Regional Positioning Services as economic and construction activity indicators: the case study of Andalusian Positioning Network (Southern Spain)

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Abstract

The Andalusian Positioning Network (RAP) is a regional GNSS permanent network in southern Spain that offers two public services for precise positioning: real-time (RAP-IP) and post processing (RAP-FTP). The most of registered users are linked to the construction sector, so the collapse of the housing bubble and the Spanish economic crisis influenced the use of RAP services from 2008. The behavior of these services has differed somewhat, although analysis for the years 2008 to 2013 reveals a general decline. Since 2009 the RAP-FTP service demand fell by 50%, but the RAP-IP service was stable until October 2011, when it began a steep decline in December 2012. Analyzing the temporal demand and the geospatial connections of RAP-IP with economic impact indicators, we found a high linear correlation between this service and jobs in the construction sector (0.98) and permit building (0.96). The real time and associated geoinformation are its main advantages.

Keywords: GPS, Network RTK, active permanent network, Spanish construction crisis, permit building.

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1 Introduction

The regional networks of Global Navigation Satellite System (GNSS) permanent stations or active geodetic networks have significantly increased their presence since the early 2000s. In Spain, they began in the mid-1990s as permanent Global Positioning System (GPS) stations in government agencies and universities (Torrecillas and Martinez-Garcia, 1999; Berne and Prieto, 2004). The free availability via the internet of data collected to improve the accuracy of relative positioning techniques, differential GPS or Network RTK and telecommunication infrastructure development for internet access (extension of mobile coverage to rural areas, arrival of 3G / 4G and cheaper services) have contributed to their spread throughout Spanish territory and the creation of GNSS networks. The Spanish National Geographic Institute (IGN) and regional agencies were the first to establish the networks that, joined to some private initiatives, resulted in the 23 active networks available in Spain today (Gárate et al, 2013; Giménez et al.,2011) ,see Figure 1. Nowadays, these networks are the main geodetic infrastructure supporting construction works in Spain. The Andalusian Positioning Network (RAP, Spanish acronym), shown in green triangles in Figure 1, is one of these networks and its services cover the autonomous community of Andalusia (Southern Spain), providing 22 stations for an area of 87268 km^2.

Figure 1: Distribution GNSS networks in Spain (green triangles: RAP stations; gray squares: IGN; colored dots: RTK stations of other regional GNSS networks).

After a brief review of the decrease in RAP use in the last few years, we wanted to determine the effect of the Spanish construction crisis on these services. No studies linking the use of these networks with the economy of a country or a specific sector such as the construction are available. This could be because such data are not usually recorded, the volume of generated information is too large, and these services have never been considered significant in economic terms. In the case of the RAP, its daily function and quality control are managed by a scientific institution, and it was considered useful to collect certain temporary variables for further analysis.

McGowan and Irvin (1995) studied the economic growth of arrival of GNSS in companies engaged in transport, but no studies on the end use or user location of these networks were found. Most researches on these networks deal with the quality of the data or improving the observables received by the stations (Bruyninx, 2007; Edward et al, 2010; Janssen et al, 2011; Garrido et al, 2013; Coulot et al, 2014).

Studies related to the geography of the crisis of an economic sector are more extensive. Examples of these are the study on changes in the routes of aircraft by Dobruszkes and Van Hamme (2011), the restructuration of automotive industry in Central Europe (Pavlinek, 2015) and Martin's study on the local geographies of the housing bubble (2011).

Construction is an important sector in these network, and the RAP network was affected by the economic crisis and the housing bubble. *The Economist* (2007) placed Spain in third position in terms of the percentage change in average house prices until 2007. In this paper, we analyze the services of the RAP network to determine their degree of relationship to the productive sectors, particularly construction. Additionally, we check if any of the studied variables can be used as an instant economic value of the activity / economy of the construction sector.

2 The Spanish Economic Crisis and the Construction Sector

In the summer of 2007 a Spanish crisis framed within the global economic crisis began (Martin, 2011), accompanied by other problems like the end of the so-called housing bubble, the banking crisis and rising unemployment (Suarez, 2010; Carballo-Cruz, 2011; Ortega and Peñalosa, 2012). This crisis has greatly affected the construction sector whose Gross Domestic Product (GDP) at market price, resulting of the sum of the gross values added of all resident producers at market prices, plus taxes less subsidies on imports, has been reduced by almost half in the last six years (see Figure 2, top). Jobs have suffered most, maintaining annual negative values that are below those of all other productive sectors (see Figure 2, bottom).

Figure 2: Spanish construction crisis. Top, gross quarterly data of GDP at market price in billions of euros (blue line) and Spanish construction sector (red line); bottom, gross quarterly data of annual variation of employees in all sectors (blue line) and in the construction sector (red line) (Spanish Statistical Office, available from http://www.ine.es)

The decline in GDP and employment in the construction sector was also associated with lower housing construction in Spain, after the housing bubble peaked, as building permits fell from 187147 in 2007 to 28956 in 2012, a rate of almost 85% (Spanish Statistical Office, available from http://www.ine.es). Government institutions have decreased their investment in infrastructure dramatically since 2011: the total was then 39.63% and fell to 23.12%, 13.5 % and 8.6% for the remaining years until 2014.

In Andalusia, Southern Spain, the regional economic situation is no different.

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Building permits were reduced from 37693 in 2007 to just 7247 in 2012, an 81% decrease (Institute of Statistics and Cartography of Andalusia, available from http:// www.juntadeandalucia.es/institutodeestadisticaycartografia). Regional investment in basic infrastructure and transport began to drop before the state budget, beginning its decline in 2009; the value for 2014 was 40.03% lower than that for 2009 (Official Bulletin of the Andalusian Regional Government, available from http://www.juntadeandalucia.es/boja).

The available data used to assess the status of the construction sector and housing are provided by the Spanish Statistical Office, and consist of specific parameters such as the housing price index, mortgages, foreclosure statistics, population census and housing statistics, price of materials and national labor rates. They include parameters collected by other agencies as well, such as number of companies, employment, hours worked and main macro variables by company size, municipal licenses by type of work, official tendering, contracting agents, lead time, budget and purpose of works, number of buildings, types of promoters, main destinations, buildable and average areas, final certificates for buildings and type of promoter. These variables are usually published quarterly (QI, QII, QIII and QIV), except for building permits that are monthly.

3　The Andalusian Positioning Network and GPS Data Services

In 2004, the design of a GPS permanent station network in Andalusia, called the Andalusian Positioning Network (Spanish acronym: RAP), was initiated. This network, framed within a project on geodetic surveys by the Institute of Statistics and Cartography of Andalusia (Sanchez-Diaz and Torrecillas, 2004), is the main active geodetic infrastructure of Southern Spain. The high number of users in these years of

operation and their importance have been demonstrated in the *Cartographic Dispositions of Andalusia 2009-12* (Junta de Andalucía, 2008) and the *Statistical and Cartographic Dispositions of Andalusia 2013-17* (Junta de Andalucía, 2013). Its installation coincided with the change of geodetic reference system in Europe, from European Datum 1950 to European Terrestrial Reference System 1989, and gave mapping producers a vital role.

In September 2006, RAP became operative, with 22 stations distributed homogeneously in Andalusia (Hermosilla et al, 2007; Redondo et al, 2007) (see Figure 1). The stations are permanently connected to the RAP Control Center located in the Laboratory of Astronomy, Geodesy and Cartography, LAGC, of the University of Cadiz (Geodetic Control of the Andalusian Positioning Network, available from http://rap.uca.es/). Daily analyses of data integrity and quality control are performed in this laboratory.

The RAP network offers two free public services (Berrocoso et al, 2006; Mesas et al, 2007) accessible to users after registration (Andalusian Positioning, http://www.idea.es/portal/web/portal-posicionamiento). The first is a file download service, RAP-FTP, with GPS observation data in RINEX format, a post-processing standard file. This service is used for precise positioning, flight photogrammetric or LIDAR support, georeferencing of satellite images or geodynamic studies, among others. The second service, RAP-IP, is an Internet streaming service of differential corrections for real-time positioning from single-base (RTK) and network (NRTK) solutions. The RAP-IP user needs an internet data connection to access the NTRIP server of the RAP network and send an approximated position to obtain the best correction. The RAP-IP service is useful for field data collection, supporting cadastral updates and determination of municipal boundaries, maritime, land or air precision

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navigation, agricultural management, and GIS applications (Kumar and Moore, 2002; Kaplan, 2005;Gleason 2009).

4   Data and Methodology

Since August 2008, the RAP Control Center has been logging data about the use of services. The total number of monthly RINEX files downloaded and the user type were recorded for the RAP-FTP service (until August 2013); user type, company, connection time, correction type, and user's geographic position (latitude and longitude). In the case of users connected to the nearest station (RTK) or network-based (NRTK) solutions, corrections are stored by the RAP-IP service and termed RAP variables in this study (see Table 1). The RAP time series were obtained by MATLAB© applications which extracted information from ASCII files in XML format, generated by Leica© GNSS Spider© software.

We compiled external economic data and parameters, called CRISIS variables, reflecting housing construction (number of building permits) or infrastructure construction (infrastructure investment), state and regional GDP, Spanish and Andalusian people employed in the construction sector and in all sectors (see Table 1). Time series of the CRISIS data were obtained from the Spanish Statistical Office (available from http://datosmacro.com and http://elmundo.es).

We treated the time series for trend parameters, outliers, seasonality, annual percentage changes and correlations among them according to Pearson's linear correlation coefficient (r):

$$r = \frac{S_{xy}}{S_x S_y} = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{1}$$

where *x* and *y* are studied variables and $\bar{x}$ and $\bar{y}$ their mean values. Also, some

quarterly data series were recalculated for annual data series to compare with other variables that were only available for annual values, such as Spain's GDP.

Table 1. List of CRISIS variables and RAP variables

Finally, the Office of Public Works and Housing of the Andalusia Regional Government provided information for geographical studies on urban areas (Spatial Data Reference of Andalucia, available from http://www.juntadeandalucia.es/institutodeestadisticaycartografia/DERA/) and civil works executed in the last six years. Its treatment required spatial analysis functions offered by geographic information systems, such as establishment of areas of influence, spatial intersections between geographic layers, and statistical analyses.

After preparation of the data, the methodology was divided into two blocks: use of RAP services, and geographical positioning or geolocation of requests. The first, centered on a time study, described the behavior of the service during this crisis and its relationship with the economy. The second analysis tried to locate the RAP connections related to the construction sector. For this purpose, we defined areas susceptible to urban construction and areas susceptible to infrastructure construction and obtained geolocated time series. Afterwards, we studied correlations with the CRISIS variables.

5   RAP Temporal Analysis 2008-13

The research was focused on the demand for RAP services and user type, particularly the analysis of the temporal evolution during this period in relation to:

- demand for RAP- FTP services

- demand for RAP- IP services

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- RAP user type

To study the evolution of <u>RAP-FTP</u> service demand we analyzed the monthly time series of a number of downloaded RINEX files (see Figure 3) until September 2013, when another way to download files was put into operation that made it impossible to register this information. The number of RINEX file downloads from 2008- to 2013 decreased by almost 50% according to the trend line. This RAP variable remarked no changes in the beginning of its operating that is a number of download files stable, probably because it regularly accessed files for years. The time series have some peaks, which are explained by the massive downloading of files by universities and other organizations for specialized courses, investigations or studies of tectonic movements, modeling of local geoids or troposphere and ionosphere studies.

The 2014 data from January to May, not represented in Figure 3, reveal an upward trend of discharges, providing values for 414, 402, 680, 839 and 953 downloads; some 78.1 % of them are hourly RINEX files. These files are widely used in survey stations or ground control points in constructive works.

Figure 3: Monthly time series of "No. downloads RINEX (RAP -FTP)" (blue line) and trend line (red dashed line)

To study the evolution of <u>RAP-IP</u> use, we analyzed "New users RAP-IP", "User RAP-IP", "Hours connec. RAP-IP", "Connec. RAP-IP" and "Geolocated connec. RAP-IP" time series. In Figure 4 we observe that "Hours connec. RAP-IP" and "User RAP-IP" time series have a seasonal structure. Their study confirms a high seasonal

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component from April to September (see Table 2). Less use occurs in December and January, when the network usage decreases, probably because of several factors including the weather, fewer daylight hours and holidays. Since the data of CRISIS variables were not filtered, correlation with these seasonally adjusted series was not performed.

Figure 4: Monthly time series of "User RAP-IP" (Top) and "Hours connec. RAP-IP" (Bottom)

Table 2. Seasonal factor "User RAP-IP" and "Hours connec. RAP-IP" variables

Figure 5: Seasonally adjusted time series and trend cycle line (gray dashed line) of RAP service: top "User RAP-IP" (Top) and bottom "Hours connec. RAP-IP" (Bottom)

The analysis of each series demonstrated that "User RAP-IP" and "Hours connec. RAP-IP" grew rapidly until mid-2009 (see Figure 5) because of the beginning of the broadcast service. In this period, the RAP was considered a stable service in Andalusia. The number of users connecting to the service was maintained until September 2011, when it began to decrease. This trend continued until the end of 2012 when an increase in demand occurred. In contrast, "Hours connec. RAP-IP" grew from the start of service until July 2010, with a slight drop in the winter for the seasonal factor. It was stable at around 4000 hours per month until October 2011, down by about

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85%. Then it saw a steep decline to 650 hours in December 2012, confirmed by the annual variation rate (see Figure 6). Subsequently, the connection hours increased again.

Figure 6: Annual variation (%) of "User RAP-IP" (blue line) and "Hours connec. RAP-IP" (red line) from zero as reference

The last temporal study of the RAP on types of network users was made possible by the information requested in the user registration service. We established five user categories: "Large enterprises," "SMEs" (small and medium enterprises), "Self-employed or individuals," "Government" and "Universities." "User RAP-IP" and "Hours connec. RAP-IP" time series by user type are shown in Figure 7. Figure 7c1 shows an increase in use by the "Self-employed or individuals", although Figure 7a1 and 7b1 shows that the number of users of large companies and SME remained relatively stable. Again, there were some peaks in the number of total hours of connection, according to Figure 5 bottom, indicating that SMEs caused these increases in the hours of RAP use. This can be explained by the outsourcing of services by large companies to reduce their employees and new job initiatives by SMEs and self-employed in this period of crisis. Data for government and universities (see Figure 7d and 7e) provided no decisive information and suggested that the economic crisis did not persuade them to continue using these services.

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Figure 7: Monthly time series of "User RAP-IP" (1, left) and "Hours connec. RAP-IP" (2, right) by user type: a) Large enterprises, b) SMEs, c) Self-employed or individuals, d) Government and e) Universities

Finally, analysis of the correlation between CRISIS and RAP variables (Table 3) showed statistically significant correlations between "Geolocated connec. RAP-IP" (55% of the total RAP-IP connections) and every employment variable at national and regional level: "Spain Jobs" (0.78), "Andalusia Jobs" (0.78), "Spain Construction Jobs" (0.80) and "Andalusia Construction Jobs" (0.80). With "Connec. RAP-IP" the correlations were very similar.

"New users RAP-IP" also had a correlation with all job variables of around 0.66 to 0.70. Conversely, the connection time ("Hours connec. RAP-IP") did not indicate significant correlations with any CRISIS variable. The negative correlation between "User RAP-IP" and other CRISIS variables was because these variables declined in the last few years but the trend of "User RAP-IP" grew, as this technology continues to spread.

Table 3. Correlation coefficients between RAP variables and CRISIS variables in quarterly analysis 2008QIV-2013QIV

The "No. downloads RINEX (RAP -FTP)" with CRISIS variables determined a higher correlation with Jobs than with GDP. The highest values obtained were for "Spain Jobs" (0.61) and "Andalusia Construction Jobs" (0.58).

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6   Geolocated Analysis of RAP 2008 to 2013

The high correlation found between RAP-IP service and the construction sector led to a

thorough study of the same based on the area (coastal, urban or non-urban areas) where

the user was located.

Figure 8: Andalusian transport network and annual spatial distribution of

"Geolocated connec. RAP-IP": a)   2009, b) 2010, c) 2011, d) 2012 and e) 2013. In pink

colour High-speed Train lines, in blue colour Motorway and in green Highways.

Figure 8 shows the location of connections to the RAP-IP service from 2009 to

December 2013. Analysis of the maps showed the rise of service use in urban and

coastal areas, which was related to the construction boom/housing bubble in Spain until

2011. We saw that there was a decreased use after 2011 in towns like Sevilla, Cádiz,

Jaén and Granada (Figure 8c). In addition, analysis showed part of the new Andalusian

linear infrastructure, defined as motorways, highways and high-speed train lines. The

neural distribution between these works and urban centers was evident. High-speed

train lines (AVE) stand out: Sevilla-Cádiz (Figure 8, 2a), Almería-Murcia (2b),

Antequera-Granada (2c), and Córdoba-Málaga (2d). Motorway works are also visible:

A-334 highway (1b), A-316 (1a), A7 motorway (3a), and AP-36 (3b).

Figure 9 (top) shows the connections from 2008 to 2013 including locations

outside Andalusia. We saw some unexpected applications of the RAP network in its

initial configuration: on the one hand, in areas of Portugal and neighboring regions

more than 70 km away from RAP stations (see continuation A66 motorway outside

Andalusia, in Figure 8, 3c) and where the use of real-time positioning services is not

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recommended because accuracy is expected to be poor; on the other hand, in areas near the coastline for access to networks of mobile phones, although there were more distant connections, possibly with satellite access.

Figure 9: Accumulative period 2008 to 2013 of "Geolocated connec. RAP-IP": top, specific locations of connections; bottom, grouping by municipality

Figure 9 (bottom) shows the number of connections from each municipality of Andalusia. It can be seen that the largest number of connections (25000 to 50000 accumulated connections) are from the capitals (marked by a white circle), because the fast growth of these cities required more constructive actions or cartographical updates, i.e. cadastral. The municipalities near to large lineal infrastructures also had high values whereas rural areas registered fewer than 360 connections. Also, we noted that the number of connections in the port and coastal areas of Andalusia increased as a consequence of the construction boom caused by foreign purchase and construction of tourism facilities such as hotels.

After this analysis, we decided to conduct a study on two geographic zones: areas susceptible to urban construction and areas susceptible to public works. The selection of geographical boundaries of these areas tried to group areas with existing buildings, where construction activity constituted, for example, rehabilitation of buildings or modification of roads, and areas where new buildings and infrastructure were constructed.

6.1 Areas Susceptible to Urban Construction

For the location of urban RAP users, an area of 1 km in all Andalusian towns was established. Then, the number of connections within these areas was counted. Subsequently, we divided these connections per year to generate a time series. Figure 10 shows the annual series of the number of urban and non-urban RAP-IP connections. The 2008 data only included connections from August, accounting for the lower value. This figure reveals that urban connections were responsible for the sharp decline in RAP use from 2009. The time series evolution of urban connections was very similar to the number of total connections; in fact, these connections represent 70% of the annual average. In contrast, annual connections from non-urban areas remained stable at around 20000, but contributed a 78% rise in use since early 2012. To determine the origin of this increased use, we obtained the number of connections in non-urban or non-civil works geolocated on rural land and probably related to agriculture, calling them "Other connections RAP-IP" (see Figure 10). Since 2012 33% of this increased use has been located in these rural areas, probably caused by the diffusion of precise GNSS in agriculture or mining.

The study of correlations between CRISIS and RAP variables in this section was performed with annual data (see Table 4) because we only had annual values for some CRISIS variables. High correlations were found between RAP variables "Connec. RAP-IP," "Geolocated connec. RAP-IP," "Urban connec. RAP-IP" and "Non-public work connec. RAP-IP" with job variables like "Spain Jobs" (0.94 to 0.95) and "Andalusia Jobs" (0.95 to 0.96), but above all with the construction sector: "Spain Construction Jobs" (0.98), "Andalusia Construction Jobs" (0.98), and "Spain Construction GDP" (0.97 to 0.98). Additionally, these four variables had a high correlation with "Andalusia Building Permits" (0.95 to 0.96) and "Andalusia Basic Infrastructure and Transport

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Budget" (0.97 to 0.98). Correlations were lower for "Non-urban connec. RAP-IP" and "Public work connec. RAP-IP" variables.

Figure 10: Annual time series: "Geolocated connec. RAP-IP" (black), "Urban connec. RAP-IP" (green), "Nº Non-urban connec. RAP-IP" (red), "Other connections RAP-IP" (orange) and "Public work connec. RAP-IP" (blue)

Table 4. Correlation coefficients between RAP variables and CRISIS variables in annual analysis 2009 to 2013

6.2   Areas Susceptible to Civil Construction

The RAP-IP service is also used in infrastructure construction. We determined an area of 20 meters from the central axis of each executed lineal infrastructure (roads, highways and other communication infrastructures) provided by the Office of Public Works and Housing of Andalusia between 2008 and 2014. To these, we added the main hydraulic lines and oil and gas pipelines. We quantified the numbers of connections within these areas, referred to as "Public work connec. RAP-IP," which accounted for 13% of annual connections. The time series evidenced that these were not responsible for the drop in the number of connections of RAP between 2009 and 2010, but contributed a 45% rise in 2013 (see Figure 10). Regarding the relation of the number of "Public work connec. RAP-IP" to the crisis and in view of the data in Table 4, a strong correlation was observed with "Spain Infrastructure Budget" (0.94), "Andalusia Building Permits" (0.96), and "Andalusia Construction Jobs" (0.94).

7   Conclusions and Discussion

The analysis of the use of RAP revealed a general decline in since 2010. Specifically, the RINEX file download from the RAP-FTP service showed a negative trend around 50% from 2008 until October 2013; RAP-IP service, disregarding the period of service expansion until July 2010, showed a decline in use close to 85% until December 2012. This decrease is directly related to the construction crisis in Spain because 86% of users belong to this sector.

As regards the variables derived from the RAP and correlated with selected economic variables, including jobs or GDP, the results indicated high linear correlation between the RAP-IP service and jobs in all sectors and jobs in construction. However, correlations were less statistically significant with RAP variables such as "No. downloads RINEX (RAP -FTP)" and "Hours connec. RAP-IP," indicating no connection with constructive activity or the economic state of the sector. The same can be said for "New users RAP-IP", if the hours of service connection reveal no overall activity, even less the user registry where users do not have an "unsubscribe" option.

The detailed study of the RAP-IP service produced a map of the construction activity in Andalusia, marking the great use of the service in urban land. The high correlation between the number of connections in this type of soil and building permits in Andalusia (0.96) and other construction-related variables (construction jobs 0.98, construction GDP 0.98) confirms it.

The advantage of real-time availability and geolocation of the activity and use of the services allow geographical discrimination of the variable "Geolocated connec. RAP-IP", which is a good variable to consider when one is establishing constructive/economic activity in the construction sector compared with others currently used, such as building permits or employment. In coordination with other GNSS

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networks administrators can easily summarize this connection information at a national level. This variable collected in real time opens up a range of possibilities for its use in urban planning control, traffic control, or urban growth control.

The results were not so satisfactory for public works' construction areas, although a high correlation with CRISIS variables was found. There was a correlation of only 0.94 between "Public work connec. RAP-IP" and "Spain Infrastructure Budget" and jobs.

This study has also shown an increase of RAP-IP service from late 2012. The 78% rise was because of the increase in agricultural land and construction of major infrastructure projects. Part of the rise was owed to SMEs (see Figure 7b), which could be explained by the outsourcing of services by large companies to reduce their labor force in response to the economic crisis. Also, it was determined that the corresponding Administrations and Universities users provided no decisive information and it can be assumed that the crisis in the construction sector did not affect them.

Other findings were the seasonal pattern of hours of service connection to RAP-IP between the months of March and September, the result of more hours of sunshine and better weather for working outside, and the unexpected applications of RAP-IP outside Andalusia and on the coastline, often more than 70 km away, where accurate positioning is not possible. Finally, given the low demand for RAP-FTP service compared with RAP-IP, these networks should aim at improving their precise positioning in real time.

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TABLES

Table 1. List of CRISIS variables and RAP variables

	Variable Name	Units	Annual data 2009-2013	Quarterly data 2008TIV-2013TIV	Description/Source
CRISIS Variable	**Spain GDP**	Millions euros	x	x	Gross Domestic Product at market prices of Spain. Offer. Source INE / Datosmacro.com
	Andalusia GDP	Millions euros	x		Gross Domestic Product at market prices of Andalusia. Source Datosmacro.com
	Spain Construction GDP	Millions euros	x	x	Gross domestic product at market prices. Offer. Construction Sector. Source INE
	Spain Infrastructure Budget	Millions euros	x		Spanish General State Budget dedicated to infrastructure. Source Elmundo.es
	Andalusia Basic Infrastructure and Transport Budget	Millions euros	x		General Budget of the Andalusian Regional Government for Basic Infrastructure and Transport. Source BOJA
	Andalusia Housing and Urban Development Budget	Millions euros	x		General Budget of the Andalusian Regional Government for Housing and Urban Development. Source BOJA
	Spain Jobs	Thousands	x	x	Jobs in Spain. Source INE
	Andalusia Jobs	Thousands	x	x	Jobs in Andalusia. Source IECA
	Spain Construction Jobs	Thousands	x	x	Jobs in the construction sector in Spain. Source INE
	Andalusia Construction Jobs	Thousands	x	x	Jobs in the construction sector in Andalusia. Source IECA
	Spain Building permits	Unit	x		Building permits of housing in Spain. Source Ministry of Development
	Andalusia Building permits	Unit	x		Building permits of housing in Andalusia. Source Ministry of Development
RAP Variable	**No. downloads RINEX (RAP - FTP)**	Unit	x	x	Number of RINEX file downloads of RAP-FTP service. Source LAGC
	New users RAP-IP	Unit	x	x	Number of new registered users in RAP-IP service. Source LAGC
	User RAP-IP	Unit	x	x	Number of connected users to RAP-IP service. Source LAGC
	Hours connec. RAP-IP	Unit	x	x	Number of hours of connections of RAP-IP service. Source LAGC
	Connec. RAP-IP	Unit	x	x	Number of connections of RAP-IP service. Source LAGC
	Geolocated connec. RAP-IP	Unit	x	x	Number of connections of RAP-IP service with geolocation. Source LAGC
	Urban connec. RAP-IP	Unit	x		Number of connections in urban areas in RAP-IP service. Source LAGC
	Non-urban connec. RAP-IP	Unit	x		Number of connections in non-urban areas of RAP- IP service. Source LAGC
	Public work connec. RAP-IP	Unit	x		Number of connections in public works areas of RAP-IP service. Source LAGC
	Non- public work connec. RAP-IP	Unit	x		Number of connections in non- public works areas of RAP-IP service. Source LAGC
	Other connections RAP-IP	Unit	x		Number of connections in non- public works and non-urban areas of RAP-IP service. Source LAGC

Table 2. Seasonal factor "User RAP-IP" and "Hours connec. RAP-IP" variables

Month	User RAP-IP Seasonal factor (%)	Hours connec. RAP-IP Seasonal factor (%)
January	93.3	67.8
February	101.7	77.2
March	105.0	100.5
April	109.2	120.4
May	108.8	129.8
June	106.3	117.6
July	99.4	100.4
August	86.4	108.8
September	101.2	111.6
October	102.7	98.9
November	100.1	99.0
December	86.0	68.1

Table 3. Correlation coefficients between RAP variables and CRISIS variables in quarterly analysis 2008QIV-2013QIV

	Spain GDP	Spain Construction GDP	Spain Jobs	Andalusia Jobs	Spain Construction Jobs	Andalusia Construction Jobs
No. downloads RINEX (RAP -FTP)	.46[*]	.44[*]	.61[**]	.57[**]	.54[**]	.58[**]
New users RAP-IP	.38[*]	.63[**]	.66[**]	.70[**]	.69[**]	.70[**]
User RAP-IP	-.15	-.62[**]	-.48[*]	-.44[*]	-.57[**]	-.53[**]
Hours connec. RAP-IP	.04	.27	.38[*]	.39[*]	.35	.36
Connec. RAP-IP	.19	**.75[**]**	**.77[**]**	**.77[**]**	**.78[**]**	**.79[**]**
Geolocated connec. RAP-IP	.15	.73[**]	**.78[**]**	**.78[**]**	**.80[**]**	**.80[**]**

$*p < .05$, $**p < .01$ (1-tailed)

Note: The correlations above .75 are bolded.

Table 4: Correlation coefficients between RAP variables and CRISIS variables in annual analysis 2009-2013

	Spain GDP	Spain Construction GDP	Andalusia GDP	Spain Infrastructure Budget	Andalusia Basic Infrastructure and Transport Budget	Andalusia Housing and Urban Development Budget
Connec. RAP-IP	.85*	**.98****	.94**	.89*	**.97****	.90*
Geolocated connec. RAP-IP	.85*	**.97****	.94**	.90*	**.97****	.91*
Urban connec. RAP-IP	.82*	**.98****	.91*	.89*	**.98****	.93*
Non- urban connec. RAP-IP	.90*	.80	.93*	.85*	.83*	.73
Public work connec. RAP-IP	.89*	.85*	.92*	.94**	.90*	.84*
Non- public work connec. RAP-IP	.83*	**.98****	.93*	.88*	**.97****	.91*

	Spain Building permits	Andalusia Building permits	Spain Jobs	Andalusia Jobs	Spain Construction Jobs	Andalusia Construction Jobs
Connec. RAP-IP	.93*	**.96****	**.95****	**.96****	**.98****	**.98****
Geolocated connec. RAP-IP	.92*	**.96****	**.95****	**.95****	**.98****	**.98****
Urban connec. RAP-IP	.92*	**.95****	.94**	**.95****	**.98****	**.98****
Non-urban connec. RAP-IP	.85*	.92*	.88*	.90*	.87*	.90*
Public work connec. RAP-IP	.88*	**.96****	.92*	.93*	.93*	.94**
Non- public work connec. RAP-IP	.92*	**.95****	.94**	**.95****	**.98****	**.98****

*$p < .05$, **$p < .01$ (1-tailed)

Note: The correlations above .95 are bolded.

FIGURE CAPTIONS

Figure 1: Distribution GNSS networks in Spain (green triangles: RAP stations; gray squares: IGN; colored dots: RTK stations of other regional GNSS networks)

Figure 2: Spanish construction crisis. Top, gross quarterly data of GDP at market price in billions of euros (blue line) and Spanish construction sector (red line); bottom, gross quarterly data of annual variation of employees in all sectors (blue line) and in the construction sector (red line) (Spanish Statistical Office, available from http://www.ine.es)

Figure 3: Monthly time series of "No. downloads RINEX (RAP -FTP)" (blue line) and trend line (red dashed line)

Figure 4: Monthly time series of "User RAP-IP" (Top) and "Hours connec. RAP-IP" (Bottom)

Figure 5: Seasonally adjusted time series and trend cycle line (gray dashed line) of RAP service: top "User RAP-IP" (Top) and bottom "Hours connec. RAP-IP" (Bottom)

Figure 6: Annual variation (%) of "User RAP-IP" (blue line) and "Hours connec. RAP-IP" (red line) from zero as reference

Figure 7: Monthly time series of "User RAP-IP" (1, left) and "Hours connec. RAP-IP" (2, right) by user type: a) Large enterprises, b) SMEs, c) Self-employed or individuals, d) Government and e) Universities

Figure 8: Andalusian transport network and annual spatial distribution of "Geolocated connec. RAP-IP": a) 2009, b) 2010, c) 2011, d) 2012 and e) 2013. In pink colour High-speed Train lines, in blue colour Motorway and in green Highways.Figure 9: Accumulative period 2008 to 2013 of "Geolocated connec. RAP-IP": top, specific locations of connections; bottom, grouping by municipality

Figure 9: Accumulative period 2008 to 2013 of "Geolocated connec. RAP-IP": top, specific locations of connections; bottom, grouping by municipality

Figure 10: Annual time series: "Geolocated connec. RAP-IP" (black), "Urban connec. RAP-IP" (green), "Nº Non-urban connec. RAP-IP" (red), "Other connections RAP-IP" (orange) and "Public work connec. RAP-IP" (blue)
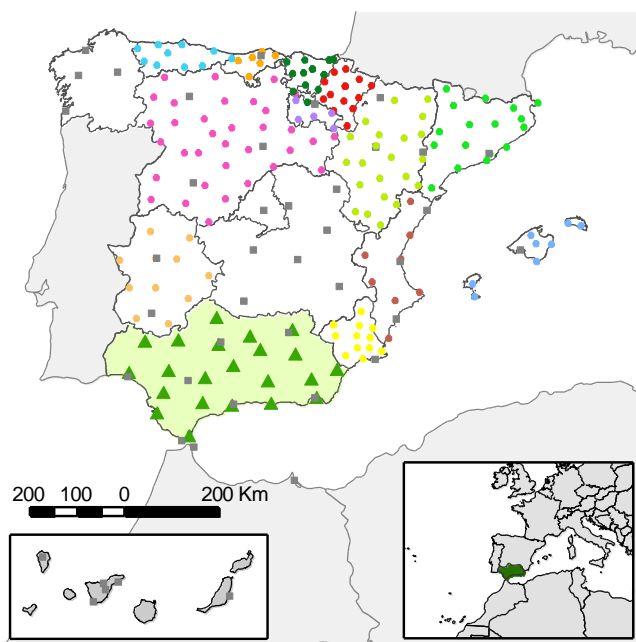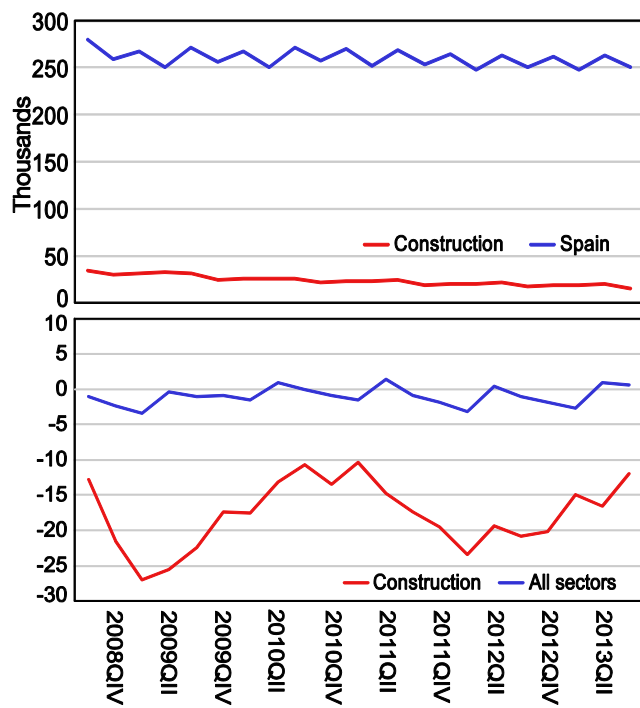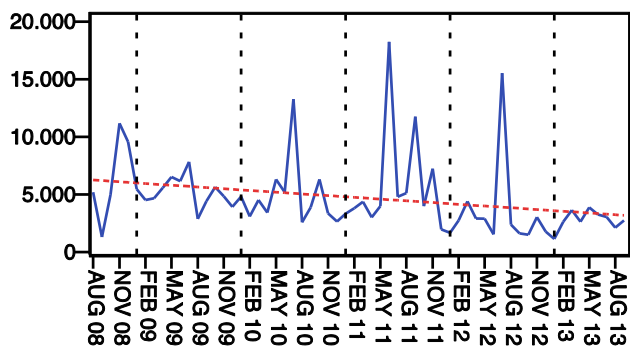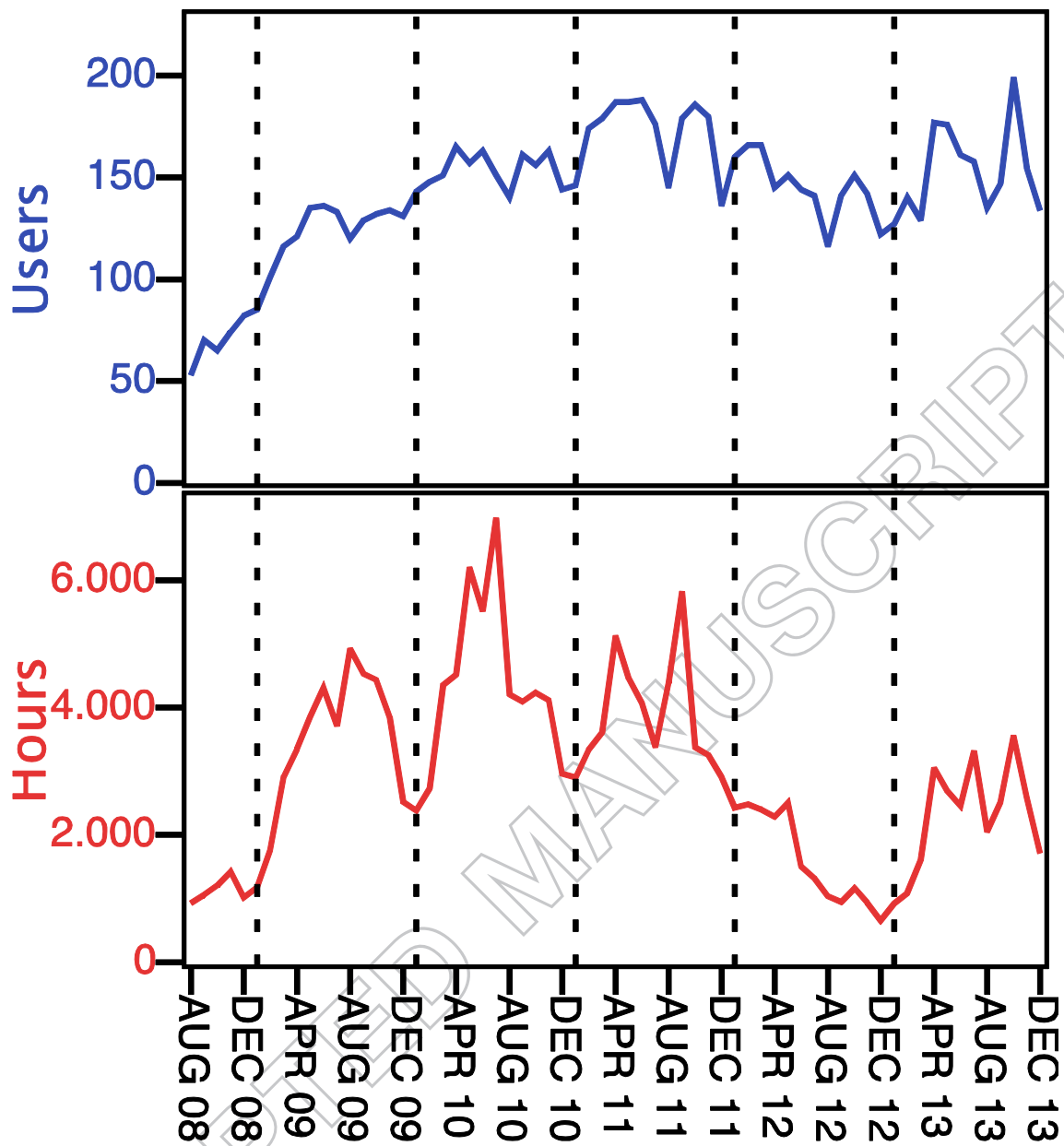
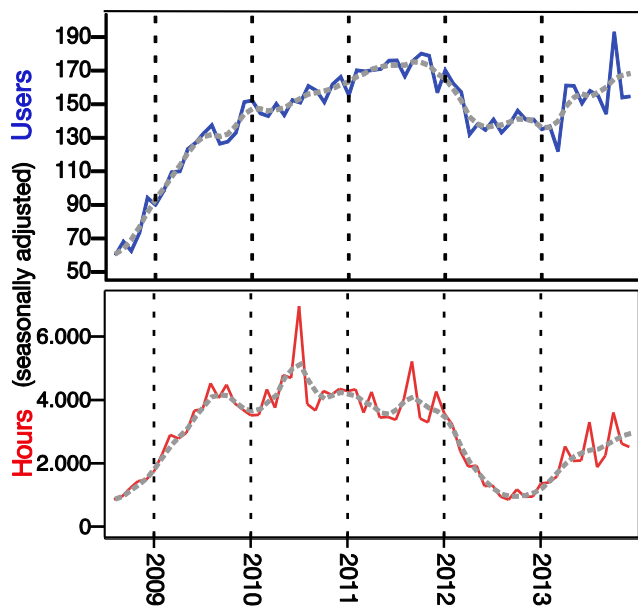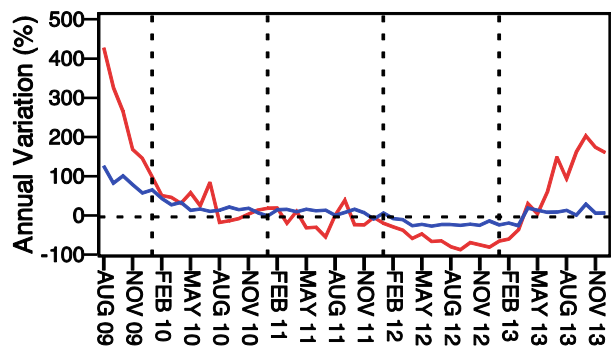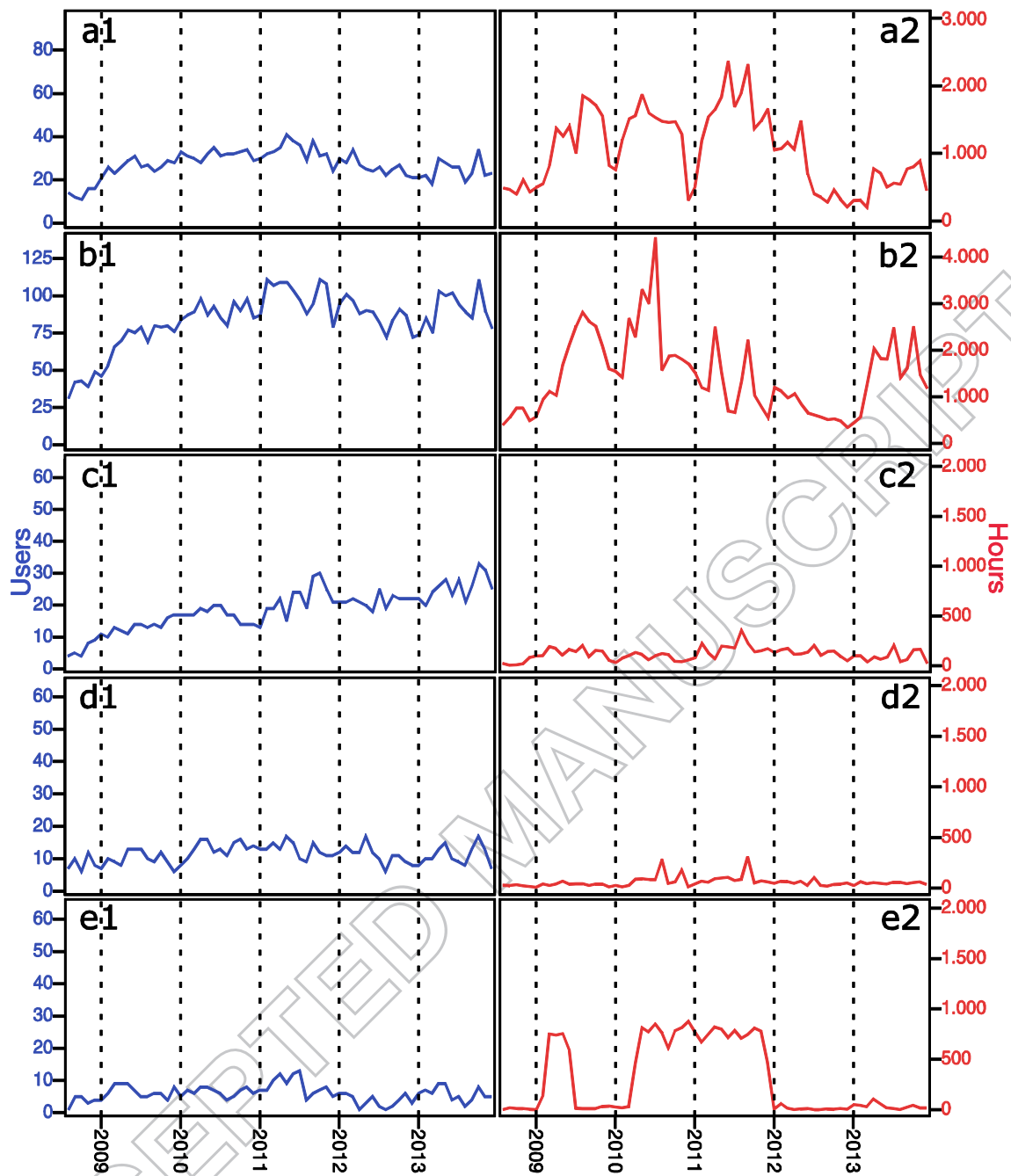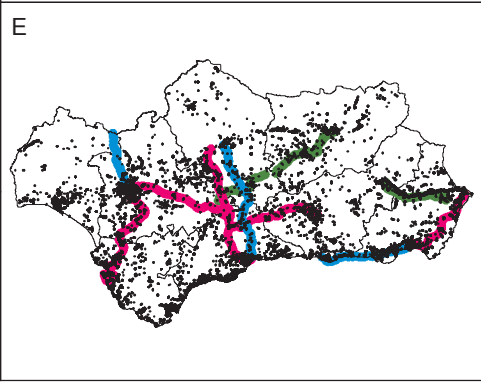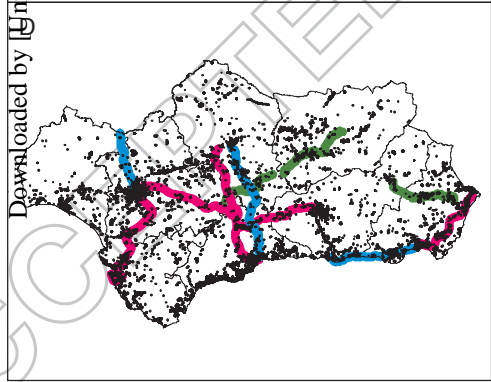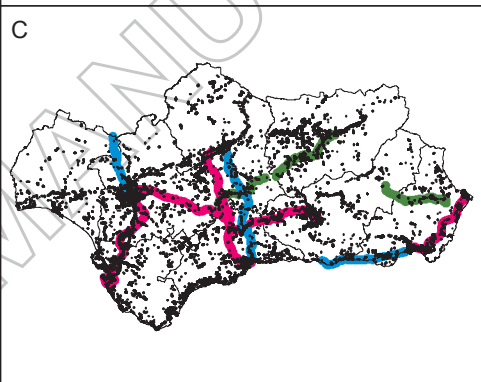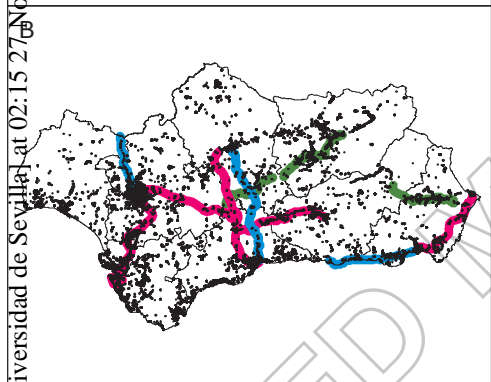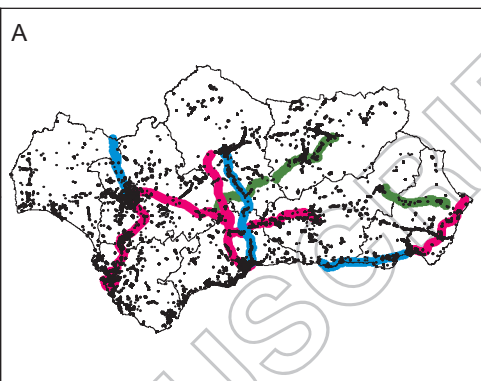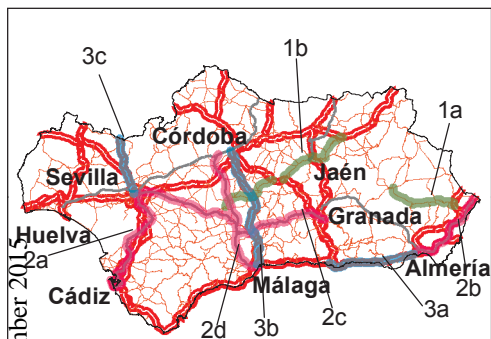— Railway A.V.E   — Regional road   — State highway

Number of connections

0 - 118
119 - 360
361 - 765
766 - 1427
1428 - 2222
2223 - 3823
3824 - 5000
5001 - 24999
25000 - 55953