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Sección ARTÍCULOS

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An exploratory analysis of disabled people accessibility to urban public transport: the use of Geographical Information Systems

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ABSTRACT: The potential information available in administrative records managed by Public Administrations is vast for its value in improving the social and economic research and its utility to evaluate, judge and plan the public policies. An advance in the standardization and coordination of the information records and systems would reduce the marginal cost of operations and would update data in order to avoid the fraud and improve the transparency. Thus, the aim of this paper is merging three independent public databases that they refer to people with disabilities, their location and their accessibility to urban transport. To do this, a new and unique database is built using a Geographic Information System (GIS). It is the ability of GIS to reconcile spatial data from different sources that allows the creation of new data sets. This framework may improve the availability of needed data, promote integration of technology and encourage collaboration among firms and the public sector what would allow Public Administrations' decision making taking into account the economic and social characteristics of the registered disabled people.

JEL Classification: D78; C80; O21; R50.

Keywords: disabled people; accessibility; interoperability; integrating public data; spatial data infrastructure; Geographical Information System.

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Un análisis exploratorio de la accesibilidad al transporte público urbano de las personas con discapacidad: el uso de los Sistemas de Información Geográfica

RESUMEN: El potencial informativo disponible en los registros administrativos gestionados por las Administraciones Públicas es muy amplio, por su valor para mejorar la investigación social y económica y por su utilidad para evaluar, juzgar y planificar las políticas públicas. Un avance en la estandarización y coordinación de los registros administrativos y de los sistemas informáticos permitiría reducir el coste marginal de las operaciones y actualizar los datos con el fin de prevenir el fraude y mejorar la transparencia. Así, el objetivo de este trabajo es relacionar tres bases de datos independientes, disponibles en el seno de las Administraciones Públicas que recogen información sobre las características de las personas con discapacidad, su ubicación y su accesibilidad al transporte urbano. A partir de estos datos se construye una nueva y única base gestionada mediante un Sistema de Información Geográfica (SIG). La capacidad de los SIG para conciliar los datos espaciales de diversas fuentes permite la creación de nuevos conjuntos de datos. Esto proporciona un marco que puede mejorar la disponibilidad de los datos necesarios, promover la integración de la tecnología y fomentar la colaboración entre las empresas y el sector público, lo que permitiría a las Administraciones Públicas tomar decisiones teniendo en cuenta las características económicas y sociales de las personas con discapacidad registradas en la base.

Clasificación JEL: D78; C80; O21;R50.

Palabras clave: personas con discapacidad; accesibilidad; interoperabilidad; registros administrativos; infraestructura de datos espaciales; Sistema de Información Geográfica.

1. Introduction

The provision of public transport to provide access for socially disadvantaged groups has long been seen as one of several major service development rationales (Larwin, 1999; Veeneman, 2002; Currie, 2004; Nielsen *et al.,* 2005; Currie and Senbergs, 2007). This is reflected on the progress in the sustainable territorial development by incorporating not only economic criteria, but also environmental and social criteria in the planning process that aims to «achieve long-term balance between economic development, protection of the environment, efficient use of resources and social equity» (Salado *et al.,* 2008; Salado *et al.,* 2011). Accessible transportation is an integral service for many people with disabilities in order to live healthy and fulfilling lives. People with disabilities have consistently described how transportation barriers affect their lives in important ways. Accessibility is the main element of a sustainable transport system. Accessible transportation can change a person's life from one of isolation and dependency to one of social integration and independence. When transportation does not work well, it can be a source of great personal frustration and economic loss. People who are unable to fully use the existing transportation systems may experience reduced access to opportunities for employment, health

care, education, shopping, recreation, and social and cultural events. European Commission encourages forms of public transport accessible to all users, including people with reduced mobility, specially those with disabilities and the elderly ones (COM, 2001). Nevertheless, there are too many obstacles for the people with reduced mobility as regards the transport accessibility: switching between modes, information services, pedestrian environment, traffic safety and others. Until these obstacles are not eliminated the vast majority of people with disabilities will continue to stay at a disadvantage and will be unable to travel as they would wish and consequently limited in the extent to which they can participate in society (ECMT, 2006).

The problem of finding adequate transportation may be compounded for people with disabilities, particularly those who need specially equipped vehicles. While Spanish Autonomous Communities have public and/or private transportation services, almost none have developed methods for examining how well the transportation services they have in place serve their community, specifically for the transportation disadvantaged who live there. Learning about the adequacy of established transportation options is the obvious first step in developing plans for improving and updating services so communities can appropriately meet the transportation needs of the handicapped people.

An outcome for this study is to create a method that Autonomous Communities can use to assess the comprehensiveness of their transportation network for people with disabilities. How information about accessible transportation services is presented can affect how well they understand the information. If information is presented in a written format, as is many times the case, it is possible to get some idea of the transportation options in a community, but it is not easy to understand how these services are organized spatially. This is specially true since this information is provided separately by each service provider, leaving it to the users to piece together all the available options. Maps showing the locations served by a transportation provider help to illustrate spatially where transportation is available, but just creating maps that show service coverage does not provide enough information to adequately analyze accessible transportation in an area. These maps do not address other pertinent issues that need to be taken into account when examining accessible transportation. These issues include, who in the community is eligible for the services, the costs of services, if there is more than one option for services for a particular location, when the services are offered, what purpose for which the service can be used, and exactly what assistance the service is able to provide to the users.

One way to assess these issues is to use the spatial analytical capabilities of a Geographic Information Systems (GIS) to visualize and spatially analyze the transportation services in a community. GIS are a special type of an information system designed to create, store, integrate, manipulate, edit, manage, analyze and present various types of knowledge or data used in a decision making process (mapping spatial data) (Vecchia *et al.,* 2012). GIS can map economic data with a spatial component; generate additional spatial data as inputs to statistical analysis; calculate distances between features of interest and define neighbourhoods around objects (Over-

man, 2010). One important aspect of GIS that will not be covered is the choice of software. Longley *et al.* (2010) consider the question of appropriate software in some depth. Bosque Sendra *et al.* (2012) also display several software tools that increase GIS applications to analyze and solve optimal location problems. Too much information is often available relative to any decision and the relevance and applicability of that information can often be unclear. GIS offer the promise of organizing and sorting through a very messy world of information, generalizing that information in some suitable fashion, combining it with other information, and producing a graphic output of understandable simplicity (Taupier and Willis, 1994).

Spatial analysis can lead to new ways of understanding transportation services and identifying patterns that were not apparent previously. If GIS assessment reveals that existing transportation resources do not provide adequate coverage and therefore are not adequately meeting essential travel needs (e.g. travel to work, medical services, shopping, etc.), in this case, the community has data to support investigating new options and to apply for new sources of funding to better meet the transportation needs of all its citizens (Jurica, 2009).

In this way, given that Spanish funds for improving transportation are limited, it is important to find ways to improve the efficiency of accessible transportation to ensure that it is available to those who need it.

Following the recommendations of European Commission (European Commission, 1999) and the European Conference of Ministers of Transport (ECMT, 1999) the development of intelligent transport systems to inform passengers with disabilities of transport conditions should help reduce the time lost on transferring between modes or access to the stops and stations.

This paper aims to observe the adaptation of transport supply to the needs of a particular group of people. To do this, a framework for decision-making has been created merging three independent databases available in the Spanish Public Administration and using the potential of GIS as a tool to map if public resources are accessible and appropriate, given the size of cities and the location of the people. In this way, this paper provides a method to reduce uncertainty in the decision-making process promoting the resolution of mobility and accessibility problems of people with disabilities from a cartographic perspective; an approach that is barely used at the moment in Spain. This approach has been applied to the Ayuntamiento de Gijón (Town Council of Gijón) in Asturias-Spain because is the municipality that has a very developed cartography at the moment of the research (Cañal *et al.,* 2006).

The paper is organized as follows. Section 2 describes the characteristics that define people with disabilities according to the database registered in the *Consejería de Bienestar Social y Vivienda in Asturias* (Regional Ministry of Social Welfare and Housing). A descriptive analysis of the methodology, the sources and the data are included in Section 3. The case study and the main results obtained are presented in Section 4. And finally, the most important conclusions drawn in the paper are displayed in Section 5.

2. A socio-spatial perspective of people with disabilities

The information available in several administrative records managed by Spanish Public Administration is wide ranging, so its value to improve social and economic research as well as its usefulness to asses, judge and plan public policies starts to be recognized in Spain now. This paper is based on this idea that is often found in the firm world, using internal information based on the consumer's behavior to create value, proposing an innovative approach to address the problem of transport for people with disabilities and people with reduced mobility.

This study proposes to merge three independent databases that are available in the Public Administration using a Spatial Data Infrastructure (SDI) for coordinating the structures and to operate consistently and safely. The term SDI was coined in 1993 by the U.S. National Research Council to denote a framework of technologies, policies, and institutional arrangements that together facilitate the creation, exchange, and use of geospatial data and related information resources across an information-sharing community (Steiniger and Hunter, 2012). Such a framework can be implemented narrowly to enable the sharing of geospatial information within an organization or more broadly for use at a national, regional, or global level. In all cases, an SDI will provide an institutionally sanctioned, automated means for posting, discovering, evaluating, and exchanging geospatial information by participating information producers and users. A SDI is now commonly considered as an important economic resource and an essential base for the sustainable development of society. This information —in the knowledge-based economy— can have a strong and positive impact on citizens' quality of life and in the development of companies and the Public Administration (public policies). In this sense, the INSPIRE Directive (Infrastructure for Spatial Information in Europe) lays down general rules for the establishment of a Spatial Information Infrastructure in the European Community based on the Infrastructures of the Member States (2007/2/CE Directive). The transposition of INSPIRE Directive to the Spanish legal framework was completed in 2010 with the approval of Law 14/2010 of the 5th of July, the Law on Infrastructure and Geographic Information Services in Spain (LISIGE). Among other things, this law creates organizational structures in the Spanish administration meant to implement and comply with the requirements defined in INSPIRE Directive and its Implementing Rules.

In this way, the GIS are the tool used to gather information on interoperable geographic data and services in order to develop the socio-spatial analysis of people with disabilities. Socio-spatial analysis allows us the combination of spatial information with other types of information to enable both mapping of various characteristics of the transport system. The discussion of Murray *et al.* (1998) about public transport coverage in South East Queensland is an example of this kind of socio-spatial analysis. These authors sought to assess the policy implications of access to public transportation in terms of proximity to public transport services among residents of the region. Access to public transport was termed «suitable» based on residential proximity being within 400 meters. Using this threshold of suitability combined with

statistical census residential location data, resulted in maps produced of areas within South East Queensland that had «suitable» public transport.

The capacity of GIS can range from depicting basic information such as the spatial coverage of the public transport network, or can be used to generate sophisticated multivariate analyses incorporating large numbers of complex calculations. The empirical meanings that are derived from manipulations of social data remain open to criticism as being inadequately sensitive to the nuances of actual social behavior (Dodson *et al.,* 2006, 2007). GIS are particularly useful for analyses of spatial disadvantage in relation to transport as it permits relatively easy calculation of spatial metrics. Thus, for example, the identification of locations where a given level of public transport service is unavailable becomes relatively easy with GIS once the necessary data is available.

GIS allow us to create a new, unique and consistent integrated database that collects all information contained in the three independent databases mentioned previously —transport supply, demand of people with disabilities and their location in their homes—. The main characteristic of this approach is its flexibility and coherence as well as the relatively low cost-maintenance because each Public Administration performs operations in the framework of its powers, but with a common and unique database. This advance in the standardization and coordination of information systems would reduce the marginal cost of these operations to the bare minimum.

Therefore, the research has been carried out in Asturias, without involving a loss of interest or generality, because the highest transaction costs to coordinate a cross-sectional research that involves three different administrations required a pilot study. Besides, the concerns of this paper are coherent with the strategy defined in the *Plan Nacional de Accesibilidad 2004-2012* proposed by the *Ministerio de Trabajo y Asuntos Sociales* (National Plan of Accessibility 2004-2012 of the Ministry of Work and Social Affairs) entitled «Accomplishment of statistics and studies of accessibility in diverse scopes» (Ministerio de Trabajo y Asuntos Sociales, 2003)[1].

2.1. Definition of people with disabilities

Legal definitions of disability have been an issue of much debate in Europe and around the world (Altman, 2001). Despite the efforts of the World Health Organization which resulted in the new *International Classification of Functioning, Disability and Health*, known more commonly as ICF, there is no international universal legal definition of disability, neither is there one in any EU country. A recent study on definitions of disability in various EU countries has shown that disability definitions vary from country to country but also inside each country (Mabbett, 2003). While there

[1] «Adequate means of control and information to promote accessibility should be created in order to use Public Administration's resources in an efficient way. Although managing and sharing the information are unusual habit in the different administrations, can be the first step to generate a new dynamic in this field, according to the Law» (p. 164). This is based on European Disability Strategy (2004-2010).

are similarities between the definitions of disabilities in some areas of social policy, legal disability definitions in each country differs with respect to income maintenance, employment measures or social assistance with daily life activities.

The Regulation EC 1107/2006[2] defines a person with reduced mobility as any person whose mobility is reduced due to a physical disability (sensory or locomotor, temporary or permanent) an intellectual deficiency, age, illness, or any other cause of disability when using transport and whose situation needs special attention and the adaptation to a person's needs of the service made available to all people. A key development during 2009 has been the publication of the III Action Plan for Disabled People 2009-2012 by the *Ministerio de Sanidad, Política Social e Igualdad* (Ministry of Health and Social Policy) as a national strategy that affects disabled people[3] in different areas. It also implements UN Convention. This Plan has a specific part focused on social and legal protection. Social inclusion is a horizontal overarching issue in the document.

- People on wheelchairs, with great motion difficulties, travelling impediments, or with problems going up and down stairs or on sidewalks, or moving on irregular pavements, etc.
- People with sensorial difficulties (vision, hearing, communication, etc.) prevented from using conventional transport service (to get a travel ticket, to access to the stop, entrance and exit of the vehicle, etc.).
- People with absence of functional mobility, amputation or arthritis on a body limb that have motion problems going up and down sidewalks, vehicles etc.
- People with hinder normal movement due to cardiac or respiratory problems.
- Older people that cannot move without other someone aide.
- No handicapped people who show some type of temporary loss of mobility, for example pregnant women, people with a plaster that must use crutches to move.

Many times people with disabilities need additional assistance when accessing vehicles, even if they do not need specially equipped vehicles. For example, many of them who no longer drive may require extra assistance in getting to and from the transportation vehicle and in boarding or disembarking due to the mobility problems or other disabilities that made them give up driving in the first place. In this sense, the concept of reduce mobility is quite ambiguous.

As it has been mentioned previously, countries have different registration systems of people with disabilities (OECD, 2003). Legal disability certificates are issued by local offices, e.g. IMSERSO in Spain or CDAPH in France. These certificates do not give eligibility to disability benefits (controlled and delivered by social insurance)

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[2] See the Regulation EC 1107/2006: *http://eurlex.europa.eu/LexUriServ/site/en/oj/2006/l_204/l_20420060726en00010009.pdf.*

[3] Older laws are being implemented from 2008 but the Act 29/2006, Promotion of Personal Autonomy and Care for Dependent Persons has caused too much expectation to people with disabilities and their families because of the positive impact that these policy changes might cause. Its implementation is different depending on each region.

but to in-kind support such as transportation, education, etc. Legal disability status often partly takes into account social factors for the differentiation of access criteria for benefit status and the definitions in terms of earnings incapacity or work vary largely. According to the legal framework for disability in Spain, the definition of disability used for disability registration is the 33 per cent work-capacity reduction in usual occupation[4].

3. Methodology: sources and data

This section presents the contents and the limitations of the data used in the proposed analysis. One of the main difficulties to achieve the objective of the research was the integrating of the information provided by the different official sources in the same format and structure. For example, the standardized addresses are an important requirement to carry out the task of georeferencing so that we can utilize useful and reliable data. In this sense, GIS technology has allowed us not only very powerful tools for storage and analysis of spatial and statistical data, but also by integrating databases of different sectors in the same format, structure and map projection in the GIS system. It brings the flexibility of allowing the user to define their own concordances between different geographical units of observation when faced with data from different sources. The software ArcGIS 9.1 has been used to integrate, explore and analyze the degree of disability, the location of the people with disabilities (spatial distribution) and the public transport supply. In addition to the calculation of distances, GIS have been used to construct measures of area or to define neighbourhoods (or «buffers») around objects (influence areas).

Figure 1 shows a geographic information system that involves the environment (*thematic database*) and allows data to be managed in association with geographic references (*cartographic database*).

The *thematic database* is built using the registered data by the *Consejería de Bienestar Social y Vivienda*. It gathers information about people with disabilities such as, their personal data (name, sex, place and date of birth and place of residence) and the type and degree of disabilities[5]. It is important to note that this database have important limitations such as: it specifies the degree of disability but the type of disability is not defined for each person; there are people they are not included in the database because they have never requested legal disability certificates. In these cases, most people have families that are providing some level of care and support and another problem displayed in the database is that there are dead people still registered because the families are not notifying Public Administration of the death.

[4] See the Law 51/2003, of 2 December, on Equal Opportunities, Non-discrimination and Universal Accessibility for People with Disabilities (LIONDAU) that establishes a range of measures to guarantee this right to equal opportunities for people with disabilities and to ensure that this becomes a reality.

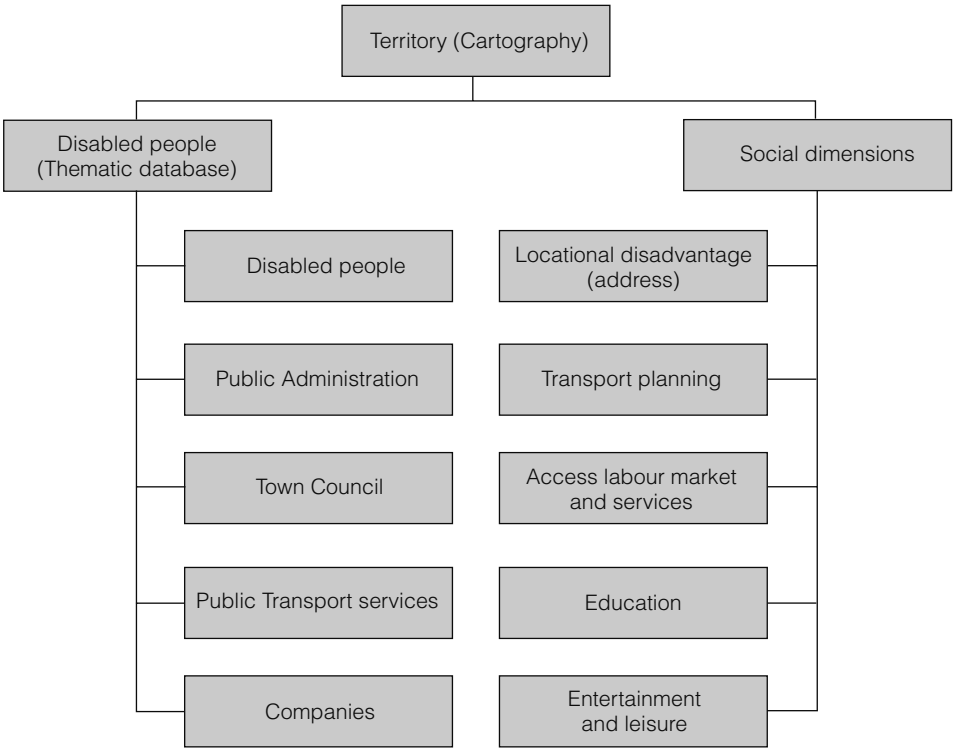
[5] Suitable mechanisms to ensure that data protection considerations are effectively taken into account to carry out this research.

The *cartographic database* is provided by the *Ayuntamiento de Gijón* to carry out the pilot study. The main reason is that it has the most accurate and disaggregated geographic information in Asturias at the time of the research.

The existing digital cartography in Gijón provides the basis for the development of a geographic database in which it is possible to locate people with disabilities, associate them with the locations of bus stops and obtain quantitative measures to assess the accessibility of transport (Figure 2). This would reduce the lack of transportation for persons with these characteristics. This is intended to promote the competitive advantages that the combination of data can bring to public and private entities for decision-making and resource allocation.

The first step consisted of studying and analyzing the *cartographic database* in order to choose the geographic reference or identification (ID) that allowed us to georeference the *thematic database*. The registered field in the two databases that allows us to merge both databases was the block number. Thus it was used as a reference ID. In Figure 2, the ID is represented by the variable NUM[6].

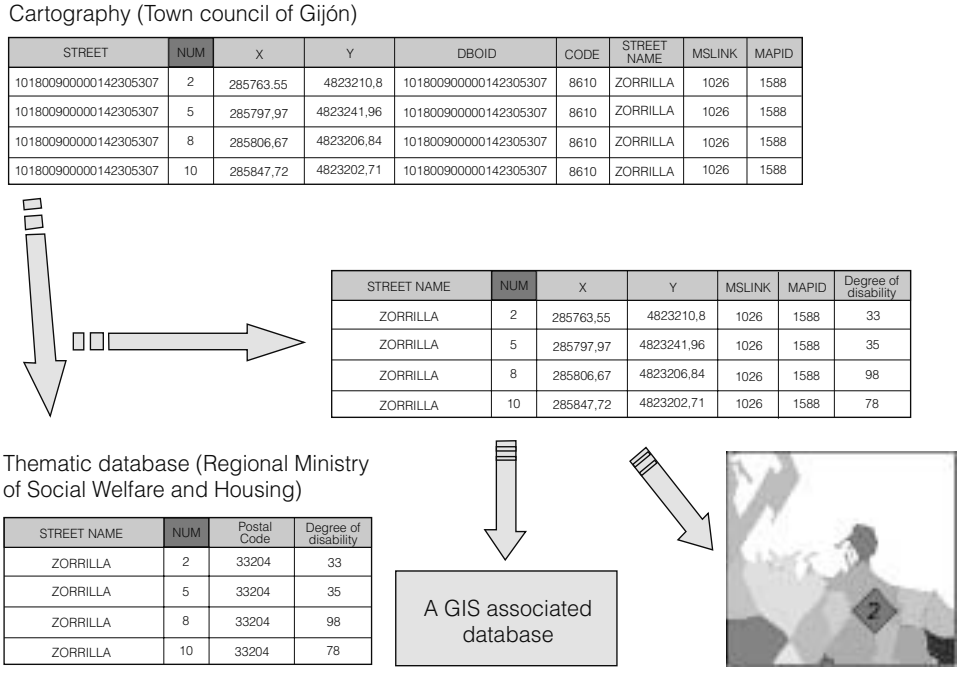
Figure 1. Geographic Information System



[6] The GIS associated database preserves privacy and confidentiality of personal data according to the Privacy Policy.

The second step (and the hardest task) was to debug and standardize the *thematic database* for adapting it to the *cartographic database*. Thus it is possible to cross both bases. The administrative registers are mainly used to gather information needed to fulfil their administrative purpose. Therefore, its statistical uses demand the data standardization that are necessary to obtain accurate and reliable estimates (Bermejo, 2006; Cárceles, 2006; Sanz Díez, 2006; Saralegui, 2006).

Figure 2. Construction of the GIS associated database



Therefore, a new data model is obtained where information is divided in three main groups (Dodson and Gleeson, 2009): users, services and space (geography). This is our GIS associated database.

Regarding the mode of transport it has been chosen the bus because of its higher spatial presence and its permeability in the urban fabric. Consequently, the bus stops of existing routes are used as a spatial transcription of the public transport supply to which it is desirable to have access. This third database is provided by the *Consorcio de Transportes de Asturias* (Transport Consortium of Asturias).

4. The case study: Gijón

This section proposes the delimitation of influence areas based on the distance to the bus stops taking into account that the georeferenced population according to the block number is the most accurate to detail the origin of the trip (i.e. houses). This influence area is interpreted as a market area (Lösch 1954), as the area that an user would choose like a location of minimum cost. This information has been used to approach to the transport accessibility based on the area in which the people with disabilities are located, and thus, to identify the areas that are better communicated. To do this, we have based on Murray *et al.* (1998) and Wu and Hine (2003). They proposed to use a distance of 25 meters as threshold to delimit the influence area around each bus stop.

Moreover, in order that potential users with disabilities can access to the bus stops belonging to another neighbourhood, i.e. their houses are located closer the bus stops belonging to another neighbourhood, we propose an enlarged area 100 meters from the boundary of the neighbourhood. So, those users can get around to another influence area if bus stops are closer than those of their neighbourhood.

The cost of implementing this methodology is almost null if the cartography and mailing addresses for the georeferencing of the population are quality (reliable and accurate). Therefore, it would be a good choice to apply it in the Spanish Autonomous Communities.

Gijón holds a privileged geographic position on the Asturias map, a few minutes away from the main cities of Asturias, Oviedo (capital of Asturias) and Avilés. These cities are linked by the motorway called «Y». The centre of Gijón has an amphitheatre shape, marked by the large beach of San Lorenzo, the main beach in the municipality.

According to 2010 statistics published by INE (Spanish Statistical Office), population in Gijón is 277,198. With a surface of 187.7 km^2 and a density of approximately 1.460 inhabitants per km^2, Gijón is located in center of the Asturias coast (North of Spain), bordered by the municipalities of Carreño, Corvera, Llanera, Siero, Sariego and Villaviciosa.

The urban neighbourhoods extend both sides of the primitive Roman quarters located in the hill of Santa Catalina holds a surface of 13.9 km^2 - it is the 7.6% of the surface of the municipality in which the 90% of the population are concentrated. The 10% of the remaining population is distributed by the 25 rural parishes of the municipality (Figure 3)[7]. These rural parishes have a double economic specialization: on the one hand, an industrial specialization and on the other hand, there is a set of rural parishes with a residential guidance that provides services and leisure.

[7] Besides of municipalities, the Asturias' spatial planning has an intermediate level of territorial division: collective entities of population or parishes that are clusters of several unique entities of population. See the Organic Law 7/1981 of 30 December of the Statute of Autonomy of Asturias, Article 6.2.

Figure 3. Gijón rural parishes

Next, we present the five territorial councils, without legal personality, that gather the neighbourhoods and the rural parishes. It is important to notice that the rural parishes partially overlap with the neighbourhoods, so, the sum of the areas sometimes does not coincide (Figure 4):

— District «Centro». It includes the Central area, «Cimadevilla» and «Laviada» *neighbourhoods*.
— District East. It gathers «La Arena, El Coto, El Bibio, Las Mestas, Viesques and Ceares» *neighbourhoods*.
— District called «El Llano».
— District South. It collects «Pumarin, Montevil, La Braña, Nuevo Gijón, Santa Barbara and Roces» *neighbourhoods*.
— District West. It consists of «La Calzada, Jove, Tremañes, Natahoyo and Moreda» *neighbourhoods*.
— This last district is called Rural District because gathers the following *rural parishes*: «Bernueces, Valdornón, Cabueñes, Caldones, Cenero, Deva, Fano, Fresno, Granda, Huerces, Lavandera, Leorio, La Pedrera, Porceyo, Poago, Ruedes, Santurio, Serín, Somió, Tacones, Vega and Veriña».

Figure 4. Neighbourhoods of Gijón

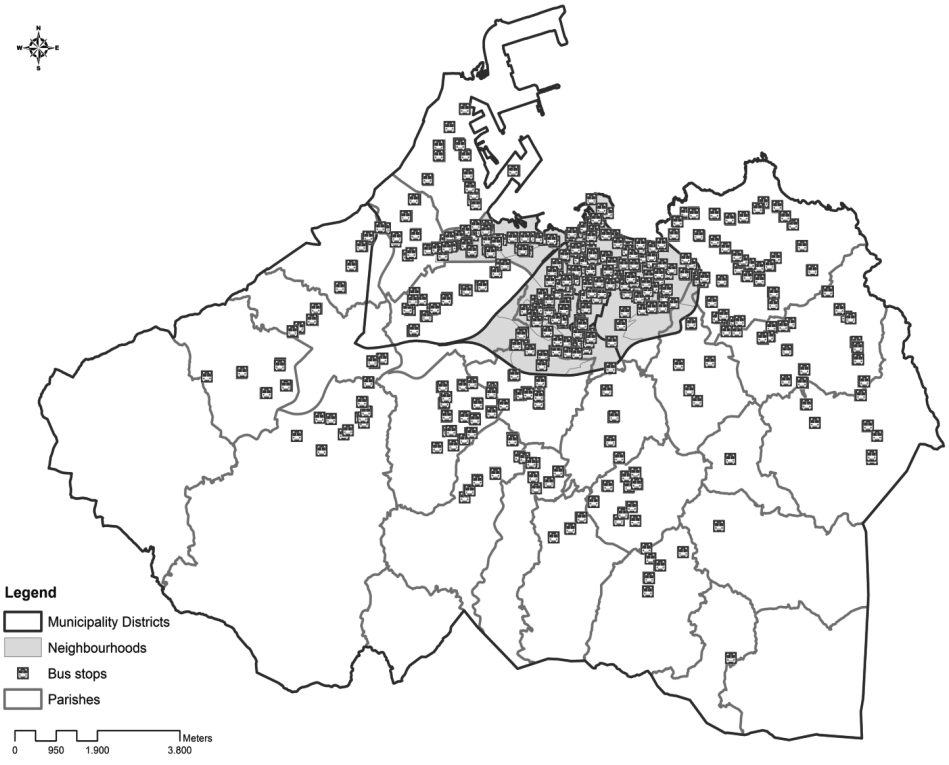
The Figure 5 shows the lines and stops of the collective urban transport in Gijón. This cartographic information is used to define the influence areas around each bus stop.

Following, the previously exposed methodology is applied to the case of Gijón in order to illustrate the aim of this paper. The GIS analysis is developed in several steps:

— Firstly, it was necessary the standardization of the database provided by the *Consejería de Bienestar Social y Vivienda* according to the cartography provides by the *Ayuntamiento de Gijón.* The *Consejería de Bienestar Social y Vivienda* has registered in its database 30,579 persons with disabilities in Gijón from which 28,723 are registered with complete address, i.e. block number. It is not taken into account the rest of the 1,856 people with disabilities in the analysis because the block number are not registered in their address. Therefore, we cannot identify them, geographically.

— Secondly, the two databases are merged using the block number —as it was mentioned in the section 3— to georeference people with disabilities. Thus, an additional database (GIS associated database) with 27,128 persons is obtained (Table 1). Secondly, the two databases are joined using the block num-

Figure 5. Location of the bus stops in the municipality of Gijón



ber to georeference people with disabilities. So, an additional database (GIS associated database) with 27,128 persons is obtained and it is exported in DBaseIII to ArcGIS 9 to visualize geographically the location of these people in Gijón. After joining, 1,595 people with disabilities do not appear registered in the associated database. In this case, this is due to official changes in the names of streets or the block numbers of the *cartographic database* that they have been not updated in the database provided by the *Consejería de Bienestar Social y Vivienda*.

— Finally, the cartography with the public transport supply is incorporated in the *GIS associated database* obtained in the step 2.

The cartography of the *Ayuntamiento de Gijón* was only available for the neighbourhoods of Gijón at the time of the research. Therefore, in order to map the people with disabilities and represented the influence areas of bus stops, the neighbourhood called «El Centro» has been used as an example for two reasons: it has more bus stops (35) and it registers more people with disabilities (4,016) (Table 1).

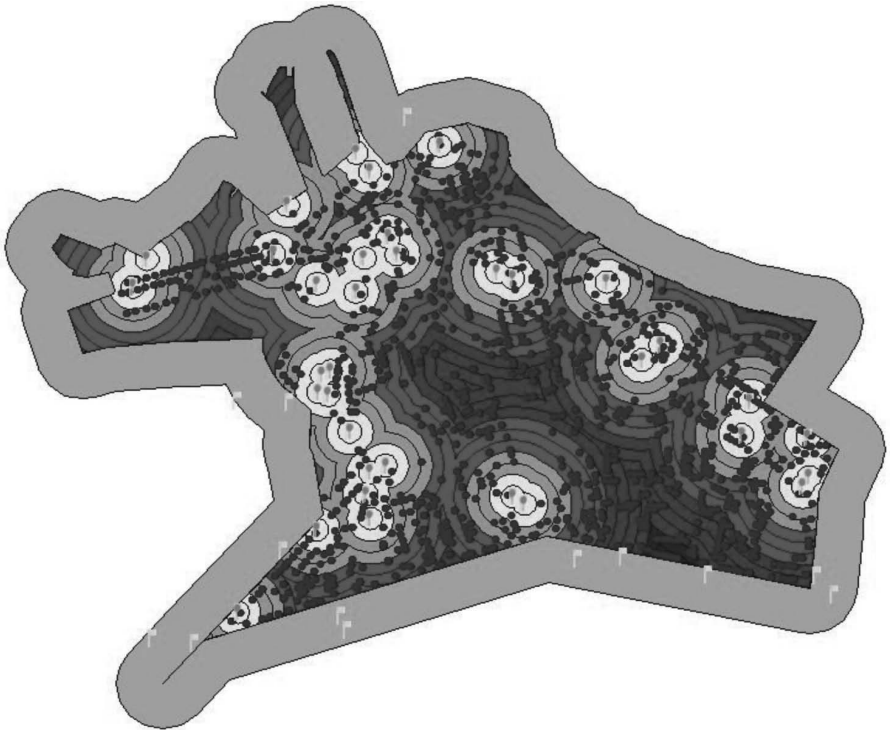
Table 1. Location of the people with disabilities in rural parishes and neighbourhoods

Parish	Disabled people	Neighbourhood	Disabled people	Bus stop (number)
Veriña	2	Ciares	2,031	10
Poago		Cimavilla	282	4
Santurio		Contrueces	464	6
Ruedes		El Bibio	418	8
Fano		El Centro	4,016	35
Jove	65	El Coto	1,220	17
Roces	42	El Llano	4,918	28
Granda		El Natahoyo	1,572	17
Vega		El Polígono	1,381	10
Bernueces	1	Jove	1	23
Leorio		La Arena	2,297	11
Fresno		La Calzada	2,553	30
Huerces		Las Mestas	92	6
Tacones		Laviada	2,007	11
La Pedrera		Montevil	281	13
Porceyo		Nuevo Gijón	518	6
Llavandera		Perchera	245	3
Tremañes	46	Pumarín	2,256	18
Cabueñes	6	Roces	211	11
Valdornón		Santa Bárbara	0	2
Caldones		Tremañes	4	23
Somió	136	Veriña	0	10
Deva		Viesques	63	13
Serín				
Cenero				
TOTAL	**298**	**TOTAL**	**26,830**	**320**

Figure 6 shows the influence areas in the «El Centro». The concentric circles are the distances to bus stops. These are measured in ranges of 25 meters to 300 meters according to the methodology proposed by Murray *et al.* (1998) and Wu and Hine (2003). Grey dots are the bus stops in both directions that are located in the neighbourhood and the dark grey dots represent people with disabilities. The grey area around the boundary of the neighbourhood is the enlarged area in 100 meters in

which the bus stops that users can access are located on yellow. This enlarged area is our contribution with respect to the proposal of Murray *et al.* (1998) and Wu and Hine (2003). The obtained result for this neighbourhood if the block numbers and people with disabilities are gathered for each distance is the following: as the distance to the nearest bus stop increases, the people with disabilities decrease. This graphic analysis may result in a quantitative analysis from the transport coverage index (TCI) that it is proposed below.

Figure 6. Influence areas of the neighbourhood «El Centro»



4.1. Spatial mismatch: transport coverage index

Next, an approach that allows us quantifying the degree of adjust of public transport supply to the spatial distribution of people with disabilities is proposed.

To do this, it is calculated a transport coverage index (TCI) in several steps:

— The first step was defining an influence area around the 320 bus stops located in the neighbourhoods of Gijón (Table 1).
— Secondly, the layers that represent the bus stops (geographically), and the neighbourhoods of Gijón where they are located were merged using «Geo-

procesing Wizard» in ArcGIS 9. Consequently, the obtained layer allows us to calculate where we can find a bus stop for each specified distance. According to the total area of each neighbourhood and the number of the bus stops, the distance it is used to carry out this analysis ranges between 75 and 375 meters.

— Thirdly, a specific search to show which part of the total area of the neighbourhood is within each distance previously set, i.e. the influence area around bus stops. For example, all the bus stops in the neighbourhood of «El Bibio» are located less than 375 meters of distance from a people with disability's house. The neighbourhood of «Tremañes» has the worst transport network, because the most of the bus stops are located at a distance more than 375 meters. This occurs in the neighbourhoods of «Jove» and «Veriña», too. Furthermore, it is possible to observe that «La Arena» has the best transport network because most of the bus stops are located within the range between 75 and 150 meters (Table 2).

— Finally, a cross reference search over the previous search allows us to calculate the TCI, i.e. what percentage of the each total neighbourhood area has bus stops to the distance ranges that we have fixed (Table 2). Next, the TCI might be expressed as:

$$TCI_i^d = (Ap_i^d / An_i)$$

where TCI_i^d is the coverage index, i.e. what part of the each neighbourhood area has bus stops to each distance range; Ap_i^d is the part of the each neighbourhood area (i), that belong to each distance range (d) and An_i is the each neighbourhood total area.

According to the TCI, Table 2 shows that «La Arena» is the neighbourhood that it has the best transport network because people with disabilities can find a bus stop in the range between 0 and 150 meters from their houses in approximately the 98% of the area. In the same way, in the 94% and 91% of the area of the neighbourhoods named «El Coto» and «Laviada», respectively, are located bus stops in the range between 0 and 150 meters. «Santa Bárbara» is the neighbourhood that it has the worst transport network because people with disabilities have to cover more than 375 meters to arrive at the bus stop in the 61% of its area, followed by «Tremañes», «Jove» and «Veriña».

In the case of «El Centro» and according to the graphic results obtained previously (Figure 5), it is not a badly connected neighbourhood, because approximately in the 83% of its area are located bus stops less than 150 meters of people with disabilities' houses.

From other perspective, Table 3 shows the distribution of people with disabilities in the neighbourhoods of Gijón according to the distance to the nearest bus stop in ranges of 25 meters (influence areas). As we have observed in Table 1, most of people with disabilities are located in «El Llano», followed by «El Centro». It is important to notice that people with disabilities are mostly located within 25 and 250 meters distance from the nearest bus stop in both neighbourhoods. If we relate Table 3 to TCI

Table 2. Coverage rates for transport (%)

Neighbourhood	Distance to the bus stop (meters)					
	[0-75)	**[75-150)**	**[150-225)**	**[225-300)**	**[300-375)**	**>375**
Ciares	15.47	29.89	22.82	14.40	11.55	5.86
Cimavilla	22.87	42.58	23.50	8.98	0.96	1.12
Contrueces	15.71	22.56	19.07	19.22	12.85	10.58
El Bibio	26.71	45.43	20.46	7.37	0.02	
El Centro	38.47	44.66	15.64	1.23		
El Coto	49.70	44.41	5.89			
El Llano	34.55	44.68	16.04	3.71	0.98	0.04
El Natahoyo	16.37	27.09	22.99	16.24	10.07	7.24
El Polígono	22.93	40.94	22.58	8.97	3.72	0.86
Jove	4.81	11.49	15.85	15.96	12.64	39.25
La Arena	47.86	50.29	1.86			
La Calzada	32.07	42.17	19.39	5.49	0.87	
Las Mestas	13.41	26.74	23.08	16.61	13.75	6.41
Laviada	44.14	47.31	8.55			
Montevil	33.54	49.88	16.00	0.59		
Nuevo Gijón	30.66	36.80	21.24	8.92	2.33	0.06
Perchera/La Braña	10.32	15.16	12.84	16.67	18.76	26.25
Pumarín	32.24	44.79	22.96	0.01		
Roces	13.29	25.15	27.64	21.42	8.80	3.69
Santa Bárbara	2.60	6.37	7.92	9.81	11.73	61.58
Tremañes	5.11	11.34	13.37	12.07	11.86	46.24
Veriña	6.19	14.83	21.84	14.19	11.18	31.77
Viesques	14.23	18.37	12.48	16.45	14.31	24.16

in Table 2, we can see that although «Santa Barbara» has the worst transport network, however, people with disabilities are not located in this area. «Tremañes» and «Jove» don't have a good connection because people with disabilities are located to more than 300 meters away from the closest bus stop.

This approach could be interesting to social services in terms of giving public aids to insert groups with special needs that are more likely to experience a transport disadvantage or transport-related social exclusion, such as the disabled and the elderly.

The merging of the information contained in the three database allows us to analyze the social reality in the sense that new data about these groups could be added to make statistical analysis that provide a relevant information about the socio-economic health in the studied areas.

On the other hand, GIS can provide management and integration technical solutions of socio-economic characteristics of the inhabitants. These data would be available to be used at a technical and political level in Public Administrations to make decisions taking into account the economic and social situation of the registered people.

Table 3. Disabled people distributed for neighbourhood and distance to the bus stop

Neighbourhood	Distance to the bus stop (meters)											Total disabled / Neighbourhood
	25	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**>275**	
Ciares	113	278	350	451	333	304	158	40	4			2,031
Cimavilla	1	40	51	42	66	48	29	5				282
Contrueces	29	103	84	111	95	22	16	3		1		464
El Bibio	12	75	81	111	74	48	17					418
El Centro	247	653	766	806	630	385	260	174	74	21		4,016
El Coto	131	306	377	253	118	18	9	8				1,220
El Llano	229	635	763	960	949	613	414	216	110	21	8	4,918
El Natahoyo	136	287	209	228	244	135	90	89	54	64	36	1,572
El Polígono	94	141	368	351	215	122	33	24	18	15		1,381
Jove											1	1
La Arena	176	458	583	500	342	205	33					2,297
La Calzada	182	440	498	606	438	230	99	51	9			2,553
Las Mestas	2	2	2	20	21	14	12	7	11		1	92
Laviada	199	303	609	367	317	186	20	6				2,007
Montevil	56	88	30	44	37	14	4	7	1			281
Nuevo Gijon	40	94	140	131	73	33	2			3	2	518
Perchera	8	38	75	79	23	5	1		6	4	6	245
Pumarín	82	287	323	305	329	385	267	166	100		12	2,256
Roces	4	24	49	39	44	39	12					211
Tremañes											4	4
Viesques	8	8	21	11	12	1	1				1	63
TOTAL	1,749	4,260	5,379	5,415	4,360	2,807	1,477	796	387	129	71	**26,830**

This geographical approach of the accessibility shows a supply perspective that it is worth being analyzed from the point of view of the public transport users. The increase in the number of bus stops determines the quality of the service from the user's point of view because it reduces the access time to the bus stops. However, the travel time increases due to the average speed reduction. This is «the opportunity cost» (disutility) of the travel time or «the generalized cost». If the

transport accessibility of people with disabilities is improved, the cross-subsidy between transport users increases: a greater desire of accessibility will induce to the transportation planner to add more bus stops in the network in benefit of such social group and with a some sacrifice of the average speed of vehicles for all users, at the margin.

5. Conclusions

Many governmental agencies and private organizations are beginning to use GIS to improve their services, assist in managing resources, and provide support for more informed decision making and policy planning activities.

In year 2001, European Union Funding Program created a new action axis called Society of the knowledge (Innovation, I+D, Society of the Information, FEDER) in order to promote knowledge-sharing, information and support to coordinate the territorial and cartographic information at local, regional, national, and European level. This may improve not only the collection and spread of data, but also the storage of new data.

Based on this premise and the proposal of the European Commission to improve the public transport accessible to all users, including people with disabilities and the elderly ones, the aim of this work is to build a new database integrated by a particular collective, i.e. people with disabilities, their location and their accessibility to public transport.

This information gathered can be used to better coordinate their services to fill any gaps or, alternatively, have evidence to support the need for additional funding for more services. This information is also important for the general public in order to improve the community's overall understanding of transportation services and the issues surrounding accessible transportation. People with disabilities can also use the information in a variety of ways including the possibility to determine where might be the best place for them to live in a community, choosing where they may make appointments for different services and deciding the transportation option that may best adapt to their needs. Furthermore, the methods employed in this research could be reproduced in other rural or small urban communities to assess its accessible transportation systems.

Besides being used as a prototype tool, this analysis can offer private companies a mechanism of control about the number and distribution of the people with disabilities through the consultations and obtaining thematic maps very useful for these companies allowing them to adapt its services to the existing demand.

In addition, with a GIS model, transport services planners can have a better equipment to coordinate, to evaluate and to control transport services. The improvement of communications to coordinate the efforts at the time of data collection and the interchange of information can lead to reduce the costs and increasing quality in the decision-making process, in long term. These spatial relations between people,

their activities and the territory in which they live allow us —through the integration of data— a better administrative management and a better knowledge of our surrounded areas.

In conclusion, promoting the development, the standardization, the dissemination and the sharing of spatial data at national, regional and sub-regional levels using appropriate information networks and infrastructures are an added value in improving social and economic research as well as, its usefulness in assessing, judging and planning public policies, as it is now recognized in Spain.

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