A GIS-BASED EVALUATION OF THE E-MOPED SHARING SYSTEMS IN SPAIN

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ABSTRACT

Sharing mobility is currently one of the most innovative features of metropolitan transportation and is rising along with the development of mobile phones and apps. Riders can rent bicycles, motorcycles, cars or PMVs like mopeds, usually electric, for short-time periods, usually per minute. Vehicle-sharing companies have entered the megalopolis, although the first sharing services were implemented in medium-size cities like Ulm in Germany, Cambridge in the USA or the main Swiss cities.

The purpose of this study was to analyze the current motorcycle sharing systems deployed in Spain based on GIS tools. The research focused on several Spanish cities, the main characteristics of which are representative of the whole country. The study can therefore be useful for companies in the sharing sector interested in introducing the system in cities which do not yet have them, and for government administrations interested in this type of system. Furthermore, this research is a starting point for future comparative studies on Spain and other countries, or electric motorcycle and other e-vehicle-sharing systems.

1. INTRODUCTION AND OBJECTIVE

This study focused on several different Spanish cities. Therefore, its conclusions serve to establish the main characteristics defining *motosharing* systems in this geographic area, and are the starting point for evaluating possible future research that can compare it with the situation in other places. These conclusions may also be of interest to the companies in the sector themselves and also to cities that are considering introducing these services.

The recent growing concern for pollution in large cities and the current trend to urban rezoning promoting more pedestrian spaces (Cervero and Kockelman, 1997; Madanipour, 2019; Plasencia-Lozano, 2014), are generating policies directed at reducing the presence of private vehicles in streets in the city center, especially, polluting vehicles (Mackett, 2001; Tomassetti et al., 2020). Sometimes the number of lanes in the main streets are reduced, causing an increase in the level of service, and thus, an increase in travel time.

It also reduces parking spaces or limits their availability to hybrid or electric vehicles, less used now (Szarata et al., 2017; Yan et al., 2019). This reality can be observed in several countries (Fitzgerald, 2020; Hooi and Pojani, 2020; Mandeli, 2019; Mozos-Blanco et al., 2018).

At the same time, in the last decade, society has been profoundly transformed due to the surge in smartphones and apps. All of this leads to the idea of mobility through per-minute rentals known as sharing, in which the facility offered is supported by mobile devices for geolocation, immediate payment, etc. Thus, companies have started up that offer riders per-minute rental in main cities of electric vehicles such as cars (*carsharing*) (Derikx and van Lierop, 2021; Guirao et al., 2018), bicycles (*bikesharing*) (Barberan and Monzon, 2016; Shaheen et al., 2012) or scooters (Fitt and Curl, 2020; Hardt and Bogenberger, 2019).

One of these options is known as *motosharing* (Spanish common word for describing the sharing of e-mopeds), now available in cities in several different countries, also in Spanish cities (Aguilera-García et al., 2020). The operator distributes a certain number of electric e-mopeds within the area for a rental time rate (usually per minute) which includes the right to the necessary safety equipment and accident insurance.

This is done by downloading the company app and searching for the closest vehicle. All of them have three different modes: (1) Rent, which causes the e-moped to appear as available on the app's map and shows the vehicle battery and autonomy. (2) Ride, which is activated when the rider begins to use it and ends when finished; in general, the rider pays a rate for the use of a e-moped that can reach speeds of 50 km/h, and some companies offer e-mopeds that reach speeds of up to 80 or 100 km/h. In this case, the rider can decide to reach those speeds, but has to pay a higher rate. (3) Repeat, reduced rate the rider can activate after having parked the vehicle to reserve it for further use.

Every company operates in a certain zone and the beginning and end of the journey should be inside that zone, although it may outside it as long as the battery and autonomy allow the vehicle to return to it. The company that offers the service is also responsible for recharging the vehicle and ensuring that all vehicles are in good condition.

The purpose of this study was to analyse the current *motosharing* services in Spain based on defining and determining a series of parameters that help to characterize the service by using QGIS open software for obtaining data.

Therefore, its conclusions serve to establish the main characteristics defining *motosharing* systems in this geographic area, and are the starting point for evaluating possible future research that can compare it with the situation in other places. These conclusions may also be of interest to the companies in the sector themselves and also to cities that are considering introducing these services.

2. METHODOLOGY

The methodology developed is based on finding parameters that characterize *motosharing* services by using two types of data: those related to the service offered by the companies, and those related to the area where the company offers the service (area covered, population density, etc.). The method is carried out in seven steps (Figure 1).

1.	**Sample definition**		Cities with mopeds; Companies in each city
2.	**Parameter definitions**		Number of companies; Prices; Speed; service area…
3.	**Sample characterization**	**Companies**	News on Company web sites; Calls; e-mails; Annual reports
		Cities	2020 census; City council websites; Urban sprawl
4.	**Lab work**		Data processing with QGIS
5.	**Parameter-based results**		Mopeds/km^2; Mopeds/100,000 pop.
6.	**Analysis of results**		
7.	**Conclusions**		

Figure 1: Method description

First, the sample (Spanish cities with a *motosharing* service) was defined. To find them, news items were searched for in local newspapers on this service being started up, increase in the city's fleet, and other published data. Data provided by the Spanish Metropolitan Mobility Observatory [*Observatorio de Movilidad Metropolitana*] were also included.

After finding the cities and the number of companies with permits to operate in each, the data that should be known about them to be able to arrive at the desired conclusions were defined. The following were chosen: number of companies, year *motosharing* began, service price range in each city, maximum e-moped speed, vehicles available, area of the zone covered for starting and ending the ride, population census in the zone, total area of urban sprawl.

Thus, the following parameters can also be determined: number of e-mopeds per 100,000 inhabitants, number of e-mopeds per km^2 and percentage of the total area occupied by urban sprawl of the zone offered for starting and ending the ride.

Once the parameters had been set, the sample was characterized. One part was characterization of the companies, for which their web pages were found and the section on news in some of them showed data of interest on the company's growth over the years (year started up in each city, growth of fleet, etc.); some data were not available on the internet and they had to be contacted or their annual reports searched. The other was the characterization of the zone available for starting and ending the ride. Using QGIS software, the area and population (data from 2020 census) were found for each of them. Finally, the results were analysed, and conclusions reached.

3. RESULTS

3.1. Cities with *motosharing*. Service characteristics.

Ten cities in Spain offer a *motosharing* service: A Coruña, Gijón, Barcelona, Zaragoza, Córdoba, Valencia, Seville, Cádiz, Málaga and Madrid (Table 1).

City	Number of companies	First year of service	Price range [€/min]	Maximum speed offered, combined [km/h]	Companies
Barcelona	5	2013	0.24 – 0.26	80	eCooltra; Yego; Movo; Acciona; Seat MÓ
Madrid	3	2013	0.24 – 0.26	100	eCooltra; Movo; Acciona
Seville	3	2017	0.26 – 0.27	80	Acciona; Muving; Yego
Málaga	2	2017	0.25 – 0.26	80	Acciona; Yego
Cádiz	1	2017	0.27	50	Muving
Valencia	4	2017	0.25 – 0.27	80	eCooltra; Muving; Yego; Acciona
Zaragoza	2	2017	0.26 – 0.27	80	Acciona; Muving
Córdoba	1	2017	0.27	70	Muving
Gijón	1	2019	0.29	50	HiMobility
A Coruña	1	2019	0.24	50	Motiños
Average	2	2016	0.26	72	

Table 1: Number of companies, year started up, prices and speed in each city.

Motosharing services were set up for a time in other cities, but were discontinued as unprofitable, and their vehicles were used to reinforce the fleets in other cities, or to start up a service where there was none yet. Murcia, Alicante, Granada and Palma de Mallorca are in this group.

Other cities have a seasonal *motosharing* service as in Gandía, where a fleet of 200 electric e-mopeds is deployed in the city every summer.

The characteristics and service conditions vary depending on the company that provides them. Some cities (Barcelona, Madrid) have had a satisfactory *motosharing* service for years, which makes the number companies operating in them larger than the Spanish average.

Another example is Valencia, where the service was begun only four years ago, but its popularity has made the number of companies operating in it grow rapidly. Other cities, such as A Coruña and Gijón, have recently begun the service and there is only one company currently operating in them.

3.2. Rates, speed

The highest rate is in the city of Gijón, which has only one company offering the service for 0.29/€/min. In the cities with more companies, the price is not over 0.27€/min, being A Coruña an exception as there is only one company operating for 0.24€/min, the minimum in the country. However, in all the cities, companies have lower rates for their regular customers, offering rides for 0.17-0.19€/min.

The maximum speed riders can reach depends on the model offered by the company. Two points should be emphasized: the users in the three smallest cities, Gijón, Cádiz and A Coruña, have e-mopeds available that can go no faster than 45-50 km/h, while in other cities there is at least one operator offering services with speeds of at least 70 km/h. This may be due to these cities having urban highways. Furthermore, Acciona offers the possibility of reaching 80 or 100 km/h, but at an added cost of 0.03 and 0.09€/min, respectively, over the original rate (Table 1).

Figure 2: Motosharing vehicles. eCooltra, HiMobility, Muving, Yego, Movo, Acciona, Motiños and Seat MO. Source: companies webpages.

3.3. Operating zone

The zone available for starting and ending the ride varies with the operator. The percentage of the urban sprawl occupied by the *motosharing* service zone varies depending on the city, although in all cases is over 40% (Figure 3, Table 2). The minimum is in Seville, where 43.76% of the total urban sprawl is zoned for *motosharing*, and the highest is in Cádiz: 100.81%. This is because the customers, in addition to the city center, can use it at the university campus, outside of the city itself. The mean of the total area is 72.31% of the urban sprawl zoned for *motosharing*.

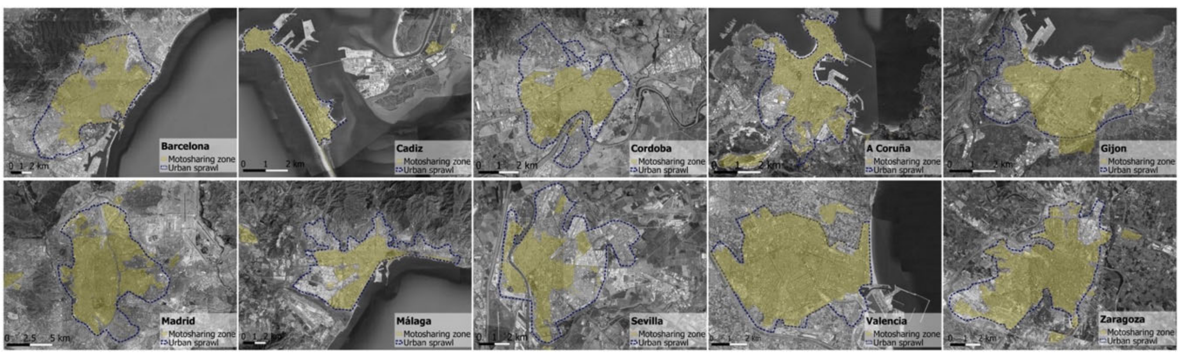

Figure 3: Motosharing operating zones and urban sprawl. Note that urban sprawl does not coincide with the municipal limits, but with homogeneity and continuity of total urbanized or partly residential space.

City	Area urban sprawl [km^2]	Area *motosharing* zone [km^2]	Percent urban area zoned for *motosharing* [%]	Autonomy [km]
Barcelona	67.57	45.06	66.68	80
Madrid	105.92	82.58	77.96	80
Seville	42.86	18.76	43.76	70
Málaga	47.24	23.13	48.95	70
Cádiz	5.37	5.61	104.42	70
Valencia	47.09	36.64	77.80	80
Zaragoza	42.79	37.18	86.88	70
Córdoba	21.44	11.38	53.08	70
Gijón	18.86	16.41	86.99	50
A Coruña	13.56	10.88	80.21	60
Average			72,7	

Table 1: Comparison of areas in different cities in Spain. The area of the *motosharing* zone includes the urban area where there is at least one operator.

3.4. Potential users

The 2020 census was used to calculate the residents in the zones set up by the operators (potential users), and also in the urban sprawl area (Table 3). Potential users have been compared with the total population of each urban area for evaluating the percentage of the population benefited by the service. In this case, the lowest percentage is in Seville, 51.17%, being Málaga the next with 71.55%. On the contrary, Cádiz, Valencia, Zaragoza and Gijón all have motosharing zones affecting over 95% of the population. Concerning the population density in each area, it has been set that the areas served by at least one motosharing company are in the same population density range of 14,455 pop/km^2 to 20,876 pop/km^2, except Barcelona, with a density of 29,152 pop/km^2. These figures are also higher than the population densities observed in the urban sprawl.

City	Urban sprawl population (2020 census)	Potential users [pop]	Percentage city population [%]	City population density [pop/km^2]	Population density in motosharing zone [pop/km^2]
Barcelona	1,725,977	1,313,629	76.11	25,542.27	29,152.89
Madrid	1,990,323	1,611,612	80.97	18,789.43	19,515.77
Seville	545,348	279,067	51.17	12,722.27	14,875.64
Málaga	467,304	334,363	71.55	9,890.53	14,455.82
Cádiz	107,253	106,922	99.44	19,514.88	18,524.42
Valencia	792,527	764,918	96.52	16,828.30	20,876.58
Zaragoza	586,055	575,617	98.22	13,694.92	15,481.90
Córdoba	267,004	201,251	75.37	12,453.42	17,684.62
Gijón	241,227	238,914	99.04	12,787.73	14,559.05
A Coruña	206,200	192,810	93.51	15,202.05	17,721.51
Average			84.19	15,742.58	18,284,82

Table 2: Population and potential users in the cities

3.5. Fleet

The fleet of e-mopeds available was defined by adding up all the companies that operate in each city. The Spanish cites with the most e-mopeds are Madrid (3,620), Barcelona (3,176) and Valencia (1,635). By contrast, Gijón and A Coruña services only offer 50. Analyzing the number of e-mopeds in each city per km^2, and keeping in mind the area zoned for *motosharing*, Barcelona is in first place, with 70 e-mopeds/km^2 followed by Valencia and Madrid with 44 e-mopeds/km^2 (Table 4). Last place is again held by A Coruña and Gijón: 4 and 3 e-mopeds per km^2 respectively.

City	Number of e-mopeds [Units]	E-mopeds/km^2	E-mopeds per 100,000 inhabitants
Barcelona	3,176	70.48	242
Madrid	3,620	43.84	225
Seville	440	23.45	158
Málaga	500	21.62	150
Cádiz	100	17.83	96
Valencia	1,635	44.62	214
Zaragoza	575	15.46	100
Córdoba	115	10.11	57
Gijón	50	3.04	21
A Coruña	50	4.59	26
Average		25,50	128,9

Table 3: Number of e-mopeds, zone for starting and ending rides, and potential users in each city.

The fleet in each city was also compared with the number of potential users in each zone by calculating the number of e-mopeds per 100,000 inhabitants. In this case Barcelona, Madrid and Valencia have over 200 e-mopeds/100,000, while Seville, Málaga and Zaragoza have over 100 e-mopeds/100,000. The rest of the cities have fewer than 100 e-mopeds/100,000, with Gijón and A Coruña at the tail with fewer than 30 e-mopeds/100,000.

4. DISCUSSION

This study analyzed some data related to the existing e-moped sharing systems in Spain (generally denominated motosharing in Spanish) in order to characterize them. Some parameters linked to the companies have been chosen, and also some data from the operating areas have been taken in account. After that, some ratios have emerged linked to the number of vehicles per inhabitant or the number of vehicles per km2.

The motosharing service was shown to be linked to large cities: the six largest cities in Spain were include here, and the seventh (Murcia) and eighth (Palma) at one time had motosharing services. It would be interesting to know the reason why in cities like Las Palmas de Gran Canaria or Bilbao, ninth and tenth in size, still do not have this service, and the reason why middle-sized cities, such as Gijón (15th place) or A Coruña (18th place), do.

It was also observed that the minimum population limit for this type of services is around 250,000 inhabitants. Rates were found to be rather homogeneous, although somewhat more economical in the cities with several operators.

Concerning the speed of e-mopeds, the larger number of operators is also linked to vehicles with higher top speeds. In general, the feeling is that competition between companies contributes to some of them wanting to be differentiated from the rest in this parameter. It has been also observed that cities with a smaller motosharing zone also offered e-mopeds with lower top speeds.

For example, Gijón, Cádiz and A Coruña, are the three cities with the smallest motosharing zone and also those with the lowest top speeds (50 km/h). On the contrary, Madrid, which has the largest zone, offers e-mopeds with top speeds of up to 100 km/h.

Another interesting fact is the percentage of urban sprawl that is covered by the different companies. Furthermore, the presence of more companies in the same city does not ensure wider coverage. One suggestive result is related to the population density in the companies' sharing zones.

This, as demonstrated, is in no case under 14,000 pop/km2. Therefore, it may be inferred that for the service to be profitable in a city, the population density in the sharing zone has to be extremely high. However, this population density is not related to the number of operators in the city.

The reason why the motosharing service is only available in areas where the population density is over 14,000 pop/km2 could be the lack of profitability of the service in areas below this density, so this cipher can be set as the minimum population density which makes attractive a central area for companies. It could be thought that although a city has a very small population, if it is a touristic city, the motosharing service would make sense there, but apparently it does not. In the end, the regular service customers are those who determine its triumph or failure in a city, so that motosharing in a touristic city would only make sense in the high season, as is the case in Palma de Mallorca.

Along this line, it is observed that the sharing zones have a much higher population density than urban sprawl as a whole. However, it is surprising that urban sprawl outside of sharing zones in Barcelona and Madrid have a population density over the 14,000 pop/km2 mentioned above, but the operators have not widened the service offered to the entire sprawl.

In percentage, the difference between the population densities in the sharing zone and the non-sharing zone is considerable in many cities, and shows that operators select the more heavily populated zones as (Table 5).

City	Density in urban sprawl [pop/km^2]	Density in sharing zone [pop/km^2]	Density in non-sharing zone [pop/km^2]	% difference in densities between sharing and non-sharing zones
Barcelona	25,543.54	29,15.89	18,318.44	63%
Madrid	18,790.81	19,515.77	16,22.84	83%
Seville	12,723.94	14,875.64	11,049.00	74%
Málaga	9,892.13	14,455.81	5,513.94	38%
Cádiz	19,514.88	18,524.42	-	-
Valencia	16,830.05	20,876.58	2,642.01	13%
Zaragoza	13,696.07	15,481.90	1,860.61	12%
Córdoba	12,453.54	17,684.62	6,536.08	37%
Gijón	12,790.40	14,559.05	944.08	6%
A Coruña	15,206.49	17,721.51	4,996.27	28%
Average	15,744.18	15,661.12	5,942.59	39%

Table 5: **Comparison of population densities in the urban sprawl and in the sharing zones**

It is worth mentioning that the rates are not related to a significant parameter a priori, the ratio which compares the e-mopeds per 100,000 pop and the *motosharing* zone, which determines the quality of the service offered (Table 6). However, this ratio may be related to the rotation of the e-mopeds, which in turn could be related to the area of the sharing zone: it seems logical that a smaller *motosharing* zone would be paired with a shorter distance to be covered by the ride, and therefore, length of time in use. This ratio was evaluated, and various groups appeared: one group is around 5.01 to 8.42, another in the fork between 1.28 and 2.72, and Cádiz with 17.11. This last is justified because the distance between the city center and the university campus, where it also provides the service, is quite long. The cities with lower ratios could be smaller, or metropolises where public transportation is easily available or transportation alternatives are high. In any case, it would be interesting to find relationships of this type in future research.

City	*Motosharing* zone [km^2]	E-mopeds per 100,000 inhabitants	Ratio
Barcelona	45.06	242	5.37
Madrid	82.58	225	2.72
Seville	18.76	158	8.42
Málaga	23.13	150	6.49
Cádiz	5.61	96	17.11
Valencia	36.64	214	5.84
Zaragoza	37.18	100	2.69
Córdoba	11.38	57	5.01
Gijón	16.41	21	1.28
A Coruña	10.88	26	2.39
Average	28.76	128.9	6.37

Table 6: **Ratio which compares the e-mopeds per 100,000 inhabitants and the *motosharing* zone**

There are some limitations and biases in this study. The data handled are rather reliable and objective, except perhaps the size of the urban sprawl, although there are metropolitan areas where the separation between the urbanized and unurbanized zones is clear, while in others, the definition could be somewhat more subjective. Thus, in Cádiz, it was decided to define the city itself as an island. However, Puerto Real or even San Fernando could have been included. Another question that could vary is the number of e-mopeds the companies offer in a city, as they fit the e-mopeds offered to the needs detected and better or worse reception of the service by citizens.

With a view to future studies of the *motosharing* service in Spanish cities, other factors could be considered in evaluating the service's feasibility, such as traffic inside the city, the percentage of the city that is pedestrianized, the city's motorization rate, the city's shape or alternative services offered, both sharing and public transportation. Another of the factors that could directly affect the use of this service is the climate, as the number rainy days per year or the mean annual temperature could influence users when making the decision to use the service or not. Another possible future study coming out of this one is of those *motosharing* services that have failed in recent times, such as in Murcia, Alicante or Granada, quantifying the parameters determined in this text, and comparing the differences in values of the cities analysed here. Furthermore, this method could be replicated for the study of other e-moped systems in other countries, and for comparing them with the Spanish system. Finally, the ciphers stated here could be used by companies and municipal administrations for planning futures services or for planning urban expansions (it is clear, for example, that low density cities are not interesting for e-mopeds sharing companies).

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