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ANALYSIS OF FIRE SERVICES COVERAGE IN SPAIN

ABSTRACT:
Previous analysis of the locations of fire stations in Spain and the extent of the areas they cover revealed significant deficiencies with regard to the proportion of communities who would not receive fire service intervention within a reasonable time period. This article discusses and describes the use of Geographic Information Systems and related tools to determine the areas and population covered by existing fire services within a specific response time. This response time by road, is based on a survey of fire service interventions in other European countries. The analysis compares data from a statistical study with georeferenced ones and demonstrates that the areas and communities not covered within this response time is greater than previously believed. The article then describes an analysis an alternative solution to reinforce the current fire stations network with part-time firefighters to cover the areas not covered mainly in rural and remote locations.

Keywords: **Fire stations; Full-time; Part-time; GIS; Location-allocation; Fire Service**

1. INTRODUCTION

The protection of people, of their possessions, and of the environment against fire and any other type of emergency is both a citizen's right and a public service that must be provided. Thus, public administrations have to devote appropriate resources to guarantee this protection in a fast, effective and efficient way [1]. In developed countries this is assured in urban areas but it becomes costly to ensure similar services in rural and more remote locations with difficult access.

Planning the best location and distribution of resources to provide an optimal level of emergency attention is quite complex. It involves not only the size and location of fire stations, but also the number and type of incidents attended, the standards which fire brigades strive to meet, the geographical constraints of the area and, of course, the financial restrictions of the fire authority.

Some countries in Europe have established regulations for the distribution and resources of the Fire Service, known as Fire Cover, which is the term used to describe the disposition and deployment of firefighting equipment and personnel to a state or national standard.

Fire Cover has been developed to assist fire brigades with the planning and disposition of resources to achieve optimal intervention. Such a system does not exist nationally in Spain. Indeed, there is not a detailed study about the amount and distribution of the population covered by the existing fire services within a specific response time.

In 2013, a work entitled "National Statistics of Fire Services" by the Professional Association of Fire Service Technicians was published (APTB) [2]. This work, among other information, provided data on the total number of firemen, identifying the type and number of services and of fire stations per service. The correlation of this information with the area and population served revealed some interesting pointers in relation to intervention in emergencies. In that work, Larrea [2] concluded that, at that time, in Spain there was a population of 1,061,828 inhabitants whose access to Fire Service intervention was not guaranteed. An examination of the areas without any cover showed that the populations affected were in rural areas.

Although the information related to the location, number of firemen, number of services etc. was detailed and accurate, the data about the area and consequently the population attended by each fire station were estimated by the author considering the information compiled through a survey conducted by phone to the firefighters themselves.

Considering that georeferenced information on the locations of urban and rural nuclei, population distribution, location of fire stations, road communication network structures, etc. of the whole of Spain is currently available, GIS tools can be used to facilitate the handling of this information to objectively determine which population are served, within a specific response time, by the current Spanish fire stations network.

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A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data.

Regarding to the response time, it is important to highlight that at European level, there is no regulation that establishes a standard for the response time of a fire station, understanding this to be the maximum time which that elapses from the moment the firefighters receive the alarm signal until they arrive at the incident place.

Between 1997 and 1998 the Fire European Association (FEU) conducted a "Survey of the career of professional fire fighters in Europe" in which, among other data, the standard response times for intervention at emergencies by a fire station in rural areas in each country was analysed. It was confirmed that the response time was not regulated in all the countries participating although it was noted that most of them, had established a maximum response time of 20 minutes for rural areas. For the purpose of this work, and taking into account the FEU study, the response time in rural areas in Spain was fixed at 20 minutes. Therefore, those areas outside the 20-minute isochrones are deemed to be outside the service area of the respective station, and, as a result, are considered as unattended.

Starting from this hypothesis, the objective of this work is to compare the data and information in the study made by Larrea [2], with georeferenced data generated by GIS analysis, in relation to the real population attended by the current fire stations in Spain.

2. MATERIAL AND METHODS

The study area of this work will be the whole geographic area of Spain, with a surface of 504,645 km² and a population of 46,745,807 (1st January 2014) inhabitants.

In order to determine the area and inhabitants attended by each fire station, it is necessary to define the service or influence areas of each respective station, i.e, the area resulting from joining the isochrones obtained, starting from each station, by applying to the road network the distance travelled by an emergency vehicle in 20 minutes, at a specified speed depending on the category of the road [3].

As initial information for determining the service or influence area of each station, the road network available on OpenStreetMap (OSM) [4] was used. OSM is a collaborative project to create a free editable map of the world. This vector layer comprises the most complete road network of the whole of Spain, and includes the network of the Cartociudad [5] project, coordinated by the Spanish National Geographic Institute (IGN) [6], with a topological continuity assured all over the country. In addition, the Census Map of Fire Stations generated by the Unitary Firefighters Platform of Spain [7] was employed. This map defines the location of current fire stations. The vector map of Spanish municipalities, including population data, were obtained from AUDES (Urban Areas of Spain) [8]. The population data included in AUDES, come from the National Institute of Statistics (INE), whereas the geographical data (surfaces, coordinates and vector information) have been generated by the IGN. All this information, summarized in Table 1, has been processed and analysed by means of the commercial software ArcGIS (of ESRI).

Table 1. Starting-out data.

DATA	FORMAT	COORDINATE SYSTEM	SOURCE
Road network	Vector Líne Shape	Ellipsoid WGS-84, projection UTM 30N	OpenStreetMap [4]
Census map of fire stations	Vector Point Shape	Ellipsoid WGS-84, projection UTM 30N	Unitary Firefighters Platform of Spain [7]
Population per municipality (2010)	Vector Point Shape	Ellipsoid ED50, projection UTM30N	AUDES - Urban Areas in Spain [8]

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2.1 NETWORK ANALYSIS VERSUS BUFFER ANALYSIS TO DEFINE SERVICE OR INFLUENCE AREAS

One of the most used GIS tools to define the service or influence area from a certain point is that of the circles of influence or buffers, which permits to easily determine the relevant area, and therefore the population which could be attended from this point. This approach could be useful in situations in which the access and communication routes are relatively homogeneous, as occurs in urban areas [1], provided that the correlation between the theoretical and real access time is considered. However, this method becomes inexact in rural areas because it does not take into account indirect routes, obstructions or discontinuities in the communication network, nor does it contemplate the existence of different speeds in each road typology. The network analysis, on the contrary, does consider these types of parameter, which permits the determination of service or influence areas more precisely.

From the spatial viewpoint, a network is a system of interconnected linear elements and cross connection points, which represent the possible routes from one location to another. The network analysis, whether of roads, railways, or rivers, etc., allows the planning and the optimisation of routes, the identification of locations in terms of distance and travel speeds, or the calculation of service and influence areas [9]. This technique deploys the spatial analysis of network data to calculate distances between its points or nodes, in order to obtain much more specific and real information on the service or influence area attended to or from a specific location and in a defined time. Fig. 2 shows the differences between the service areas calculated for one fire station, using a circular buffer and the network analysis. In both cases, a response time of 20' has been considered. In the case of the network analysis, the maximum speeds permitted for a fire engine in each road category were taken into account. As shown in fig. 1, the service area calculated applying network analysis is smaller and more constrained than the area calculated by means of buffers, since the latter do not consider the complexity of the real road network, either in its spatial component or in relation to the category or typology of the roads.

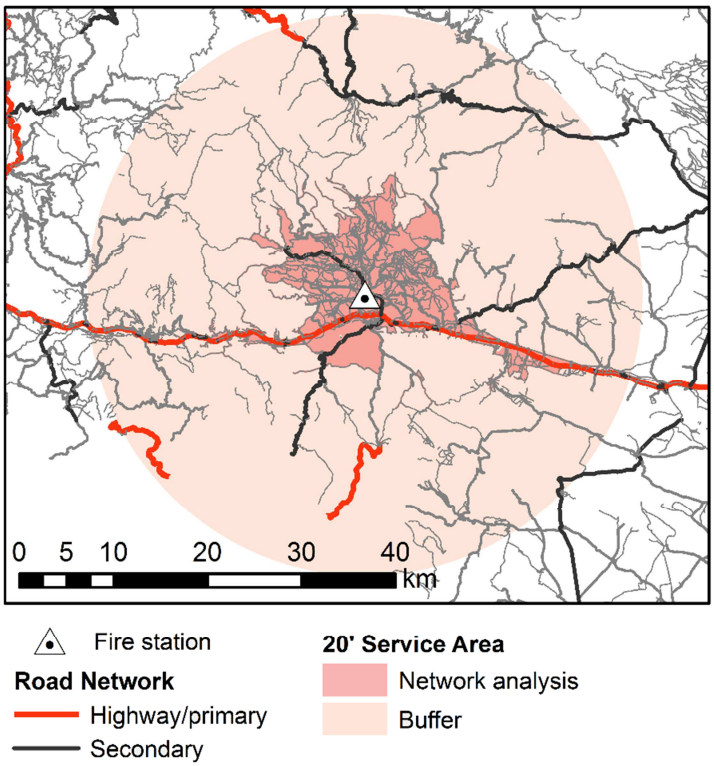

Fig. 1 Service area

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2.2 CALCULATION OF THE POPULATION ATTENDED BY THE CURRENT FIRE STATION NETWORK

In fig. 2, the GIS procedure followed to achieve the stated objective is detailed. As the starting-out information comes from different sources, the coordinate systems are not the same in all cases, so that, at an initial stage, all the data are reprojected to WGS-84 reference system. At a second stage, and to prevent possible topology errors, the road network is divided by the crosses between the lines verifying that the lines are correctly connected at their ends. Next, and taking into account the type of the road, the maximum speed at which a fire engine can travel is assigned to each stretch, defined following the recommendations of FSEC Toolkit Review Manual [3]: Motorway 88.5 km/h, Secondary roads 64 km/h, Tertiary roads 56 km/h, and other minor roads 48 km/h.

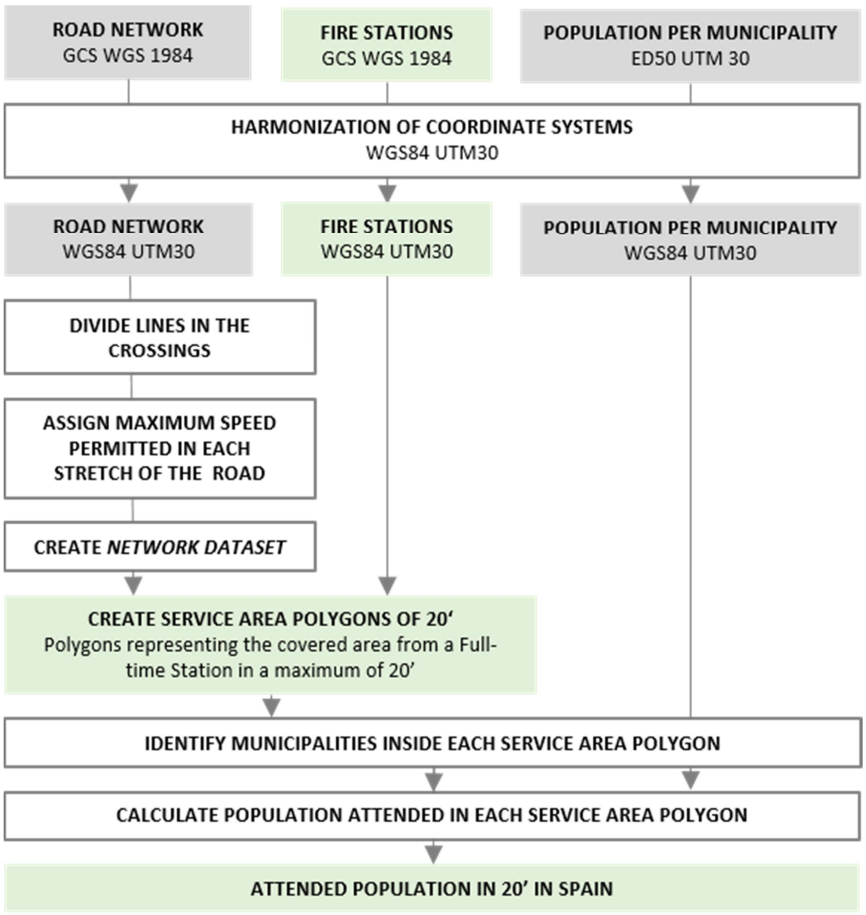

Fig 2 GIS procedure followed

The process above provides a complete definition of the road network. This layer, together with the point layer of fire stations, constitute the input data in the Network Analyst tool of ArcGis. Taking the above information, this tool generates polygons representing the distance that a fire engine can travel in 20 minutes from each of the fire stations according to the type of road, i.e. the service or influence area of each fire station. This process is carried out for all of the existing fire stations in Spain [7]. Finally, the service areas are intersected with the vector layer of the municipalities, identifying those that are inside a service area, and therefore calculating the population served from the current fire station network.

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3. RESULTS

3.1. POPULATION ATTENDED BY THE CURRENT FIRE STATION NETWORK

The GIS analysis of the municipalities and populations attended in a time equal to or under 20 minutes by the current fire station network demonstrates that, as is indicated in Fig. 3, the areas most attended (marked in green) correspond to coastal areas and those close to large urban nuclei, these being precisely the most populated ones in Spain. However, many rural and inland areas are not attended as they are outside the of 20 minute isochrone from the nearest fire station. All this information is summarized in Table 2.

Overlaying this graphic information with the alphanumerical one provides the data shown in Table 3. It can be seen that almost 42.83 million inhabitants, representing approximately 92% of the population, are attended by a fire service at a time of less than 20 minutes. However, nearly 4 million, that is over 8% of the population, remain outside the 20-minute isochrone, which implies that they are not attended by any fire service in a minimum effective time. In the case of the municipalities, 52% are attended compared to 47% unattended ones.

According to Larrea [2], the population not attended in Spain by a fire service amounts to 1,061,828, which constitutes 2.2% of the total Spanish population. This figure was determined analytically after the survey made by Larrea of the territorial coverage assigned to each of the different fire services considering the territorial assignation of the stations which, in many cases, greatly exceeded the 20-minute response time. However, the results obtained in the present study, which was made using network analysis GIS tools, considering the road network, the maximum travelling speeds and a response time fixed at 20 minutes, demonstrate that the unattended population was of 3,917,125 inhabitants, i.e., 8.4%, of the total population [5].

It can be seen that data obtained in this study, applying European criteria to emergencies, are more restrictive and realistic than those obtained in Larrea [2]. It should be noted that, of the total of 8,112 municipalities in Spain, approximately half of them are not attended in time by a fire service, with a large majority of them in rural areas.

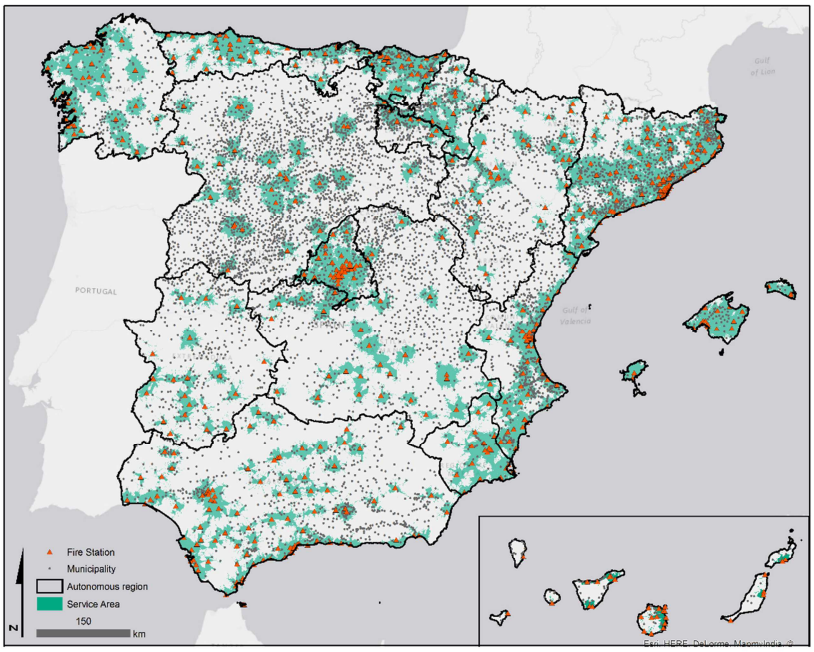

Fig 3. Areas attended in 20 minutes
Table 2. Population attended in 20 minutes

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	total Municipalities	total Population	Atended municipalities	% atended municipalities	Atended population	% atended population
4. Andalucía	770	8302923	451	58,57	7395967	89,08
Aragón	731	1345473	274	37,48	1141620	84,85
Asturias	78	1085289	66	84,62	1067722	98,38
Islas Baleares	67	1095426	62	92,54	1079330	98,53
Canarias	88	2103992	50	56,82	1674169	79,57
Cantabria	102	589235	83	81,37	567376	96,29
Castilla La Mancha	919	2081313	284	30,90	1502995	72,21
Castilla y León	2248	2563521	647	28,78	1863799	72,70
Cataluña	946	7475420	829	87,63	7390788	98,87
Ciudad de Ceuta	1	78674	1	100,00	78674	100,00
Ciudad de Melilla	1	73460	1	100,00	73460	100,00
Valencia	542	5094675	403	74,35	4971694	97,59
Extremadura	383	1102410	147	38,38	815003	73,93
Galicia	315	2796089	192	60,95	2395238	85,66
Madrid	179	6386932	151	84,36	6319839	98,95
Murcia	45	1446520	44	97,78	1435761	99,26
Navarra	272	630578	214	78,68	602015	95,47
País Vasco	251	2172175	239	95,22	2144452	98,72
La Rioja	174	321702	118	67,82	308780	95,98
Sum	8112	46745807	4256	52,47	42828682	91,62

Table 3. Result of the analysis of the municipalities and population attended and not attended with the current fire station provisions

Attended in under 20’	Municipalities		Population	
	Number	%	Number	%
YES	4,256	52.47	42,828,682	91.62
NO	3,856	47.53	3,917,125	8.38
TOTAL	8,112	100	46,745,807	100

3.2. A POSSIBLE SOLUTION TO REINFORCE THE CURRENT FIRE STATION NETWORK WITH PART-TIME FIREFIGHTERS

In those areas that are outside the European response time criteria for fire service assistance, the population’s right to be attended by a fire service in an emergency in a time of less than 20 minutes is not accomplished. In European countries neighbouring Spain this right can be guaranteed for the majority of population by using the part-time of retained firefighter model. It is precisely in rural and in sparsely populated urban areas in which the role of the part-time professional firefighter has been developed, since it is in those areas that hazards are limited and the risk considered to be low. Generally, these areas do not justify the provision of full time firefighters, but they do require some service and technical quality in response to emergencies.

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For much of the time, a part-time or retained fire station is unmanned. Each retained firefighter carries an alerting device, which is activated when firefighters are needed and they have a maximum of 5 minutes to report to the fire station and mobilise the necessary appliance(s). Retained firefighters will have other occupations, but when the call is received, they cease whatever they are doing, report to their fire station and to form a firefighting team. Depending on the type of cover provided, a retained firefighter must respond from home and/or work, day and/or night .

Part-time firefighters have contracts and make a service commitment that obliges them to undergo similar training to full-time firefighters and to participate in similar continuous training and development. In the contract, duties and terms of employment are stipulated, for which they are paid a corresponding monetary compensation, hence their professional standing. The retained service is characterised by having an on-call roster which permits firefighters to carry out any other type of activity be it work, recreation, sport, etc., which they have to leave when required to attend an incident, presenting themselves at the station within a certain time. Therefore, the essential difference from the full-time firefighter is that they are not physically in the station while they are on-call, and are therefore paid for availability and for attendance at incidents.

The full-time model is well established in Spain, the part-time one does not exist and the voluntary firefighter model is not widely used. In recent times, the voluntary service has gone into serious decline, mainly due to the social changes generating a lack of personnel and of a commitment to its organisation, except for those few places in which this model is traditional. The guarantee of a response to an emergency, as well as its technical quality, cannot be ensured by structures based on the voluntary model, principally the unpaid ones, which has meant that this model has disappeared in many places.

Knight [10] analysed the efficiency of fire services in England taking into account, on one hand, the activities carried out and, on the other, the possible margin of change in those services. In that study it was determined that the full-time station cost is 10 times more than the part-time one given that facilities for a full-time service require more infrastructure and the wages paid to the fire fighters, based on the commitment required, are different.

Part-time firefighters, in addition to offering a basic service to society, are strongly identified with the communities they serve because they live, and in many cases were born and raised, in these communities. And this benefits the development and sustainability of the local service. All these reasons support the idea that it could be possible to reinforce the current Spanish fire station network, especially in rural areas, by adopting a part-time firefighters model.

4.- DISCUSION

According to the statistical study made in 2013 by Larrea for the whole of Spain, the number of inhabitants not guaranteed an emergency response in a time equal or under 20 minutes with the current fire station network, amounted to 1,061,828, or 2.2% of the whole population. The present study, considering the fire station network, the location and population of all the Spanish municipalities and their corresponding road network, integrated in a network analysis GIS tool, enabled the determination of the unattended population, i.e. the population which cannot be reached in a response time equal to or under 20 minutes, which actually amounted to 3,917,125 inhabitants. This means that 8.38 % of Spaniards would not have their right to be attended by a fire service in an emergency in a time of less than 20 minutes, and this represents a difference of 6.18 % with respect to the proportion of the population initially calculated.

With respect to the Fire Service model that could be set up in rural areas, the part-time one seems to be ideal since, at the same financial cost as the full-time model, it permits attendance at emergencies in a significantly larger number of municipalities and to a greater population. Besides, part-time firefighters are strongly identified with the populations and locations they serve and this sense of public service is a great motivation for them. Moreover, the part-time firefighters also bring important knowledge to the service in terms of knowing the people in their communities, the physical characteristics of the area and the risks in their communities which contributes to the strengthening and the development of the service. In other European countries it has been confirmed that these part-time stations provide attendance within the same quality parameters as the full-time ones.

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