First study on mobility for a medium size town: Ciudad Real, a Spanish experience

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Abstract

Ciudad Real is a medium size Spanish town of 70,000 people located 190 kilometres South of Madrid and enjoys collective public transportation and a high-speed rail link with Madrid. This paper presents and analyses the results of the first study on mobility and public transportation's acceptability carried out in this town. Consequently, the methodology proposed is based on a household survey campaign (more than 995 valid questionnaires), main streets counting, a survey campaign at the main entrances and exits of town (1050 surveyed cars at the rush hour) as well as a sampling of travel time and occupancy of bus lines. Along with an analysis of city mobility, a detailed study is presented in which the relationship between the city's interurban mobility with Madrid by high-speed train line is depicted.
Keywords: urban mobility, transportation planning, public transport.

1 Introduction

In Spain, according to the census conducted in 2001, 24% of the population lives in towns with less than 10,000 inhabitants, 26% in towns whose population ranges from 10,000 to 50,000 inhabitants and another 26% who lives in towns whose populations range from 50,000 to 250,000 inhabitants. In short, more than 75% of Spaniards live in small or medium size towns. These percentages vary between different countries but most of the population is concentrated in medium size towns. The concern to improve public transport efficiency and efficacy in these towns is directly linked to their level of development. Therefore, comparing towns of similar size but with different mobility guidelines does not seem to be fruitful.

The local mobility of a given town should not be studied apart from its interurban mobility, especially for those medium size towns which have a very

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immediate connexion with a big town (more than 250,000 inhabitants). This is the case of Ciudad Real (see Fig. 1). Its peculiarity inside the national transport system lies on the fact that it was the first provincial capital of Spain to be provided with more than 20 daily high-speed rail shuttles (50 minutes travel time) to Madrid since 1993. A research paper carried out by the Transport Department of the University of Castilla-La Mancha, (Menéndez et al. [1]) tried to analyze the mobility in European medium and small size towns that would be similar to Ciudad Real: located in a high-speed train line, connected with an attracting centre in a trip time shorter than 90 minutes and with a connexion frequency of at least 9 daily services (both ways). The timetables should be compatible with work activity in order to facilitate the existence of commuters. As a result of the criteria mentioned above, the chosen cities turned out to be twelve: Mâcon, Le Creusot, Montbard, Vendôme and Valence (France); Göttingen, Würzburg and Fulda (Germany); Arezzo (Italy); Katrineholm (Sweden); and Ciudad Real and Puertollano (Spain). For all of them, the existence of commuters had modified some aspects of local mobility according to the place where the station was located in relation to the city centre (central station, external station and station located at the edge of the city). Nevertheless, the strategies used by the local authorities for mobility improvement were very different.

Ciudad Real is one of the Spanish towns included in this research but some data regarding its local mobility remain unknown. This is due to the fact that local authorities, though they knew that the town suffered from certain traffic-related problems at some specific points of its road network and that the use of public transportation was very low, had never carried out a transportation integrated study. The promotion of this type of transportation is intrinsically related to the knowledge that the potential traveller has regarding the characteristics of alternative ways to travel from a point of town to another. Information providers assume that users make reasoned choices between and behave rationally when considering alternative modes, making a rational trade off between the costs and the benefits of travel by each mode. Thus, if information about the true costs and benefits are revealed, travellers would choose to travel by the most cost-effective mode, where cost is seen to encompass factors including comfort, convenience, financial cost, journey duration and reliability, (see Ortúzar and Willumsen [2]). In spite of the information supplied by the local administrations, the role of habit in modal choice and the presence of symbolic affective motives behind modal choices have a lot of weight, especially in medium or small size towns. These cannot only affect the acceptance and the use of the information that is provided, but they can actually prevent the user from seeking the information about alternative modes (Kenyon and Lyons [3] and Abdel-Aty et al. [4]).

The household surveys carried out in Ciudad Real showed the great extent to which the population ignores the way bus lines work as well as their own transportation habits. This is the source of the second research work whose results are contained in this paper that is complementary to the former which deals with the Madrid-Ciudad Real interurban mobility.

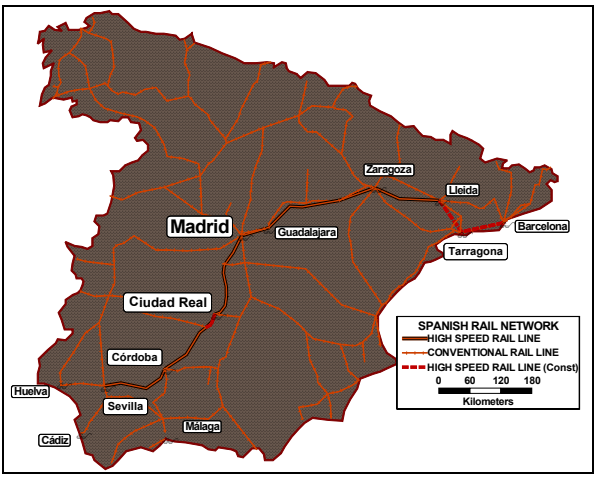

Figure 1: Location of Ciudad Real on the Spanish rail network.

2 The case of study: Ciudad Real

Getting to know the urban structure and the planning evolution of a certain town is the first step that needs to be taken in order to understand the way its inhabitants move. The old part of the town which is currently the town centre is located inside a ring-road called "Ronda" which runs along what used to be an old roman wall and which has been surpassed by the town's growth. 28% of Ciudad Real employment is located inside this ring road which explains the great attracting power of this part of town. The Ronda works as well as a distributor of all entry and exit moves around the centre. The train station and the bus station are both located outside the Ronda and are over 3 kilometres far from each other (see Fig. 2 left). The average expense per person in 2001 was 8.028'89 euro and the activity rate of the population is 50%.

In order to work with the basic road network of the town, all data was geographically expressed through a geographic information system (GIS), identifying for everyone the traffic direction (unidirectional or bidirectional), the number of lanes for each traffic direction, the type of pavement and the type of parking available. Only 45% of the road network is bidirectional and practically all the intersections with traffic lights are located in the Ronda. There are two parking areas in the town centre which offer 472 parking places with an average hourly fare of 1'10 euro. There are 5 urban lines in the town, 2 of them stop at the high-speed train station. In 1987, there were only 4 urban bus lines in Ciudad Real, but in 1992, due to the new high-speed train station, services increased with a new line which connects the town centre directly with the station that is located in the periphery and whose time tables are coordinated with those of the shuttle trains.

In order to analyze the mobility, the town was divided into 25 zones (see Fig. 2 right) organized in compacted neighbourhoods according to the local census. This zone division allowed the organization of each neighbourhood's household survey. The number of households was already known. The survey allowed us to obtain among other data the average number of people living in a household, the number of workers, students and vehicles per household. An approximation was made to obtain the number of student posts and jobs available in each neighbourhood, this taking into account the work place and study place of everyone of the people interviewed, with a dependent expansion factor of the surveyed analysis household neighbourhood.

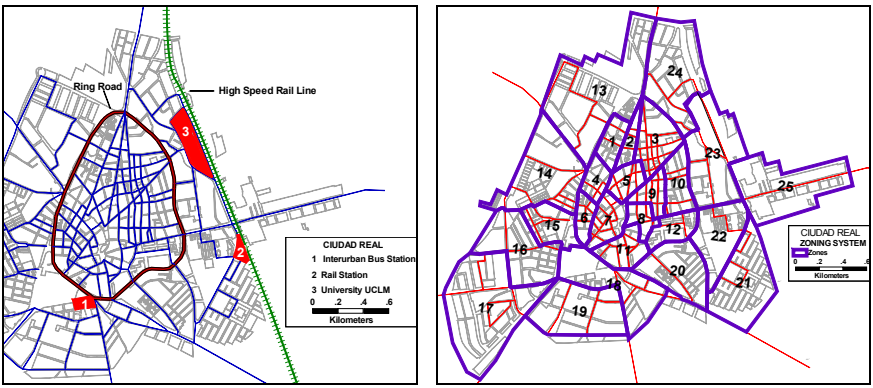

Figure 2: Urban structure, main streets and location of stations (left). City zoning system (right)

3 Household travel survey

This information gathering consists of a collection of data related to daily trips made by people living at a certain household on a typical day and inside the urban zone. This data collection is done through a survey with the people living at a certain household that has been previously selected. The goal of this method is to define the characteristics of those trips that start at the household of the surveyed population. The household, which is considered as the basic unit for information collection, allows the possibility of characterizing the trip generation and trip attraction rates referred to the residential zone as the known point of permanent departure and arrival, (see Taylor et al. [5]).

Regardless of the sampling procedure used, the sample size is a basic function of the two important factors: the standard deviation and the estimation error. The Spanish National Institute of Statistics (Instituto Nacional de Estadística, INE) suggests that there were 28,784 households in Ciudad Real in the year 2001. This information was complemented by the town council database associated to the control of household units in the administrative perimeter of Ciudad Real in the year 2003. Likewise, the information issued from the town council was also useful to eliminate the registers related to towns outside the built-up area of

Ciudad Real, since it has been suggested that a study be done of the mobility of these towns with Ciudad Real by means of a cordon survey. After having eliminated this data, a sampling frame of 27,793 households was established for the year 2004.

The sample's values of trips average and standard deviation still remain unknown for the case of Ciudad Real. This means that they must be obtained either through the results of similar researches or through a pilot survey which could allow approximating these values. The sources of information for this simplification that are already known are the household's trips average in similar towns which amounts to 7,98, and also a standard deviation of 24,39. According to the town conditions and apart from the budget restrictions that could limit the number of surveys to be done, a selection of a sample size of 982 household is suggested which match up with an estimation error of 3,80% with 95% of availability.

Taking into account the fact that a part of the information that is available includes the geographically referenced localization of each of the households in Ciudad Real (thanks to the town council's data base), the number of households of a certain zone can be associated to each zone of transport analysis. In this way, we can know the geographical distribution of the households and we can also estimate the housing density of every zone. Thanks to that, it seems to be appropriate to use the stratified sampling procedure in order to carry out the sampling selection. The stratified sampling methodology, where each statistical stratum matches up with a transport zone, aims to distribute with equity the total number of surveys to be done according to the size of each stratum.

After having determined the number of surveys to be done in each of the transport zones, the selection of the households to be surveyed in each stratum matches up with a simple contingent sampling. In order to carry out this process, the use of the Fan et al. [6], methodology, the selection sampling echnique, is suggested. Once each individual has been given a contingent number a, this methodology presents the following election criteria:

$$a < \frac{n_i - j_i}{N_i - k_i + 1} \tag{1}$$

where n_i is the number of elements that are to be selected in the stratum i, N_i is the stratum size i, j_i is the number of elements that have been selected up to now in the stratum i, and k_i is the consecutive that has been assigned to each element of the stratum i.

After having selected the households where the work was to be carried out, a first pilot survey showed very little receptiveness from the part of the families towards the interviewers. This was in part due to the fact that they had never submitted to a questionnaire meant to know their mobility. In order to alleviate this effect, the Ciudad Real town council sent a letter to every household to inform them about the possibility of them being interviewed. Likewise, the local radio station began an advertising campaign informing about the objectives of the household survey that was being carried at that time. After having adopted

these actions, the results of household responses improved remarkably. Finally, the surveys campaign was carried out between 19th May and 11th June 2004.

Once the survey forms were computerized, 6,448 trips having been registered, a trip histogram was done with the trips already expanded (237,909). The purpose of a histogram is to graphically summarize the distribution of a univariate data set. The cumulative histogram is a variation of the histogram in which the vertical axis gives not just the counts for a single bin, but rather gives the counts for that bin plus all bins for smaller values of the response variable. The calculation of this histogram was obtained by evaluating the percentage of each trip belonging to each period of 15 minutes during an entire day. The estimation of the total number of trips that occurs in the town within each studied amount of time can be achieved by knowing the percentage of each trip belonging to each period of 15 minutes and its respective expansion factor. In order to improve the analysis and to be able to define the hours of maximum demand, the 15 minute periods were grouped into one hour periods displaced every 15 minutes.

As the histogram shows in Fig. 3 there are three daily peaks on trip periods the most important being that of the morning, followed by the one at noon and, finally, the evening period which, though it presents fewer trips per hour, is the longest interval. Differently from a big city, the peak period of the morning starts later although, as we see later on when we study the cordon survey, there are towns less than 10 kilometres from Ciudad Real that are beginning to play the role of true dormitory towns.

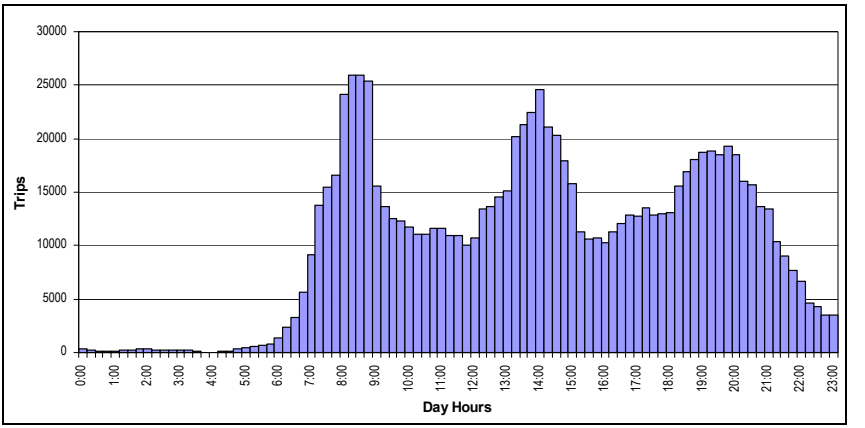

Figure 3: Trips histogram (2004).

Regarding the resident profile, 43% of the population is employed, 27% are students and the rest falls within the group of retired people, unemployed and housewives. The economic sector where most of the active population is located is clearly the services sector (68%), followed by commerce (9%) and finally the industry sector (7%). It is plain that we are talking about a tertiary population. The motorization rate of the population is high. 76% of the surveyed households

are motorized. From the total number of vehicles available in the surveyed households, 88% are private cars, 5% are motorbikes and 5% are bicycles. Only 23% of the resident private vehicle parking space belongs to the vehicles owner, 4% is rented, 60% of the people literally leave the vehicle "in the street" and the rest of the people resort to reserved public parking areas which are normally payable per hours. In relation to travel purpose, 45% are related with household needs, 19% are work-related, 7% are purchase-related and the rest fall within the group of "personal business".

Concerning modal split, of all the trips made by the surveyed residents, (6,448 trips), 61% were on foot, 31% by car, 4% on bus and 1% by motorbike. The use of public transportation is normally greater in big towns (over 250,000 inhabitants) and with a type of user who is very different from that of small towns. When a more thorough analysis of bus lines services is carried out by counting the number of travellers that get on and off at every stop and by comparing the *running speed* with the *travel speed*, the counters discover that the most numerous group of users consists of elderly people, children and students, a captive demand that does not own a private vehicle or that cannot drive anymore. There is also a less numerous group of users that travel from the centre of town to the high-speed train station. Even as the first group of users is characteristic of small or medium size towns, the second group appears as a consequence of the railway connexion between Ciudad Real and Madrid and it should be promoted so that more travellers can be attracted.

4 Analysis of the urban bus services

As we have already seen in the survey's data analysis, the use of public transportation is very low (only 4% of trips are by bus), and this first data encouraged us to carry out a series of trials aimed at knowing more in depth the way bus lines work. These trials allow establishing system operation characteristics such as trip duration, travellers that get on and get off the stops, speed of circulation, causes of delays on difficult points of the routes, etc. Two people in charge of counting are required for each chosen vehicle as part of the sample. One of the counters registers the number travellers get on and off the bus. The other counter registers the starts time, the stops time, the end time or the starting of the vehicle at each place of control or at each place where delays occur. The sample selection is made separately for each of the bus routes that are currently operative. Taking into account the duration of the trip and the frequency of passing, this sample shouldn't be inferior in each case to 10% of all services (the characteristics of the operation of the city bus services are shown in Table 1). In order to know the behaviour patterns, this selection must be made taking into account the peak hours mentioned in the previous pilot trial as well as some off peak hours. Since there are not different frequencies of passing on a day in the operation mode of the public transportation routes in Ciudad Real, the selection of the buses was made only taking into account the rush hours and the off peak hours which resulted from the standard stations.

Afterwards, both the running and the travel speed of the selected buses were measured by each stretch of the route. By running speed we imply the relationship between the distance covered by a vehicle and the time taken to cover that same distance while it was moving. This means that the time that the bus was stopped wasn't measured. By travel speed we imply the relationship between the distance covered by a vehicle and the time taken to cover that same distance including the times when it was stopped. At those times when the vehicle stopped or reduced its speed in a significant way to a speed that would be similar or even lower than walking speed (4 or 5 km/h), with all the subsequent delays, the observer had to identify that point and he had to register the time of start, the time of stop, the end time and the starting time as well as the cause for the delay (traffic jam, red traffic light, turn to left, travellers getting on or getting off), by using the appropriate convention or code included in the field format.

Table 1: Features of Urban Bus Transportation in Ciudad Real.

Line	Timetable	Frequency (min)	Length (km)	Travel (min)	km (2003)	Passengers (2003)	Pass/km
1	7:00–22:30	15	9,7	60	215,958	754,306	3,49
2	7:22–22:37	15	11,6	60	250,719	735,842	2,93
3	7:25–22:25	25	11,2	48	136,792	165,101	1,21
4	7:15–22:17	22	14,5	60	211,692	261,124	1,23
5	6:30–23:30	20	5,6	20	53,682	176,740	3,29

Most delays take place in unidirectional streets inside the Ronda and at some points on it. The two main causes for delay are people getting in and getting off the bus and also red traffic lights. When we analyze more in detail how the traffic lights placed in the Ronda work we find that their coordination was practically inexistent. When there are several traffic lights close to one another along a street or a road, it is necessary for them to work in coordination in order to avoid other cars crossing an intersection from having to stop again at a new intersection after having waited for the previous traffic light to change into green. Therefore, the gap or the time gone by between the change of phase of two successive traffic lights must be determined in such a way that the vehicles can cross a number of intersections without being obligated to stop several times, (see Cedar and Wilson [7]).

5 Effects of the high-speed train

As has been mentioned, one of the particularities of Ciudad Real as a medium size town is the fact of being connected with Madrid since 1993 through a high-speed railway line with more than 20 daily trips. In fact, railway mobility between Madrid and Ciudad Real amounted to 892,744 travellers in 2002 and the induced traffic generated by the new infrastructure has been also estimated (Guirao et al. [8]). This type of transportation offer, perfectly compatible with the work activity of both cities, gives place to a group of commuters which is also favoured by the existence of monthly tickets which are economically very

advantageous compared with the simple tickets. In March 2000, a survey to the high-speed shuttle users was carried out to analyze the users' mobility patterns for this stretch of the line. The surveys were carried out during the last week of March 2000 (4245 valid questionnaires) and the questionnaires consisted of two different blocks of questions. The purpose of the first one was to define the shuttle user's profile. The second one was exclusively directed to the "commuters" and its purpose was to know the characteristics and certain stated preferences of these daily users who are also called "abonados" (from the Spanish word for monthly ticket "abono").

One of the aspects that was analysed in the survey was whether there was a relationship between the commuters and the sudden growth of the neighbourhood next to the train station. Ciudad Real's train station is located in the periphery and there is much land available for construction around it. Fig. 4 (left) shows the percentage of commuters living in Ciudad Real according to their home's postcode. These values are especially remarkable when compared with those of Fig. 4 (right) which expresses the percentage of commuters living in Ciudad Real who stated in the survey that one important reason why they chose their place of residency was the closeness to the train station. This fact confirms the extent to which the high-speed train station favours the development of these zones in the city. These data affect local mobility because the commuter residency determines the route of certain urban bus lines in Ciudad Real.

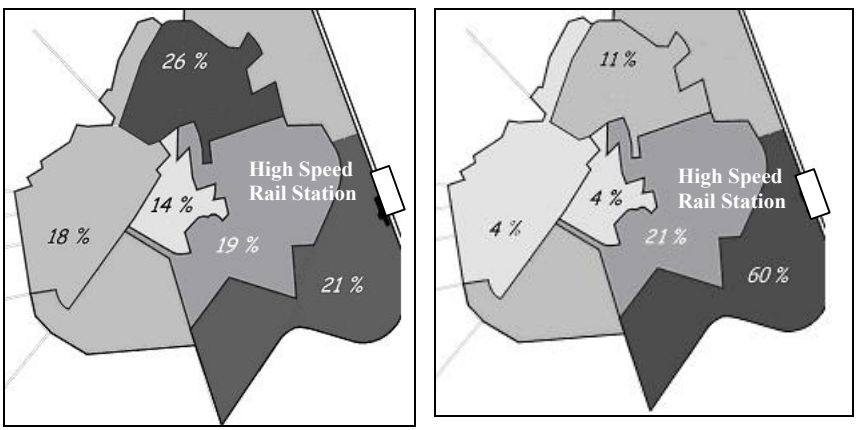

Figure 4: Percentage of commuters living in Ciudad Real according to their home's post code (left), and percentage of commuters living in Ciudad Real who stated in the survey that the most important reason why they chose their place of residency was the closeness to the train station (right).

The survey also gathered information regarding the time it takes for the users to arrive at the station as well as the transportation mode they use for that purpose. While most of the commuters living in Madrid can reach Atocha high-

speed train station in less than 25 minutes, to the Ciudad Real residents it takes around 10 minutes to reach the station. Taking into account the fact that most Madrid users live mainly in the city centre (80%), the distance from their homes to the aforementioned station allows good communication mainly by the underground and suburban train, and also, but not as importantly as the former, by bus. Therefore, the transportation mode used by Madrid residents in their home-Atocha trips is mainly private car (29%), underground (24%), bus (13%) and suburban train (23%). Only 9% of the travellers walk to the station and the rest of all must arrive by taxi or taken by a car driven by another person. Nevertheless, 19% of Ciudad Real commuters go to the station by private cars (the station is located in the periphery), 52% use the urban bus because of the existence of a service between the town centre and the high-speed train station and 24% walk to the station.

6 Conclusions

This paper shows the main mobility problems in a medium size town as well as the most appropriate methodology to detect them and to measure them. The household survey carried out in Ciudad Real, as well as a number of private cars counts in the main streets and a thorough analysis of public transportation made up a key tool for this research. The low use of public transportation is a common characteristic in this type of towns. Therefore, it is important to define those routes with most possibilities to attract passengers, to promote public transportation use and to coordinate the bus routes' timetables with those of interurban transport stations (Ciudad Real high-speed train station). The town connection with Madrid through the high-speed train line does not just condition the town's urban mobility to a great extent but it also conditions its land planning (residence of commuters). Precisely, because of this very reason, it cannot go unnoticed. Cordon surveys are useful to detect the presence of small dormitory towns located around the analyzed town as well as the repercussion it has on urban traffic. This fact, together with the knowledge of the town peak hours through a trips histogram, implies a vital tool for the transport planner. In this way, traffic calming measures can be implemented for the urban centre, giving thus true preponderance to pedestrian transport, which must be favoured in small and medium towns. The promotion of pedestrian transport also implies the improvement of life quality in the town centre and avoids the geographical population spreading.

Lastly, the usefulness of this kind of studies lies on the fact that they can show problems still unknown by small town councils because they lack the professional equipments specialized in transportation that big towns do have. An example for this is the lack of coordination among the different traffic lights of a given street or the fact that they don't know the commuters' place of residence nor their transportation needs in the access to the high-speed train station.

Acknowledgments

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