ACCESSIBILITY INSTRUMENTS FOR PLANNING PRACTICE: BRIDGING THE GAP BETWEEN ACADEMIC RESEARCH AND DECISION-MAKING

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ABSTRACT

One of the core objectives of urban planning practice is to provide spatial equity in terms of opportunities and use of public space and facilities. Accessibility is the element that serves this purpose as a concept linking the reciprocal relationship between transport and land use, thus shaping individual potential mobility to reach the desired destinations. Accessibility concepts are increasingly acknowledged as fundamental to understand the functioning of cities and urban regions. Indeed, by introducing them in planning practice, better solutions can be achieved in terms of spatial equity. The COST Action TU1002 "Accessibility instruments for planning practice" was specifically designed to address the gap between scientific research in measuring and modelling accessibility, and the current use of indicators of accessibility in urban planning practice. This paper shows the full process of introducing an easily understandable measure of accessibility to planning practitioners in Madrid, which is one of the case studies of the above-mentioned COST action. Changes in accessibility after the opening of a new metro line using contour measures were analyzed and then presented to a selection of urban planners and practitioners in Madrid as part of a workshop to evaluate the usefulness of this tool for planning practice. Isochrone maps were confirmed as an effective tool, as their utility can be supplemented by other indicators, and being GIS-based, it can be easily computed (when compared with transport models) and integrated with other datasets.

1. INTRODUCTION

The classic concept of accessibility is based on two pillars: land use patterns and transportation systems. The various components of accessibility derive from these pillars, and are as follows (Geurs and Van Eck, 2001) the transportation component, which contains indicators of quantitative aspects such as travel time, travel cost and movement in space; land use, which measures the distribution of activities and opportunities in space; time, where users' limitations are measured with regard to their activity patterns; and lastly, an individual component that covers aspects such as users' needs, capabilities and opportunities for transportation, and takes into account elements of social, demographic and economic development (jobs, population, etc.).

Accessibility measures are, among other things, tools to work with and consider when

dealing with urban planning, by providing a framework of information that allows an understanding of the behaviour of the complex system derived from this concept, both quantitatively and graphically. These measures have been categorized in several ways throughout various research studies. The work of Curtis (2011) contains an interesting classification, in which information is compiled from several methodological approaches and classified according to spatial separation, contour, gravity, competence, time-space, utility and network.

However, despite the large number of instruments available in literature, Vandenbulcke et al. (2009), and more recently Hull et al. (2012) reported the challenge of choosing an indicator with the right balance of interpretability, communicability and of an operational nature, among other criteria, which hampers the actual use of accessibility indicators to support urban planning practices. The COST Action TU1002 "Accessibility instruments for planning practice" was specifically designed to address the gap between scientific research in measuring and modelling accessibility, and the current use of indicators of accessibility in urban planning practice.

The first output of this COST action is a review of accessibility instruments and of the use of accessibility concepts in planning practice (Hull et al. 2012). The publication also provides a compendium of examples of accessibility planning instruments developed in several European countries. In addition, an interactive online tool1 was developed in order to guide users to choose the most appropriate instrument according to the geographical scale, transport mode involved, the purpose of the trip or type of opportunities to reach, the planning goal to be achieved, as well as the phase and role in the decision making process. It, thus, offers a detailed understanding and comparison of accessibility instruments across Europe in order to launch a wide debate on their purpose and operational detail and to foreground ways of improving their potential for use in practice.

In this paper we present the full process of introducing an easily understandable measure of accessibility to planning practitioners in Madrid, which is one of the case studies of the above-mentioned COST action. The remaining of this paper is structured as follows. Section 2 sets the framework of accessibility measures. Section 3 introduces the case study area and an analysis of the change in accessibility after the opening of a new metro line using contour measures. Section 4 explains the process to evaluate the demand of accessibility instruments of urban planners and practitioners developed by the above-mentioned COST action, and its implementation in Madrid. The final section contains the main conclusions regarding the accessibility measures implemented and their usefulness to urban planners.

2. UNDERSTANDING ACCESSIBILITY THROUGH CONTOUR MEASURES

Maps showing lines of equal distance to a particular point of interest are a very useful accessibility measure for planners. These lines (isochrones) can be defined as on a Euclidean basis (in straight lines) in the simplest model, or in relation to distance or travel time along a network. This procedure is of crucial importance, since the selection of the method for calculating the distance significantly affects the final results (Tillema, 2007). Fortunately, current data availability allows for the computation of isochrones along a transport network. Therefore, they can be easily calculated for the private transport, and

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1 Accessibility Instruments list, available at: http://www.accessibilityplanning.eu/accessibility-instruments-list/

also taking into account public transport and soft modes.

Isochrones are computed in a Geographic Information System (GIS), thus allowing the estimation of a variety of indicators and contour measures that offer information on the number of resident population, employees, potential customers, etc. covered by each distance or travel time area to a particular centre of interest (workplace, commercial centre, hospital, university, and so on). GIS allows isochronal measures to be visualized.

These are measures of accumulated opportunities when considering the amount of population or employment within a certain distance or time threshold from one or several centres of interest. Taking into account the total population within time thresholds, the measure of accumulated opportunities provides an estimation of the potential demand. Isochrones and derived indicators allow the identification of the areas which fall outside the accessibility threshold, as well as an estimation of the population or workplaces located within each accessibility threshold. Planning practitioners might find the identification of populated areas with poor or inexistent accessibility to public transport particularly useful.

Isochrones and derived measures received critics for requiring a subjective and sometimes rather arbitrary decision on what constitutes the spatial boundary for a phenomenon of interest. Still, isochronal measures obtain high marks for their transparency and intuitiveness (Cervero, 2005). Practitioners and the general public can easily understand a value such as the presence of hospital and medical-clinic beds within a half-hour bus ride as a gauge of how accessible an individual is to medical care via transit. The following section illustrates the use of isochrones and contour measured in the case study area.

3. MEASURING THE IMPACT OF A NEW METRO LINE ON ACCESSIBILITY: THE CASE OF THE METRO-SUR LINE IN MADRID

3.1. Introducing the case study area: the southern ring of Madrid metropolitan area

The metropolitan area of Madrid is characterized by high population densities, connectivity and public transport accessibility (both commuter rail and urban underground rail system), and also by its considerable economic dynamism. It is therefore possible to define an urban continuum from the city of Madrid to the municipalities in the southern arc, the Henares corridor to the northeast, and some adjacent municipalities in the north and west. This ring contains some of the most populated municipalities with over 75,000 inhabitants (Figure 1). All the municipalities in the first zone have a population of over 75,000 inhabitants: Móstoles, Alcalá de Henares, Fuenlabrada, Leganés, Alcorcón, Getafe, Torrejón de Ardoz, Alcobendas, Coslada, Pozuelo de Alarcón and Las Rozas de Madrid; with the exception of San Fernando de Henares. The first six municipalities have a population of between 150,000 and 200,000, and can be classified in the range of medium-sized cities according to Spain's urban hierarchy. They are set to the second urban stage from the Madrid metropolitan area (Dimensión metropolitana..., 2007). One of the elements defining urban planning has been the growth towards the municipalities surrounding the national highways leading out of the city, such as the case of the A-4, A-42 and A-5 which connect the city with the south area (Getafe, Leganés, Alcorcón, Fuenlabrada and Móstoles), which has the highest population density and is closest to the capital, at a distance of 20 km from the centre of Madrid.
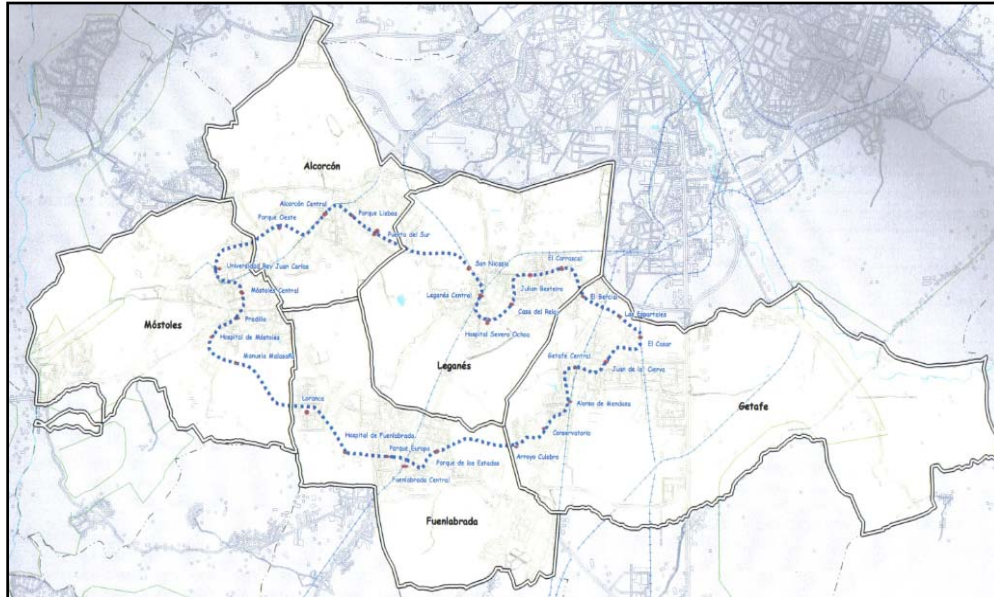
Figure 1. Municipalities in the south of Madrid, and Metrosur. Source: INE, 2010.

The public transportation system in the Region of Madrid is very comprehensive, and includes an urban underground rail system, a light rail/tram system, buses, commuter train, and interurban buses to meet the annual demand of 1,448.1 million travelers (Madrid Regional Transport Consortium -CRTM, 2010). Due to the expansion mentioned above, the regional government has enacted various measures to satisfy the demand generated in parallel to the growth of the cities located to the south of the Madrid Region: Alcorcón, Móstoles, Leganés, Getafe and Fuenlabrada. These measures included the opening of line 12, new circular subway line (Metrosur), which linked the five most important cities in the south of Madrid, without passing through the capital. This project represented the start of a non-concentric transportation network around Madrid, as shown in Figure 1. The objective of this new circular subway line (Metrosur) is to connect these five municipalities together. It has 28 stations, six of which have connections to the commuter rail network, and also connects to lines bound for Madrid via line 10, and has a total of 54.6 km, Melis et al, 2003 (Melis et al., 2003). A survey of Metrosur users was conducted following its opening in 2004 (October-November), which revealed the total traveller demand, as shown in Table 2.

Municipalities	Demand	% demand
Alcorcón	82,415	26.17
Fuenlabrada	53,515	16.99
Getafe	61,984	19.68
Leganés	61,706	19.59
Móstoles	55,338	17.57
Total line 12	314,958	100

Table 2. Metrosur traveler demand 2004. Source: Consorcio Regional de Transportes de Madrid.

3.2. Methodology

We aim is to assess whether travel time and transportation stages in certain activity centers (universities, hospitals, shopping centers, industrial areas and town halls) decreased in comparison with the scenario prior to the construction of Metrosur, and if travel time and opportunities (population and employment) increased, in order to quantify the changes. This research compares two scenarios i) year 2000, and ii) year 2009. The first scenario is derived from a study by the firm TEMA Consultores S.A. for the Madrid Regional

Transport Consortium, and the second scenario was developed in the course of this study in order to conduct a comparative analysis by applying a methodological procedure in two sections: a) construction of the isochrones; and b) construction of the indicators.

3.2.1. Construction of the isochrones

This first section of the methodology comprises five consecutive phases for the definition of the ex-ante and ex-port scenarios (scenario 1 and 2 respectively), the definition of the travel origins, the computation of travel times between each origin and each centre of interest, and finally drawing the isochrones.

The first scenario corresponds to three years prior to the existence of Metrosur, for which there are isochrones available for travel times to the various activity centers in these five municipalities. They were compiled in 2001 by the Madrid Regional Transport Consortium (CRTM) in collaboration with the firm TEMA Grupo Consultor, S.A.

The zoning of the study area was examined using a Geographic Information System, ARCGIS, and was organized into "microsections" (areas with similar urban characteristics based on size) generated by the CRTM for the study of scenario 1. This information was compiled from the data available (zoning census and population from 1996 and 2000, Index of Place Names in the Madrid Region for 1996, General Urban Plan, changes to previous plans, etc.). This zoning reflects the population of each microsection, each with an average size of 2 ha., is represented graphically in the Figure 2.
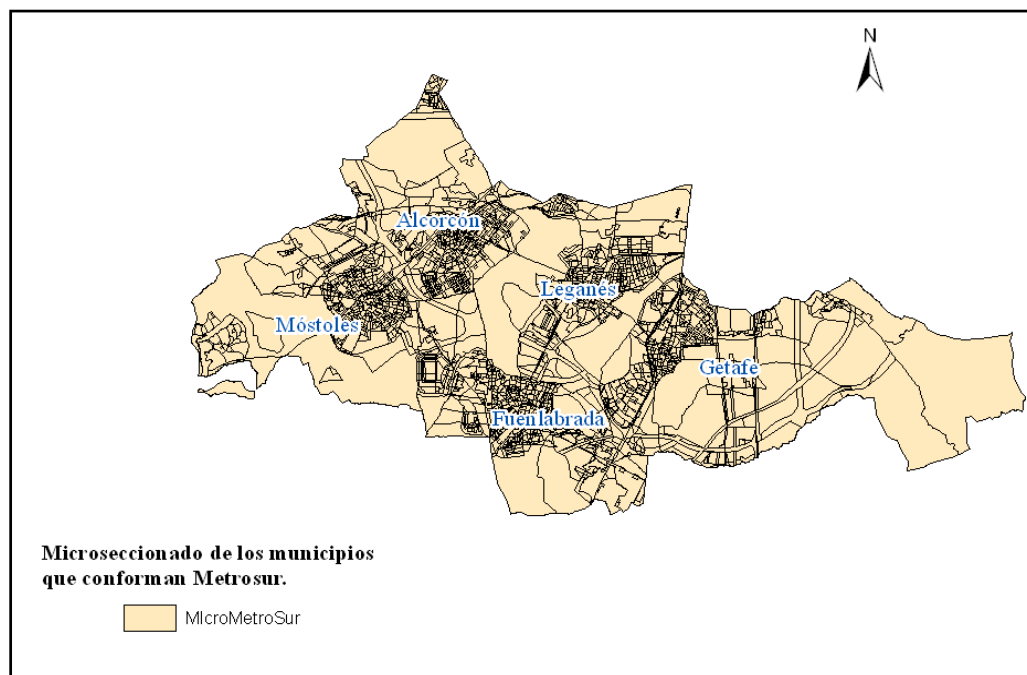

Figure 2. Geographical microsection of municipalities in the south of Madrid

The second scenario for this research was simulated with real data from 2009 provided by the Madrid Regional Transport Consortium (CRTM). This data represents a digitalized and more updated version compared to the door-to-door research in the municipalities in the study. This scenario was drawn up in order to reveal the real situation and confirms the changes that have been generated after the opening of the new subway line. To prepare this scenario, the following five travel generator sites were chosen for each one of the

municipalities: town halls, university campuses, shopping centers, industrial areas and hospitals. These give a total of 25 activity centers, which are located in Figure 3.
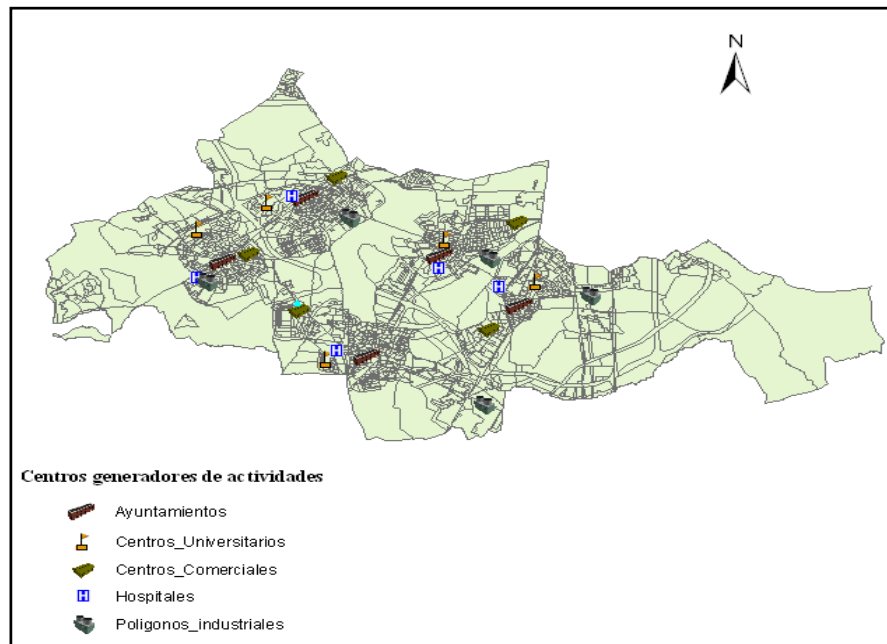

Figure 3. Location of the selected activity centers for the study in the municipalities in the south of Madrid: Alcorcón, Fuenlabrada, Getafe, Leganés and Móstoles.

The places of origin, thus departure points, where defined based on scenario 1 and using the available demographic data for 2009. According to the information from the door-to-door census provided by the CRTM, a new centroid was created by weighting the number of inhabitants per microsection to represent each of the potential sources of traffic for journeys between each of the five municipalities.

Travel times were obtained with the support of CRTM in order to simulate user trips in our study area. This information was obtained from a demand modeling system for urban, regional and national transportation forecasting, called "EMME" and used by Consortium. "EMME" contains all the lines currently available in the public transport network –urban underground rail system, bus and commuter rail. The model was developed for journeys to the 25 activity centers, in order to show the access time and transfer from line to line. This model determines the basic mobility parameters, which are subsequently represented on the GIS to obtain the isochrones. Maps of isochrones for each generating centre selected where produced and be compared with existing isochrones of year 2000.

3.2.2. Construction of the indicators

Two types of indicators were defined to evaluate accessibility: a) impedance indicators, which study time involved in travel and transfer from train to train; and b) opportunity indicators, which study the demographic uptake rate and employment in the surroundings of a reference node. These were calculated in several phases as follows:

Impedance was evaluated with the use of two indicators: "Average Travel Time", ATT, based on the average time of travel; and "Average Transfer Index", ATI, based on the number of stages in the transport. These indicators were calculated in the 25 activity centers for the two scenarios, also verifying the increase or decrease produced. The

impedance indicators were classified according to the reduction in travel time and transfer stages.

Then, we created an indicator to evaluate catchments opportunities. This indicator was based on research of Curtis: SNAMUTS (Hull et al., 2012) "Contour Catchment", CI, which is defined as the number of inhabitants and jobs within in an area of 30 minutes by public transport. It can be easily calculated from each one of the activity centers following equation (1):

$$Ci\ (r) = \frac{act\ (ci)}{act\ (m)} \qquad (1)$$

Where;

CI (r): Contour Catchment Index
   act (ci): Number of residents within at least 30 min by public transport from node i.
   act(m): Total number of residents in the metropolitan area.

This catchment opportunity indicator for residents was calculated for the 25 activity centers for both study scenarios, verifying the increase or decrease produced. The range of the indicator is from 0 to 1, where 1 is the value representing the greatest increase.

The same indicator can be used with the number of jobs available within at least 30 minutes by public transport from each node studied. However this information is not directly available on a scale in greater detail. For this reason, the analysis of employment opportunities was carried out focusing on the transport zones defined by the CRTM, which divides the municipalities in the study into different zones as follows: Alcorcón, 14 zones; Fuenlabrada, 17 zones; Getafe, 18 zones; Leganés, 24 zones; and Móstoles, 22 zones. The information on these zones for 2000 and 2009 was provided by our study. In addition, this analysis contains data provided by the National Institute of Statistics (INE) on commercial activity from the transport zones; an indicator designated "jobs" was correlated with the number of jobs in each municipality corresponding to 2000 and 2009.

The interpretation of the results according to these two elements can be seen in the discussion of the data. However, the direct impact of transport accessibility improvements on employment is one of the most difficult variables to estimate. This is due to the fact that it also depends on historical evolution, economic cycles and even on specific situations that requires long maturity time.

Finally, bearing in mind the indicators calculated for each activity center, the values obtained were classified by municipalities, and scaled following the pattern L (Low); M (Medium) and H (High). The purpose of this approach is to facilitate the interpretation of the results. The opportunity indicator was classified according to the increase in CI, and finally, the jobs indicator was classified according to the number of jobs in each municipality. (See Table 4).

No.	Municipalities	Reduction in ATT			Reduction in ATI			Increase in CI(r)			Jobs		
		L	M	H	L	M	H	L	M	H	L	M	H
1	*Alcorcón*			X			X	X			X		

No.	Municipalities	Reduction in ATT			Reduction in ATI			Increase in CI(r)			Jobs		
		L	M	H	L	M	H	L	M	H	L	M	H
2	*Fuenlabrada*		X		X					X			X
3	*Getafe*	X			X				X		X		
4	*Leganés*	X				X		X				X	
5	*Móstoles*	X				X		X				X	

L= Low, M=Medium, H=High

Table 4. Evaluation of indicators according to the changes produced in accessibility.

3.3. Analysis and results

After analyzing the 25 activity centers in our study, two municipalities were selected as having the highest and lowest changes in their travel times: Alcorcón and Getafe respectively. The isochrones for Alcorcón university campus (figures 4 and 5) and Getafe hospital (figures 6 and 7) are shown in years 2000 and 2009 respectively, since these are the activity centers with the highest and lowest change. We focus our analysis on these municipalities.

With the opening of Metrosur, Alcorcón benefited from a notable reduction in travel time. The most important changes were observed in the average travel time from each municipality to the U.C. of Alcorcon ("Rey Juan Carlos University"), which in 2000 had an average duration of 48.4 minutes, and after the opening of the new line dropped to 37.3 minutes. It is also worth noting the case of Alcorcón Hospital, to which the average travel time in 2000 was 38.7 minutes, and is now 32.7 minutes. This represents a reduction of 11.1 and 6 minutes respectively. The isochrones made in 2000 show that 700 people were around 0-15 minutes from this university campus. With the new database created in 2009, these isochrones show that this number has risen sharply to 66,892 people after the opening of new public transport network.

This is the most representative time saving of the 25 activity centers, taking into account that the U.C. of Alcorcón is located far from residential areas and train stations. The best connected municipalities to the U.C of Alcorcón are: Alcorcón and Móstoles (23 and 30 min.), while the other municipalities are located around 50 minutes away. Before Metrosur they were over 60 minutes away.

According to the isochrones made in 2000 for hospital centers, 263,700 people took around 15-30 minutes to reach a hospital. The isochrones in the new database created in 2009 show that these numbers increased to 295,203 people. Similarly, 98,977 people took around 60-90 minutes to reach a hospital according to the isochrones from 2000, while with the new data from 2009 this number was reduced to 7,124 persons. The numbers show that the new travel times benefit a large proportion of the population.

It can thus be seen that the new network has improved accessibility times to places in which public service was not available before. It should be noted that Alcorcón is the municipality with the fewest Metrosur stations (four stations).

Figure 4 shows the isochrones of the U.C. of Alcorcón created by the CRTM in 2000 before the inauguration of Metrosur, and Figure 5 shows the same result for 2009, after the inauguration of the Metrosur network.
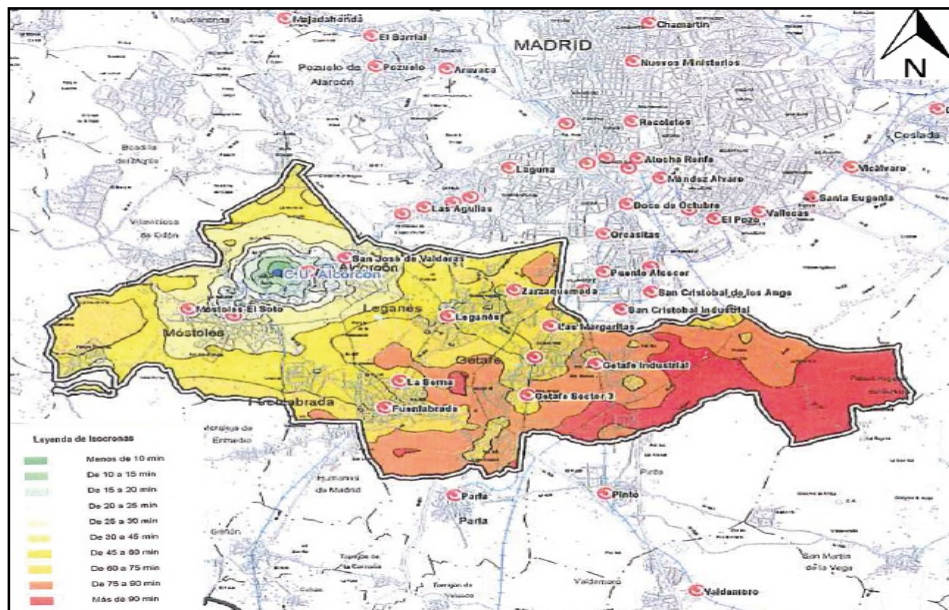

Figure 4. Isochrone's map of U.C Alcorcón showing the municipalities of Alcorcón, Fuenlabrada, Getafe, Leganés and Móstoles for 2000. Source: CRTM.
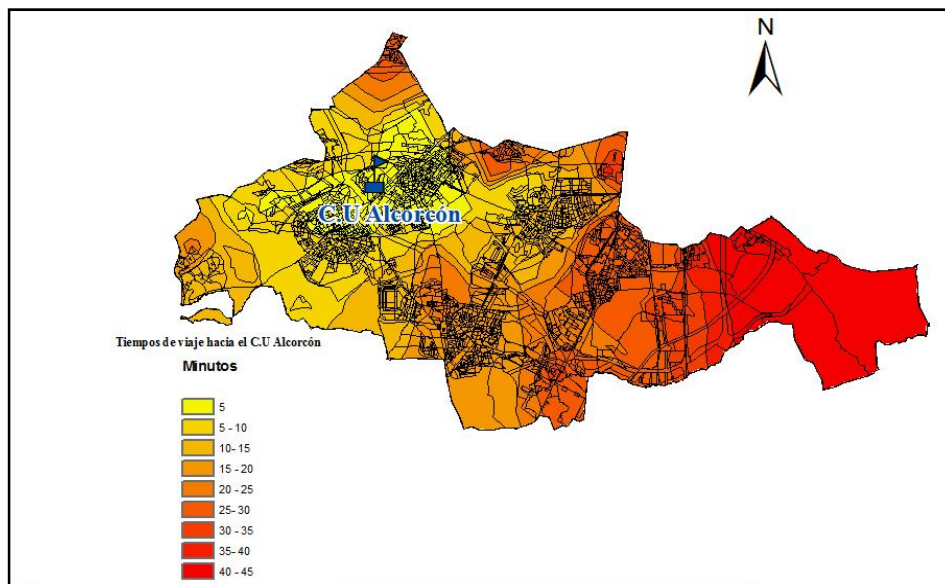

Figure 5. Isochrone's map of U.C Alcorcón: Differences in travel times compared to the scenario for 2000, generated after the opening of Line 12 (Metrosur) in 2009.

In contrast, the lowest reduction in average travel time after the opening of line 12 was obtained in Getafe. Travel time in journeys to U.C Getafe ("Carlos III University only dropped from 43.2 minutes in 2000 to and 41.9 minutes after the new line was opened. This was also the case of Getafe Hospital, whose travel time of 37.2 minutes in 2000 was reduced to 35.8 minutes in 2009, representing a decrease of 1.3 and 1.4 minutes respectively to each site.

According to the isochrones made in 2000, 66,892 people took around 0-15 minutes to reach the university campus. The isochrones in the new database created in 2009 show that these numbers rose to 70,230 people. Similarly 31,486 people took from 0-15 minutes to reach the hospital according to the isochrones from 2000, while with the new data from 2009 this number was reduced to 18,400 people. The numbers show that the new travel time is slightly reduced, but people living farther away obtain benefits due to better connections.

Of all the university campuses, U.C. Getafe benefits least in terms of travel time. The municipalities that are best connected to this center are Getafe and Leganés (16.9 and 32 minutes respectively), while the rest are over 60 minutes' travel. Regarding Getafe hospital, the two best connected municipalities are Getafe and Leganés (20 and 24 minutes respectively), while the rest are over 30 minutes' travel. These time savings are the lowest among the 25 activity centers in the study. Thus the new transport network has not brought any significant changes to these activity centers. It should also be stressed that Getafe is the municipality with the highest number of Metrosur stations (eight stations).

Figure 6 below shows the isochrones of Getafe hospital created by the CRTM in 2000 before the opening of the Metrosur network. Figure 7 shows the isochrones for the same hospital after the opening of the Metrosur network in 2009.
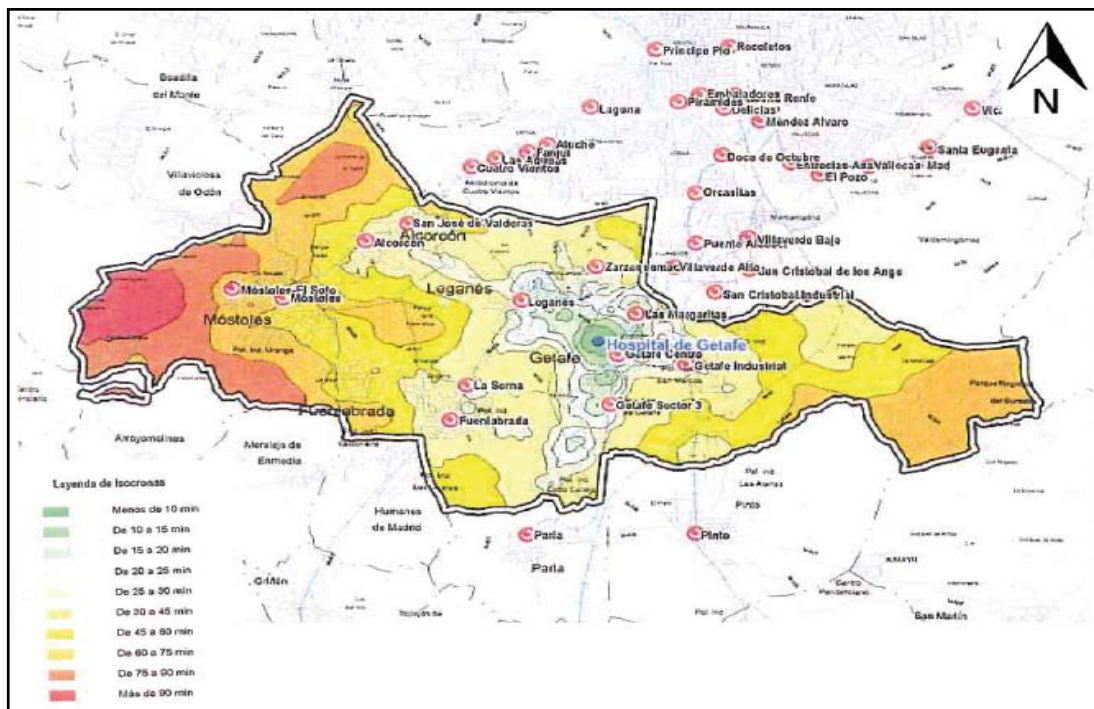

Figure 6. Isochrone's map of **Getafe Hospital** in relation to the rest of the municipalities: Alcorcón, Fuenlabrada, Getafe, Leganés and Móstoles in 2000. Source: CRTM.
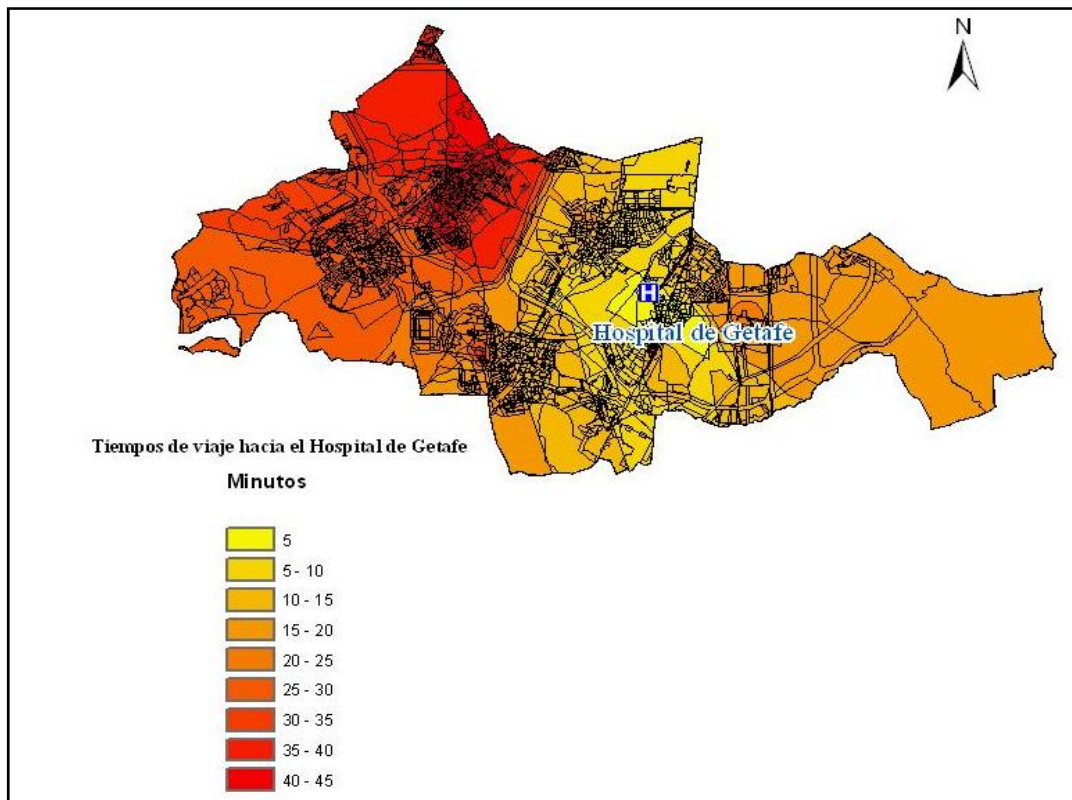
Figure 7. Isochrone's map for **Getafe Hospital**: Differences in travel time compared to the scenario in 2000, generated after the opening of line 12 (Metrosur) in 2009.

The analysis of the impedance revealed that, again, the highest and lowest changes in travel time and transfer stages were produced in Alcorcón and Getafe, respectively. The results are shown in Tables 4 and 5, which give the overall ranking of the results obtained for impedance indicators in the 25 centers. These results are then classified as shown in Table 8 at the end of this chapter.

The reduction of AAT in Alcorcón was the most significant of the whole sample. Based on the travel time and the isochrones, a reduction of 17% was obtained in average travel time after the opening of the new public transport network. In Fuenlabrada and Móstoles the reduction was 13% and 14% respectively.

As with travel time, the reduction in the transfer stages (ATI) generated after the opening of the new network in this municipality are the most significant compared to all the other municipalities, accounting for an average reduction of 10.7 % towards all the selected centers. In Fuenlabrada and Leganés the reductions were 6.8% and 6% respectively.

Based on the information for travel time and isochrones, Getafe showed the least significant reduction towards the rest of selected centers in Getafe. The expansion of the transport network produced a 9% reduction in travel time. The reduction in transfer stages generated by the new network in this municipality –as in the case of travel time– are the least significant, with an average reduction of 2.7%.

After analyzing the 25 activity centers in this study, the two municipalities with the highest and lowest change regarding job opportunities were selected: Fuenlabrada and Leganés. Their results are shown in Table 6. The overall classification of the results obtained in the evaluation of the 25 centers in terms of job opportunities is shown below, allowing each

municipality to be ranked. These results were shown in Table 4.

Fuenlabrada shows the highest demographic growth with a total of 12,384 inhabitants in nine years, accounting for an annual growth of 1.2%, according to the INE. This growth has been fuelled by the urban development generated in the municipality. According to the Madrid Department of Urban Planning, Public Works and Transport, Fuenlabrada ranks second in housing developments in the whole of the Madrid Region for 2009, according to Regional Spatial Strategy Plan (Consejería de Obras Públicas, Urbanismo y Transportes de la Comunidad de Madrid, 2009) , with 5,921 new homes. This volume represents 39% of all new housing in the five municipalities (15,095 new homes).
In summary, the catching opportunities for the activity centers can be seen to increase sharply with the growth of the population, especially around Fuenlabrada hospital and the university campus which have rate of over 100% and 52% respectively. These are the highest values of the entire region in the study.

On the other side, Leganés has a low demographic increase, consisting of 9,404 inhabitants during the nine-year period, accounting for an annual compounded growth of 0.5%. This slow growth is related to the scarce number of housing projects developed in the area. According to the Madrid Department of Urban Planning Public Works and Transport (*"Consejería de Obras Públicas, Urbanismo y Transportes de la Comunidad de Madrid"*), this municipality ranks fourth in new housing developments of the five included in the study, with a total of 3,300 new homes. This figure represents 21% of all new housing in the five municipalities for 2009. In summary, it can be seen that the catching opportunities for the activity centers do not show any significant change. Evidence for this is that the Parque Sur shopping centre and the university campus in Leganés show an increase of 0% and 9% respectively.

Finally, employment opportunities were analyzed based on the number of jobs in each municipality and transport zone, as well as on the data on commercial activity obtained from the CRTM. The results are shown in Table 5.

No.	Municipalities	Jobs 2000	Jobs 2009	% Reduction in jobs
1	Alcorcón	26,456	17,866	32
2	Fuenlabrada	38,954	23,084	41
3	Getafe	39,840	16,646	58
4	Leganés	32,584	18,819	42
5	Móstoles	30,807	20,941	32

Table 5. Jobs in the southern area of Madrid. Source: CRTM.

For the year 2000, employment rose in the municipalities that conform Metrosur at an annual accumulated rate of 2.8% according to the INE, with the commercial and industrial sectors highlighted as being the most representative. However, Spain's ongoing economic crisis has generated a notable reduction in jobs all over the country; these figures can be seen from the value of the jobs variable. Despite this, Fuenlabrada was the municipality that retained most jobs in 2009. This result is directly related to the development of new housing and commerce. These results are also certified by the CRTM for year 2000 and 2009 and specifically in the Loranca sector where there was no commercial activity in 1998, and where activity increased notably after the opening of subway line 12. These results are consistent with another study by Mejía (2011). An example of the growth of commercial activity can be observed with the Loranca shopping center, which was inaugurated along with the neighborhood in 2000 and became consolidated after the

opening of Metrosur, which generating increased economic activity, Gonzalez (2011).

In contrast, Getafe has the lowest job conservation rate for 2009 (45% reduction), although in 2000 it was in first place with the highest number of jobs. This situation has changed drastically due to the economic downturn. Observation of the transport areas of the CRTM reveals evidence that the economic land use has not changed significantly over the years, and nor has there been any major change in economic activity. The most important activities in 2000 were industry (due to the widespread availability of land for factories) and services; this situation continued in 2009. These results are confirmed by a study on the agglomeration of economic activities by Mejía(2011), where Getafe emerges as having the slowest annual commercial growth rate among the five municipalities.

A general aggregate analysis was made for the five municipalities, including the four consolidated indicators for the 25 activity centers. It was compiled using the evaluation of all the centers.

The value of each indicator is the % of reduction in ATT and ATI, % of increase in CI, and number of jobs. This value is obtained as a comparison between 2000 and 2009. These results were classified according to the following scale: Low (L), Medium (M), High (H), for each municipality. The results were shown in the Table 4.

The reduction in travel time was notable in the patterns studied towards the selected activity centers. Alcorcón and Fuenlabrada were the municipalities that benefited most from the new underground rail line with regard to travel time. The isochrone maps for the different scenarios highlighted the changes generated in the reduction in travel times, with the most important being the scenario recorded in the isochrones towards U.C Alcorcón (University Rey Juan Carlos). The time saved in these journeys is an interesting variable to assess and can be used in a cost-benefit analysis with regard to the advisability of investing in transport infrastructure, since this is the most important benefit for consideration in the planning stage for these kinds of projects.

The transfer stages necessary for travel towards the selected activity centers within these five municipalities did not show any relevant changes; the most important changes were observed in Alcorcón –more specifically in travel to U.C. Alcorcón. In view of the fact that this center was isolated from residential areas and commuter rail stations, the new underground rail line has represented a major reduction in the number of transfers needed to make this journey. In general terms, it can also be assumed that this marked reduction is also related to its connection to Madrid via subway line 10, which is the only point of connection between the southern municipalities and the capital.

In general terms, the contour catchments (CI) showed significant changes in every municipality. It is important to highlight that this index is calculated directly using demographic size, and these municipalities have undergone a very rapid demographic increase over the past ten years –particularly Fuenlabrada, which has the highest demographic density (5,238.8 inhabitants per square km). However, even though the catching opportunities improved, this municipality has the lowest demand for line 12 of the Madrid underground rail system, with an index of 16.99%. It is also important to highlight the station at Fuenlabrada hospital, whose catching opportunities increased by over 100%, with among the lowest user demand in the whole network, at 2.2% (*Aforo y encuesta de los usuarios de la red de Metrosur 2004 del CRTM*). This leads to the conclusion that accessibility represents potential mobility but not necessarily real mobility; that is to say,

improved accessibility does not necessarily represent more mobility. This last analysis could contribute to interesting lines of investigation in the future with regard to the correlation between these two variables in order to identify the extent to which new investments in transport infrastructure are justified. This analysis is particularly recommended for the stations of La Polilla and El Vivero in the Fuenlabrada project.

4. INTRODUCING ACCESSIBILITY TOOLS TO URBAN PRACTITIONERS

A series of structured workshops across European cities were developed in order to confront the scientific and practitioner viewpoints and to further understand the specific needs of urban planners and consultants, and the potential barriers for their use. In this paper we present the development and main conclusions after its implementation in Madrid.

The potential location of a mega-leisure centre in southern Madrid was presented during a workshop as an example for discussing the implications of new development on the accessibility of different parts of the metropolitan area. The results of the research presented in this paper, as well as basic private vehicle isochrones maps for the particular study case, were shown, followed by a discussion about the usefulness of this tool.

The participants in the workshop consisted on the four members of the working unit in Madrid and five external people from the urban planning perspective. Some of the participants had used accessibility measures in the past, particularly those coming from the transport planning and research fields, whereas others were interested in introducing the concept in their projects, thus their knowledge on the topic was at an initial stage.

The topic was first introduced in a pre-workshop meeting, where participants were asked to outline potential accessibility questions that they would like to discuss. Based on their comments, the working group defined the final planning problem, which was presented in the workshop. During the workshop, the working group developed an example of isochrones by private vehicle in order to start a discussion about the implications of the development of a new mega-leisure facility on the accessibility of Madrid. We explained how isochrones can be useful to measure accessibility to a certain point of interest and to count and characterize the population that have access to it. The role of public transport in the study area was also introduced to the participants showing the above mentioned analysis of accessibility to hospitals and universities with the use of isochrones and related indicators before and after the Metrosur subway line connected southern Madrid with the city centre.

The participants were asked to suggest measures that should be taken to improve accessibility to the new development while avoiding an increase in the congestion level of the transport network of the metropolitan area. Different kind of measures and viewpoints arose from participants with different profiles. For example, the participant with an academic profile emphasized the need to implement soft measures (i.e. road pricing vs. road construction), whilst urban planners showed their concern on the efficiency of that type of measures.

The group had an intense debate on potential measures that could help solve the problem of increasing accessibility to a certain point without worsening the current situation in other parts of the city. During the discussion, moderators exemplified the results of the

suggested measures based on their own expertise. Therefore, participants could evaluate its usefulness and the need to complement those measures with other in order to mitigate collateral effects.

5. Conclusions

Isochrone maps have been confirmed as an effective tool in this type of research, as their utility can be supplemented by other indicators, and they can even constitute an assessment model in conjunction with maps and indicators. This opens up possibilities for a wide field of investigation.

The correlation between employment and the expansion of public transport is difficult to estimate as it does not depend only on historic evolution or economic cycles but also on single performances that require a long time to mature. Moreover, this information is hard to find, since the census for economic activities is not available on level of detail scale, as would be required for the present study. Despite this, an analysis was made by observing the number of jobs retained by each municipality. This revealed that Fuenlabrada has the highest rate of employment. The analysis of these municipalities confirms the generation of commercial activity with the opening of line 12, especially in the area of Loranca and in the new districts established after 2003. This analysis was carried out using tools and indicators that have proved their usefulness, not only for transportation planning but also for urban planning activities. The conclusions of this study indicate that an adequate land use analysis must include an accessibility study and the corresponding graphic tools, such as isochrone maps, which facilitate the interpretation and handling of large amounts of information.

In general terms, after analyzing the four accessibility indicators for our study and the isochrone maps, the municipalities of Alcorcón and Fuenlabrada can be seen to have undergone greater changes in accessibility after the opening of line 12 of the subway system. In the case of Alcorcón, this was predictable due to its proximity to Madrid and its connection with line 10, which allowed both a reduction in travel times and transfer stages. Fuenlabrada also obtained significant benefits in accessibility after the opening of line 12, taking into account the fact that it is the farthest of the five Metrosur municipalities from Madrid, and is at an initial disadvantage with regard to public transport supply. For this reason the reduction in travel times represents a significant change. Furthermore, this research shows that Metrosur produced improvements in the connections between the five municipalities, creating direct access to universities, hospitals, service areas, shopping centers, entertainment activities and –to a lesser degree– to industrial areas.

Regarding the expectations of these measures to be integrated in the planning process, all the participants in the workshop agreed that the main strength of the tool is that it is GIS-based, thus it can be easily computed (when compared with transport models) and integrated with other datasets (i.e. population, credit card use…). It was agreed that results would benefit with the inclusion of traffic data and the integration of the public transport system. In addition to the recognition of the accessibility instrument as a valuable input for urban planning, it was also detected that policy making would benefit from a closer integration of data sources from different departments in order to better analyze land use and mobility needs through a transversal perspective.

REFERENCES

CERVERO, R. (2005). Accessible cities and regions: A framework for sustainable transport and urbanism in the 21st Century. *Working Paper*. University of Califormia, Berkeley.

Consejería de Obras Públicas, Urbanismo y Transportes de la Comunidad de Madrid (2009. *Plan Regional de Estrategia Territorial*.

CURTIS, C (2011). Integrating Land Use with Public Transport: The Use of a Discursive Accessibility Tool to Inform Metropolitan Spatial Planning in Perth. *Transport Reviews*, 31, 179-197.

Dimensiones metropolitanas de la Ciudad de Madrid (2007). Website: http://www.esmadrid.com/recursos/doc/es/Negocio/ObservatorioEconomico/67711256_78 2007152258.pdf. Last accessed on 28 August 2012.

GEURS, K. AND VAN ECK, J. (2001). *Accessibility measures: Review and applications*. Rijksinstituutvoor Volksgezondheid en Milieu (National Institute of Public Health and the Environment, RIVM) and Urban Research Centre. Bilthoven/Utrecht, Netherlands.

GONZÁLEZ, C. (2011). Ac*cesibilidad de centros comerciales en el suroeste de la Comunidad de Madrid en transporte público y bicicleta. Análisis en la zona de influencia de Metrosur*. Thesis (Master), Universidad Politécnica de Madrid. Spain.

HULL, A., SILVA, C., BERTOLINI, L. (Eds). (2012). *Accessibility Instruments for Planning Practice*. Portugal. COST Office.

MEJÍA, L. (2011). *Transportation infrastructure impacts on house prices and firms' location: The effect of a new metro line in the suburbs of Madrid*. Tesis (Doctoral), E.T.S.I Caminos, Canales y Puertos (UPM).
 Website: http://oa.upm.es/11288/2/INVE_MEM_2011_103577.pdf.

MELIS, M., ARNAIZ, M., TRABADA, J. (2003). *Metrosur*. Consejería de Obras Públicas, Urbanismo y Transportes.

TILLEMA, T. (2007). *Road pricing: a transport geographical perspective*, Ph.D. Thesis, Utrecht: Faculty of Geosciences, Utrecht University.

VANDENBULCKE, G., STEENBERGHEN, T., THOMAS, I. (2009). Mapping accessibility in Belgium: a tool for land-use and transport planning? *Journal of Transport Geography* 17(1), 39-53.