, 1811	1830	1851, 1869	1880	1908, AlbMartin	1927mtn50	1951mtn50, Vuelo56	UMZ1990
Logroño		1839	1851, 1852		AlbMartin	1939mtn50	1952mtn50, Vuelo56	UMZ1990
Lugo	1812	1830	1864, 1871	1880	AlbMartin	Vuelo45	1950mtn50, Vuelo56, 1974mtn50	UMZ1990
Madrid	1812	1848	1852, 1853, 1857, 1867	1890, 1896	AlbMartin	1937mtn50, 1944mtn50	Vuelo56, 1962mtn50	UMZ1990
Málaga	1811	1838	1863, 1874	1883, 1887	AlbMartin, 1913	1928	Vuelo56	1983mtn50, UMZ1990
Murcia	1809, 1810, 1812				AlbMartin	1932mtn50	1955, Vuelo56, 1962	1987mtn50, UMZ1990
Orense			1856		AlbMartin	1946mtn50	Vuelo56	UMZ1990
Oviedo			1853, 1857	1885	AlbMartin	1941mtn50	Vuelo56	UMZ1990
Palencia			1852	1875, 1886	AlbMartin, 1918mtn50	Vuelo56	1955mtn50, Vuelo56	UMZ1990, 1992mtn50
Pamplona	1813		1861	1882	1900, AlbMartin	1931mtn50	1954mtn50, Vuelo56	UMZ1990
Pontevedra			1856		AlbMartin	1944mtn50	Vuelo56	1988mtn50, UMZ1990
Salamanca	1812	184-	1858, 1867		AlbMartin	1930, 1934mtn50	Vuelo56	UMZ1990
San Sebastián	1813	1848	1850, 1852, 1867	1881, 1897	AlbMartin, 1924	1942mtn50	Vuelo56, 1960	UMZ1990
Santander		1848	1861, 1865	1883	AlbMartin	1942mtn50	Vuelo56	UMZ1990
Segovia		1849			AlbMartin	1927mtn50, 1932	Vuelo56, 1971mtn50	1987mtn50, UMZ1990

City	1800-1825	1825-1850	1850-1875	1875-1900	1900-1925	1925-1950	1950-1975	1975-2000
Sevilla		1848	1868	1884, 1890	1900, AlbMartin, 1918mtn50	Vuelo45	Vuelo56	1988mtn50, UMZ1990
Soria			1860		AlbMartin	1931mtn50	1955mtn50, Vuelo56	UMZ1990, 1991mtn50, 1999mtn50
Tarragona	1806, 1811	1827	1858	1880, 1882	1900, AlbMartin	1925mtn50, 1936, 1937mtn50, 1949mtn50	Vuelo56, 1958, 1968mtn50	UMZ1990
Teruel			1869	1881	AlbMartin	Vuelo45	Vuelo56	UMZ1990
Toledo	1809	1847	1858	1879, 1880, 1882, 1882mtn50, 1885, 1890, 1892	1908, 1910, AlbMartin, 1917, 1924	1926, 1928, 1934mtn50, 1935, 1944mtn50	1950, Vuelo56, 1964, 1974, 1974mtn50	UMZ1990
Valencia	1812	1831	1852, 1857	1882	AlbMartin	1944mtn50	Vuelo56	UMZ1990
Valladolid	1820	1846	1852, 1847-67	1881	AlbMartin	1932mtn50	Vuelo56	1987mtn50, UMZ1990
Vitoria	1825	1848	1864	1886, 1888	AlbMartin, 1909	1929mtn50	1954mtn50, Vuelo56	UMZ1990
Zamora	18--	1847	1863		AlbMartin, 1910	1939mtn50	Vuelo56	UMZ1990
Zaragoza	1808, 1809, 1820	1830, 1842	1852,1853, 1872	1880, 1892	1908, AlbMartin	1926mtn50, 1943	1952, Vuelo56, 1960	UMZ1990, 1993