ABSTRACT

Housing density and the relative length of road or frontage are different urban variables which are proportional only in the case of homogeneous developments based on single-family dwellings. However, when the impact of an urban pattern on the operating cost of public services is analyzed regardless of the settlement morphology, both variables are often considered as equivalent, overlooking the role of the relative length of road, which might be important due to the linear component of the cost of many of them. This study highlights the differences between the economic role of the two variables, showing that housing density explains better the operating cost per unit area of services such as roads and parks maintenance, while the relative length of road does so in water cycle, waste collection, disposal and treatment as well as street cleaning.

Keywords: Linear efficiency; Housing Density; Economic Sustainability; Urban Public Services

INTRODUCTION

Housing density and the relative length of road or frontage are two different urban form indicators which are usually closely related (Schwarz, 2010), but are proportional only through a specific size and shape of lot in developments exclusively based on single-family dwellings, as when the buildings possibly have different number of flats or there are large non residential areas, the same housing density may lead to different urban patterns (Peiser, 1989; Dekel, 1995). Despite the above, when urban planners or public authorities try to analyze the relationship between the set of variables which characterize an existing or future urban area, and the operating cost of its public infrastructures - even in the case of complex urban patterns -, both variables are considered as equivalent, and the role of one of them, usually the relative length of road, is overlooked. Since the operating cost of most public services is composed of many factors, some of them with a predominantly linear character, this improper practice may lead to erroneous economic assessments. The aim of this study is to highlight the different impact of housing density and the relative length of road on the operating cost of the services more closely related to the territory, the so-called property services (Mace, 1961), and the need to consider both variables simultaneously but independently when the influence of a set of urban factors on the operating cost of urban services is analyzed.

In order to carry out this study, a set of medium-sized Spanish cities with population between 100.000 and 300.000 inhabitants were described according to their average housing density and relative length of road; the operating cost of their services was estimated, namely water supply, sewage and treatment (water cycle), waste collection, disposal and treatment, street cleaning, public lighting and maintenance of parks and pavements. This allowed for highlighting the different economic role of both urban variables by estimating the correlation level between them and the operating cost of the public services analyzed.

The study is organized thusly: the next section reviews the studies which have analyzed the relationship between both urban variables and the operating and maintenance cost of the public services, as well as the problems arising when their roles are confused or overlapped. This is followed by a statistical analysis of the relationship between these two urban form parameters and the operating cost of the public services more closely related to the territory in the set of cities selected. Finally, the main findings and conclusions of the study are shown.

BACKGROUND

Since the relative operating and maintenance cost of urban infrastructure is closely related to a set of political, social, economic and urban factors (Guengant et al., 1995; Bastida et al., 2013), many researchers have tried to identify both each of them as well as the intensity and direction of their influence. For example, in the field of urban planning, the economic role of variables has been identified, such as the land use (Margolis, 1956; Isard and Coughlin, 1957; Paulsen, 2009; Burchell y Dolphin, 2009), settlement dispersion (Wheaton and Schussheim, 1955; OFDT, 2000; Speir and Stephenson, 2002; Carruthers and Ulfarsson, 2003; Fluvià et al., 2008), the level of service (Kain, 1967; Hirsch, 1968; Ladd and Yinger, 1989; Heikkila and Davis, 1997; Hortas-Rico and Solé-Ollé, 2010), the building-type (Stone, 1973; Brück et al., 2000), housing density (RERC, 1974; Carruthers, 2008; Edwards and Xiao, 2009; Hortas-Rico and Solé-Ollé, 2010, Libertum and Guerrero, 2015) and the relative length of road or frontage (ULI, 1958; Caminos and Goethert, 1978; Speir and Stephenson, 2002; Chen et al., 2008). The latter is also named linear efficiency or edge density. Moreover, the urban form does not only affect the economical sustainability of the city, - an inherently complex concept that is not based exclusively on the lowest cost of service provision, since it includes the efficient delivery of services, job creation, housing prices, etc. (Xing et al., 2009) -, but also the social and environmental one. From a social point of view, the influence of urban variables such as housing density or building-type is well-known, due to their impact on people's living conditions (Bramley and Power, 2009; Mulliner et al., 2013) and for example housing density and mixed land use are involved in the level of pollution in the urban environment (Jabareen, 2006).

Among the studies which have tried to identify and measure the role of the urban variables on the operating and maintenance cost of the urban public services, it is possible to distinguish two main groups. Those studies which have analyzed the role of a single urban variable would be included in the first group, either because this was their aim or because the contribution of the built environment has been simplified only to one of them. Studies which have analyzed the simultaneous influence of a set of urban variables are included in the second, either by using econometrical or engineering techniques (Ladd, 1992). In the first group, when a single urban parameter is used in order to characterize the urban form, this variable is usually the density in its different forms (Downing and Gustely, 1977; Carruthers, 2008; Edwards and Xiao, 2008; Holcombe y Williams, 2009; Hortas-Rico, 2014; Libertum and Guerrero, 2015); and also, when a set of urban factors are considered, one of them is always this variable (Wheaton y Schussheim, 1955; OFDT, 2000; Speir and Stephenson, 2002; Hortas-Rico and Solé-Ollé, 2010). However, despite the large number of studies developed, the role of housing density remains ambiguous (Edwards and Xiao, 2009; Libertum and Guerrero, 2015), partially due to the contribution of a number of methodological shortcomings.

The first methodological problem is that neither the characterization of the variable nor the expression of results is consistent across studies (Churchman, 1999; Hortas-Rico, 2014). Although housing density has always been defined as the number of inhabitants or dwellings per unit area, econometric and engineering studies have measured very distinct realities on the basis of the data available in each case (Ladd, 1992; Solé-Ollé and Bosch, 2005). Econometric studies usually examine statistical data that can hardly be broken down below the municipal level; hence, they tend to measure housing density across the municipal area as a whole (Ladd, 1992; Ladd, 1994). The disadvantage of this measurement scale is that any rise in population will automatically increase housing density, which in turn overlooks the possible impact of growing population dispersion within the municipal limits and produces unrepresentative average values (Elis-Williams, 1987). To overcome this problem, recent econometric studies have focused on data for the developed area of the municipality rather than the total area (Carruthers and Ulfarsson, 2003; Hortas-Rico and Solé-Ollé, 2010). In addition, it is necessary to consider that housing density is not the best parameter to define the urban pattern when there are large non residential areas, being necessary in this case to replace it with the "net dwelling density", which considers the average housing area on the total urbanized land (Alexander, 1988). However, its use has a problem arising from the difficulty to allocate the operating cost of the services to a specific use. In contrast with econometric analyses, engineering studies focus on specific existing or theoretical areas (Frank, 1989), where housing density is exclusively representative of the area analyzed, and it is usually expressed as the number of dwellings per unit area. As a result of those differences, the main stream in engineering studies usually suggests that an increase in housing density leads to savings in municipal expenditure on many public services (Whaton and Schussheim, 1955; RERC, 1974; Camagni et al., 2002; Speir and Stephenson, 2002), although there are some exceptions (Kain, 1967; Gordon and Richardson, 1997; Morlet, 2001); while in econometric studies results are very dissimilar . For example, Burchell and Muckherji (2003), Hortas-Rico and Solé-Ollé (2010) and Bastida et al. (2013) show that high density decreases the operating cost of many public services, while Ladd and Yinger (1989) or Holcombe and Williams (2008) reach the opposite result; Ladd even (1992) indicates that there is a U-Shaped relationship. Both types of studies also differ in the presentation of results. Whereas econometric studies usually express the relationship between housing or population density in per capita cost terms, engineering studies may examine the correlation between that urban variable and per inhabitant (Isard and Coughlin, 1957), per unit area (Caminos and Goethert, 1978), per dwelling (Wheaton and Shussheim, 1955; Speir and Stephenson, 2002) or for a specific area (RERC, 1974; Downing and Gustely, 1977) cost.

The second factor that has complicated the analysis of the impact of housing density on municipal spending is the correlation between this variable and other urban, social or economic factors (Fouchier, 2001; Castel, 2006). For example, low housing density is usually correlated with high incomes (Kain, 1967; Dekel, 1995; Kotval and Mullin, 2006), which usually leads to positive fiscal results in low density-areas, overlooking that the effects of low housing density, taken in isolation, might be negative (Paulsen, 2009). In addition, areas with the highest housing densities are often populated by low-income households, creating a “harsher” social environment which might generate additional expenditure on specific services such as street cleaning, police or fire protection (Ladd, 1994). Another example is the relationship between housing density and the level of service, particularly given the range of public services provided in some areas. It is often considered that in low-density areas collective sewage can be omitted (Wheaton and Schussheim, 1955; Isard and Coughlin, 1957), while other services such as traffic lights are only provided in the highest-density areas (Ladd, 1994; Guengant et al., 1995; Ewing, 1997). For this reason, in order to identify the specific influence of housing density, a gamma correction is needed to adjust the different set of services provided (Guengant et al., 1995). A similar effect is observed in the relationship between housing density and population size. In general terms, higher densities are only recorded in large urban settlements (Solé-Ollé and Bosch, 2005), which leads to a combination of economies of scale and density (Carruthers and Ulfarsson, 2003). The exception, identified by Holcombe and Williams (2008), would be the significant saving on infrastructure costs registered in small urban settlements with high housing densities.

A third problem might be pointed out : the mistaken identification of housing density as a determinant of municipal expenditure on certain public services when the cost is determined, at least in part, by another urban variable as is linear efficiency, which is not equivalent, defined as the road length or frontage per unit area. There are essentially two reasons why a direct relationship does not usually exist between housing density and linear efficiency as determinants for the operating cost of public services. Firstly, although population size is dynamic, the basic infrastructure of the city is relatively fixed. Secondly, the same linear efficiency can be found in urban patterns with extremely varied levels of housing density.

For example, if the total number of inhabitants is reduced by half, thus reducing the population density, is it reasonable to assume that municipal expenditure for the provision of certain public services will also be halved. It seems evident that this would not be the case, since the volume of existing infrastructure such as lighting installations or water supply and sewage pipelines would remain unchanged. Trash collection vehicles would continue on the same route to collect half the volume of waste. It is true that certain costs, such as those associated with the volume of water requiring sanitation and treatment, would be reduced in the same proportion as the population, but total expenditure would not fall by half and thus affect the expenditure per inhabitant or per unit area. This is one of the most pressing issues in the administration of cities with declining populations (Koziol, 2004; Moss, 2008). Due to this mixed nature of the operating cost of most public services, housing density largely determines the “amount of supply” necessary per unit area in the services of water supply, sewage and treatment (TCRP, 1998; AEAS, 2011) or waste collection, disposal and treatment (Álvarez et al., 2005; Bel, 2006), while the linear efficiency or frontage length as the main determinant of the development costs per unit area (ULI, 1958; Caminos and Goethert, 1978) does so in the maintenance of the infrastructure, since it is well-known that there is a relationship between their size and their operating and maintenance cost (Stone, 1973; Martin and March, 1975). This has been observed in public services such as the water supply and sewage (Speir and Stephenson, 2002), street lighting (Tähkämö et al., 2012), waste collection (Bel, 2006) or street cleaning (Álvarez et al., 2005).

Similarly, as indicated above, the same housing (or population) density over a particular area is likely to be linked with different urban configurations (Peiser, 1989; Dekel, 1995; Chen et al., 2008; Schwarz, 2010). If a particular part of the urban settlement has double road length per unit area but the same housing density as others, are the operating costs of public services the same? Clearly not. This underpins the doubts expressed by Windsor (1979) about the results of the RERC study (1974).

However, despite the fact that the different economic role of the two variables and the mixed nature of the expenditure components of many public services are well-known, when the urban pattern is characterized by a set of parameters in order to analyze their incidence on the operating cost of its public services, the simultaneous influence of the two variables is not considered, establishing a sort of equivalence between these two variables even when the complexity of the urban morphology does not allow for establishing a direct proportion between them. Econometric studies, for example, make no reference to the relative dimensions of public space as a determinant for expenditure on public services due to the lack of broad statistical data on the total road length of whole towns or cities (Ladd, 1992; Bastida et al., 2013); but when they do, they suggest that the reduction in municipal expenditure on public services whenever there is a high housing or population density derive largely from linear services such as water supply and sanitation, street lighting, etc. - assuming that the high density is always characterized by low relative length of roads (Hortas-Rico and Solé-Ollé, 2010). This situation also occurs in studies where the relationship between the development cost of infrastructures and the urban variables is analyzed, even when it is known that many elements of the cost - as is the case with pipelines - have a linear nature (Álvarez et al., 2014). In engineering studies, the failure is more pronounced. Although focused on reduced existing or theoretical areas where it should be possible to measure both factors simultaneously, they focus predominantly on one of them, establishing a direct relationship between housing density, frontage length and lot size (ULI, 1958; Kain, 1967; Speir and Stephenson, 2002; Najafi et al., 2007; Mohamed, 2009), when, as indicated, this approach might only be reasonably in a few situations (Dekel, 1995); and of course it is not assumable in cities with complex morphology, varied building types or larger areas of non-residential land use.

METHODOLOGY

In order to analyze the different role of the housing density and linear efficiency as determinants on the operating and maintenance of the public services more closely related to the territory, so-called services “to the property” (Mace, 1961), it was necessary to select a set of urban areas and to measure both these two urban variables and the operating cost of its infrastructures. Since the operating cost of the public services is not usually available for specific urban areas (Castel, 2006), the study was carried out at municipal level considering average gross housing density and linear efficiency; although it would have been desirable to have focused exclusively on the residential areas of the city. However, since the sample cities are essentially residential, the approach is considered sufficient.

For economic data, the most direct source of information for the operating cost of the basic public services is the municipal budget. However, as many authors have indicated, there are a number of caveats:

i) Municipal budgets take the form of forecasts (Downing and Gustely, 1977; Guengant et al., 1995), although in the case of current expenditure the execution is in excess of 95% (Morala and Fernández, 2006).

ii) The cost of public services may be spread across various budget allocations and include common expenses on a range of services (Hirsch, 1968; Camagni et al., 2002). It is also necessary to distinguish between operating and maintenance costs, on the one hand, and costs corresponding to depreciation of infrastructure, on the other (Castel, 2006).

iii) Real costs may include expenditure deriving from the delivery of public services by private contractors, public-private partnerships, local authority associations, etc. that is not reflected in the municipal budget (Guengant et al., 1995; Klug and Hayashi, 2007).

Consideration of the economic factors described above requires a comprehensive analysis of municipal budgets and detailed research into the management of public services in each municipality in order to identify those services that are provided indirectly or by third parties.

In the case of urban planning data, since municipal expenses on public services are mainly generated in effectively developed areas, it is necessary to measure the total municipal developed area to obtain its average housing density and relative length of road. Since the aim of this study is to highlight the different role of these two urban variables, in the cities analyzed, statistical correlation between both regressors cannot exist (Schwarz, 2010).

The complexity of analyses both of the municipal budget and of finding urban settlements without statistical correlation between the housing density and the relative length of road means that, unlike the econometric studies, large samples cannot easily be examined. This is not a problem for this study, since beyond obtaining consistent statistical results about the correlation between the two urban variables and the operating cost of the public services, the main objective of the research was to highlight the differences between said variables in this field, and for this reason, the need to consider its concurrent effect in multi-variate analysis.

Given the above considerations, this study focuses on Spanish cities with a population between 100.000 and 300.000 inhabitants, since the current expenses in municipalities with populations above or below this range may be affected by uncontrollable external factors (Solé-Ollé and Bosch, 2005); the cities of Algeciras, Almeria, Salamanca, Logroño, Lleida and San Sebastian have been chosen as they form a sample without correlation between the housing density and the linear efficiency. The sample size is similar to other studies such as Wheaton and Schussheim (1955), Mace and Wickler (1968) and German Federal Ministry of Finance (2006) and it is enough for the purpose of this study. All cities in the sample have the typical structure of Mediterranean cities, with a very compact pattern formed by a mixture of residential multifamily dwellings and commercial areas with some industrial developments in the urban fringe. Given the Spanish legal structure, all municipalities provide the same range of services, most of them with similar level (water cycle, public lighting and waste disposal and treatment) although some differences are likely to be found in the waste collection or street cleaning services (the level of the latter is not homogeneous throughout the city). Service level for these two services (2010) in each city is summarized in Table 1:

CITY	WASTE COLLECTION				STREET CLEANING	
	ORGANIC	GLASS	PACKAGING	PAPER	MANUAL	MECHANIC
Algeciras (AG)	6 days/week	Not available	Not available	Not available	Not available	Not available
Almeria (AL)	7 days/week	1 day/week	2 days/week	2 days/week	7 days/week	1 day/week
Salamanca (SA)	7 days/week	1 day/week	3,5 days/week	3,5 days/week	6 days/week	1 day/week
Logroño (LO)	7 days/week	Not available	2 days/week	3 days/week	6 days/week	3 day/week
Lleida (LL)	7 days/week	3,5 days/week	3,5 days/week	3,5 days/week	4 day/week	1 days/week
San Sebastian (SS)	Not available	Not available	Not available	Not available	Not available	Not available

Table 1. Level of service for waste collection and street cleaning

Source: Author, from municipal responsible of the service

The total urbanized area and each city's length of road were measured directly by using the aerial photography provided by the SigPac geographical information system of the Spanish Ministry of Agriculture, Food and Environment, which ensures that only effectively developed areas are considered. Certain econometric studies of Spanish municipalities have delimited the developed area on the basis of Property Assessment Office figures (Hortas-Rico and Solé-Ollé, 2010; Bastida et al., 2013), but this practice might present problems as unoccupied developable land could be officially classified as developed land and often covers considerable areas (Spanish Ministry of Development, 2006). An example of measurement for total developed land and length of road is shown in Figure 1:

Figure 1. SigPac image showing measurement of total urbanized area and road network. Salamanca

Source: Author, from SigPac

Finally, the statistics of Property Assessment Office of the Spanish Ministry of Finance and Public Administration were used to estimate the total number of dwellings in each city (number of buildings categorized for residential use). The results for the urban data in the set of cities selected are shown in Table 2:

CITY	INHAB.	ROAD LENGHT (km)	URBANIZED AREA (ha)	TOTAL DWELL.	INHAB/ DWELL.	POPUL. DENSITY (inh./ha)	ROAD LEGHT/ INHAB.	LINEAR EFFIC. (m/Ha)	HOUSING DENSTY (dwell./ha)
Algeciras (AG)	116,417	266.4	1515.3	51,694	**2.25**	**76,82**	**2.29**	**176**	**34**
Almeria (AL)	190,013	369.0	2410.7	90,779	**2.09**	**78,82**	**1.94**	**153**	**38**
Salamanca (SA)	154,462	283.5	1807.7	89,908	**1.71**	**85,44**	**1.84**	**157**	**50**
Logroño (LO)	152,650	185.2	1805.7	74,705	**2.04**	**84,53**	**1.21**	**103**	**41**
Lleida (LL)	137,387	225.1	1689.4	62,281	**2.20**	**81,32**	**1,64**	**151**	**37**
San Sebastian (SS)	185,506	288.5	1936.4	82,336	**2.25**	**95,79**	**1.56**	**149**	**43**

Table 2. Urban variables for sample municipalities

Source: Author, from SigPac and Property Assessment Office data

Once each city is characterized by its average gross housing density and linear efficiency, it is necessary to check the lack of statistical correlation between these two variables for the sample as a whole. This is shown in Figure 2:

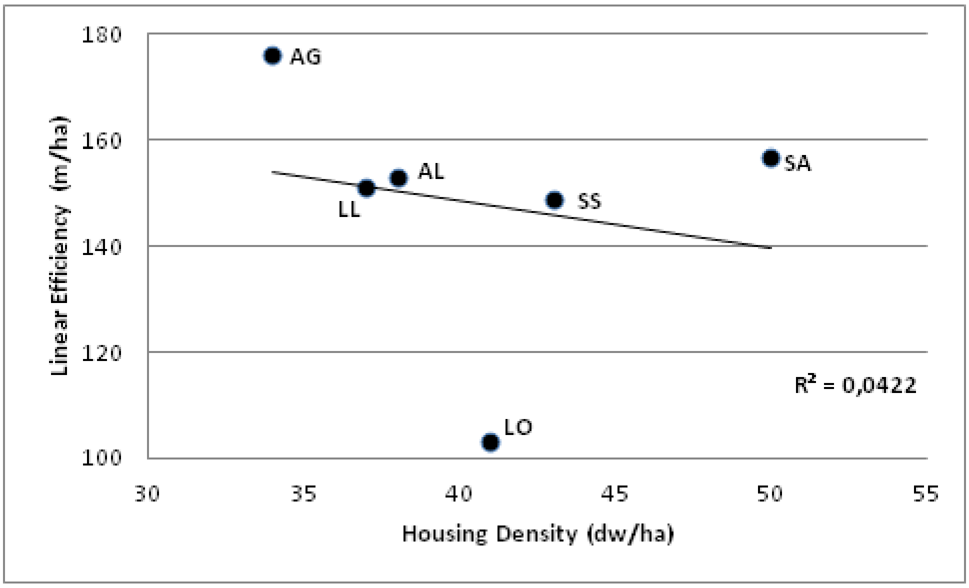

Figure 2. Relationship between housing density and linear efficiency of the sample cities

Source: Author

For economic data, operating costs for each service considered were calculated from the municipal budget (2010), once taken into account the above considerations. The results are shown in Table 3 in the form of cost per developed unit area (€/ha/yr), since both housing density and linear efficiency are expressed this way (for the purpose of this study, per hectare):

CITY	OPERATING COST OF SERVICES TO PROPERTY (€/ha/yr)					Total services to property (€/ha/yr)	Total services to property (€/inh/yr)
	Road maint.	Lighting	Water supply/sanit./purif.	Waste/cleaning	Parks		
Algeciras	940	2,161	7,009	12,122	3,299	**25,531**	**332**
Almeria	0	1,456	9,178	12,495	3,067	**26,196**	**332**
Salamanca	1,743	1,878	7,607	10,737	2,414	**24,379**	**285**
Logroño	430	1,790	3,931	6,546	3,327	**16,024**	**189**
Lleida	1,529	1,489	4,745	7,467	2,271	**17,501**	**215**
San Sebastian	2,713	1,968	7,318	13,393	2,725	**28,117**	**293**

Table 3. Cost of services to property per hectare (2010)

Source: Author, from municipal budgets (refined)

It would have been preferable to break down water cycle services into supply, sewage and sanitation and to examine waste collection, disposal and treatment separately from street cleaning services, but the configuration of the public budget in Spain makes this largely unfeasible. As stipulated in Ministerial Order EHA/3565/2008, which governed the budgetary structure of local authorities in Spain (2010), the program code 161 encompasses water supply, sewage and sanitation as integrated services. In the case of waste management, although it should theoretically be possible to distinguish between collection and processing (program 162) and street cleaning (program 163), in practice a lack of budgetary discipline makes this impossible (Bel, 2006).

SUSTANTIVE FINDINGS

If the degree of linear correlation between the urban form parameters shown in Table 2 and the level of expenditure obtained in Table 3 for the set of services considered is analyzed, the results obtained are shown in Figure 3 and Figure 4:

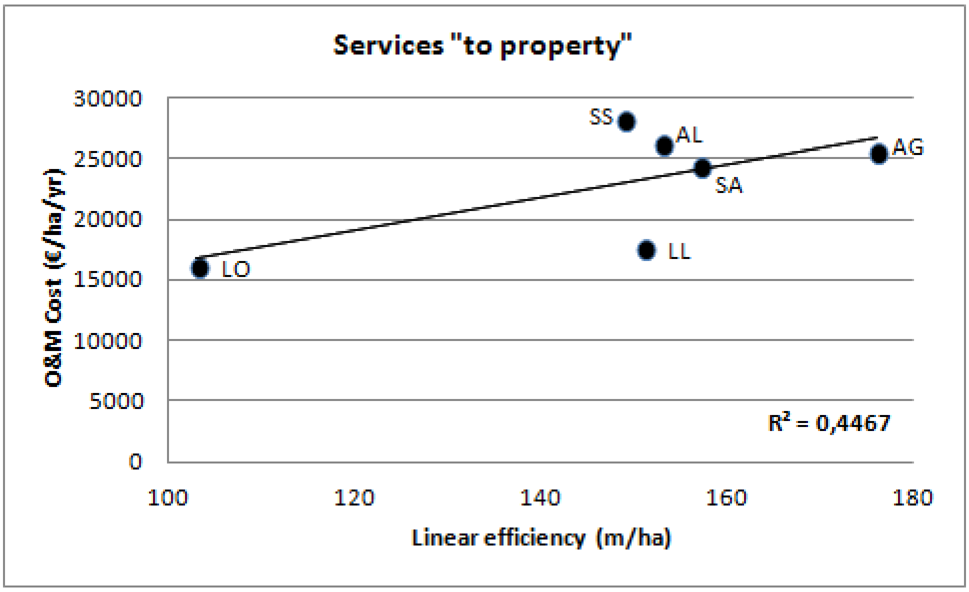

Figure 3. Correlation between linear efficiency and total O&M cost of services to property per hectare

Source: Author

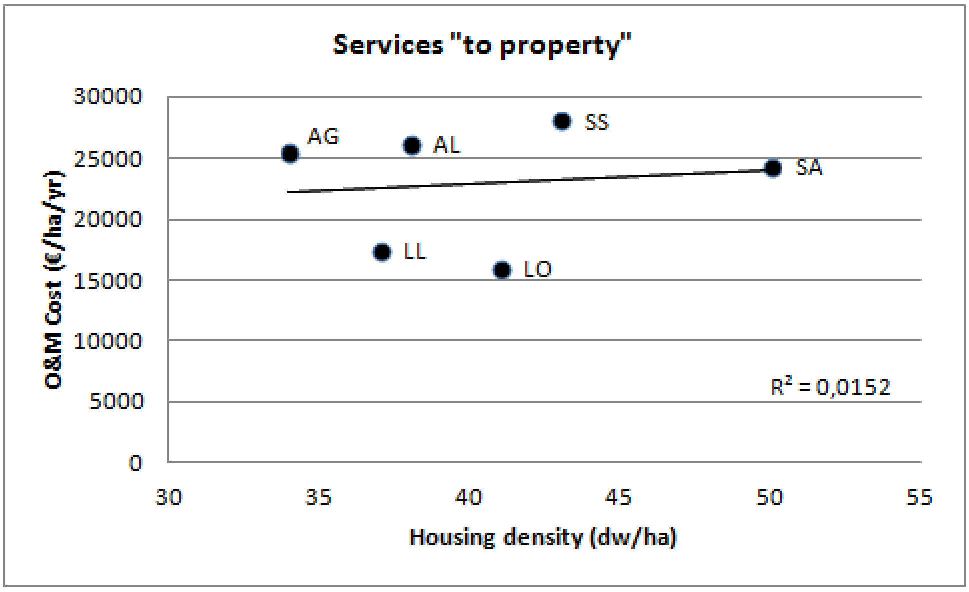

Figure 4. Correlation between housing density and total O&M cost of services to property per hectare

Source: Author

Although the sample size is reduced, and it is no possible to obtain consistent statistical results beyond the numerical results of the correlation, it is clear that there is a relevant difference between the two urban variables as determinants for the operating costs of public services more related to the territory. For the set of cities analyzed, the results show a moderate correlation between annual operating costs per hectare for the set of public services and linear efficiency (R^2 = 0.45) and no influence of housing density (R^2 = 0.01). This difference is more evident if the above per area ratios are transformed into per capita ratios, as shown in Figure 5 and Figure 6, which indicates, with the caution due to the sample size, a clear preponderance of the relative length of road in front of the housing density as determinant of the operating cost of public services more closely related to the territory, or what is the same, the preponderance of the amount of infrastructure per unit area against the quantity of the supplies.

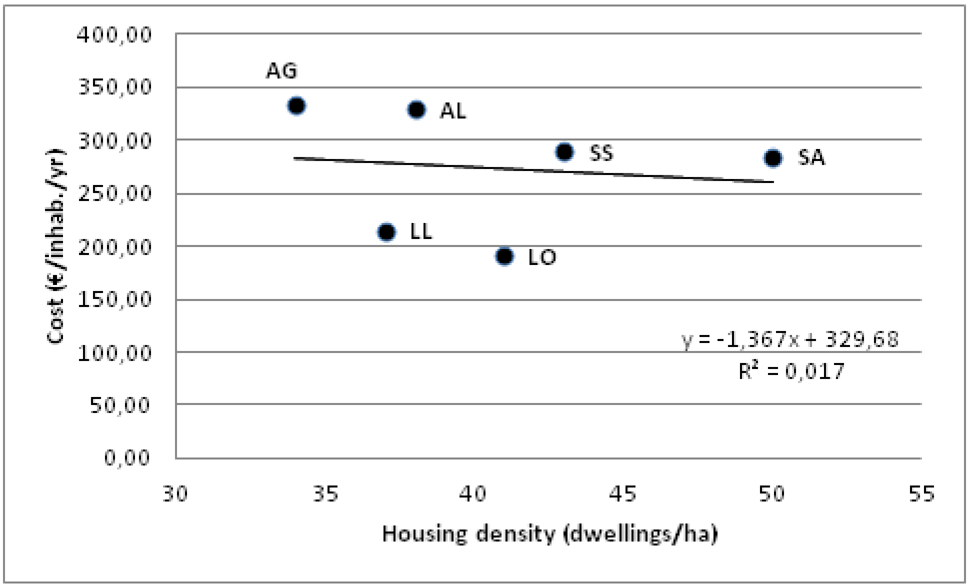

Figure 5. Correlation between housing density and total cost of services to property per inhabitant

Source: Author

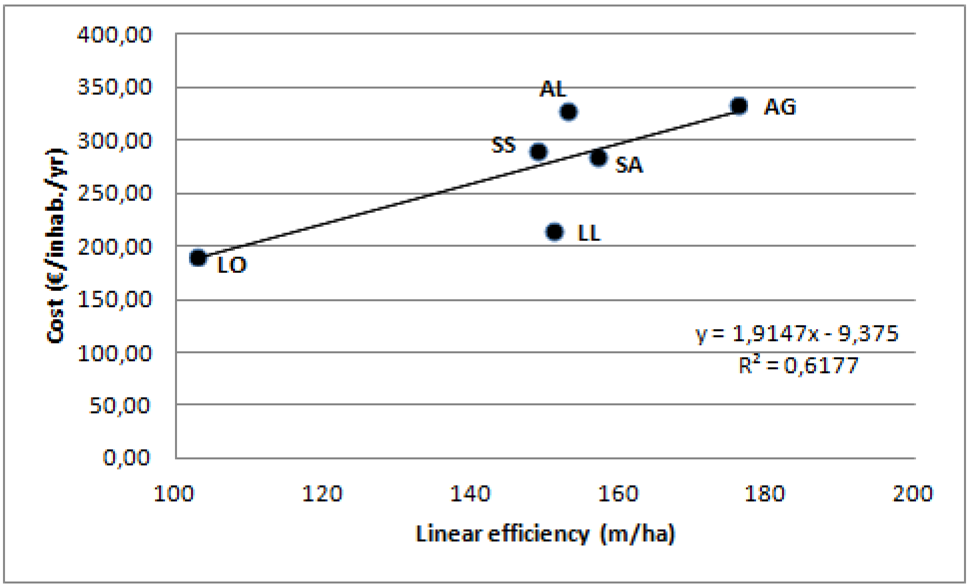

Figure 6. Correlation between linear efficiency and total cost of services to property per inhabitant

Source: Author

However, the above results are the average values for a set of public services with very different natures, whose effects on the operating cost may be contradictory; for this reason, the analysis was performed for each of them independently. The results are shown in Figure 7:

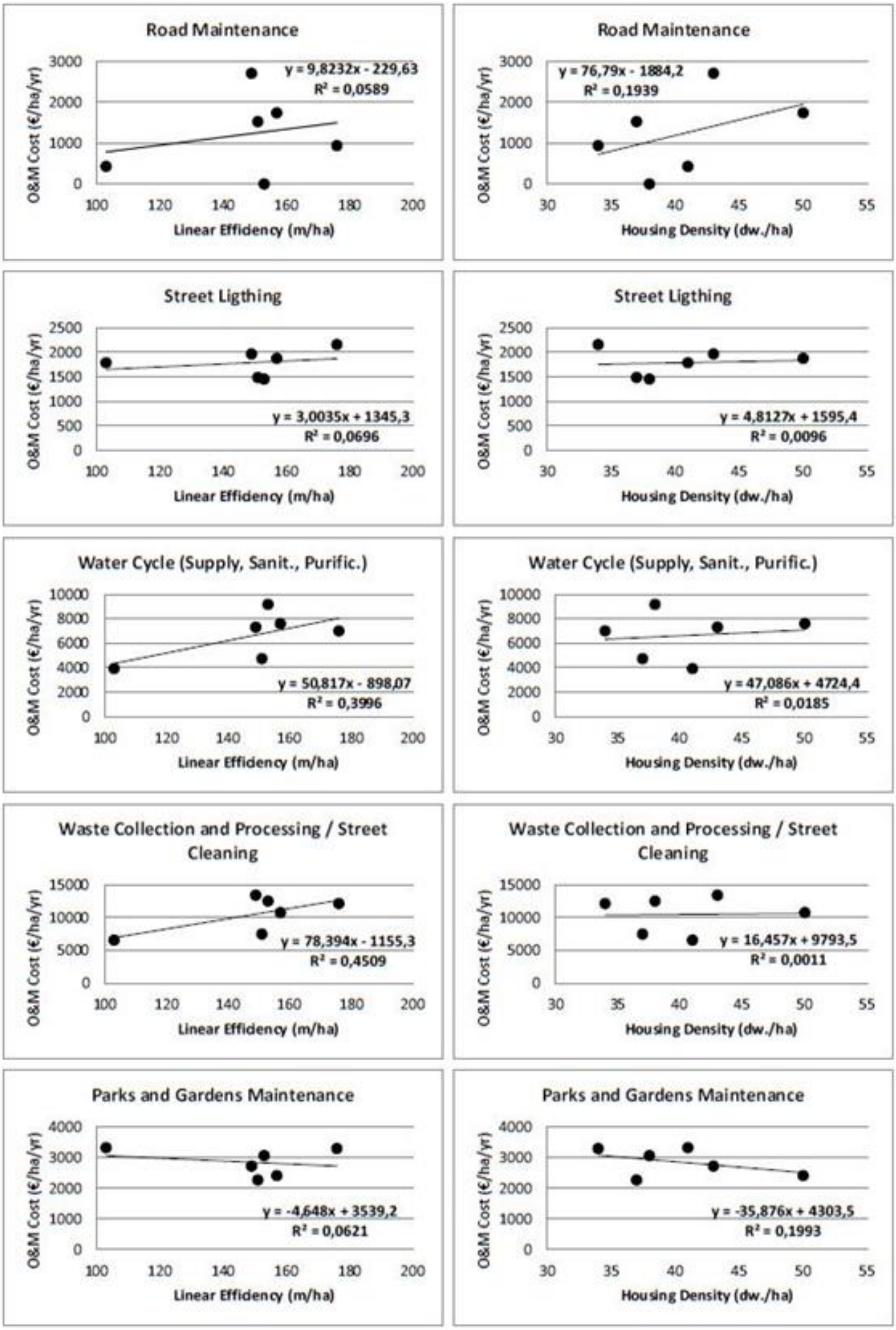

Figure 7. Correlation between operating costs of services to property and linear efficiency / housing density

Source: Author

The first result arising from the individualized analysis for each service to "the property" is that the correlation values are very different within the same urban variable for different services, as was to be expected, and so on for the same service between the two variables, which is very significant. On the other hand, the correlation values are moderated due to the contribution of non-urban factors (Guengant, 1995; Bastida et al., 2013).

Although, as indicated, statistical results are conditioned by the small sample size, and the differences between variables in complex urban patterns are the main result of the study, linear efficiency correlates better with the operating cost of water cycle (R^2=0.39) and waste collection, disposal and processing plus street cleaning (R^2=0.45), showing that in these services the linear components of the cost would be the main ones, like pipeline maintenance and the paths of the collection trucks, rather than the cost of the water supply and sanitation or the refuse treatment (Speir and Stephenson, 2002; Álvarez, 2005; Bel, 2006). The opposite result was obtained as regards housing density , with a moderate correlation in the services of pavement (R^2=0.19) and parks and gardens (R^2=0.19) maintenance. Said result might be related to the largest percentage of open spaces in areas of higher density housing (Wu and Plantiga, 2003). Despite the essentially linear nature of public lighting infrastructure, the figures show a low correlation between its operating cost and both variables (R^2=0.06 with linear efficiency and R^2=0.01 with housing density), which appears to confirm the findings of previous studies where correlation between energy costs for street lighting and population density was not found (Larivière and Lafrance, 1999).

Beyond the differences between the correlation values, the results obtained contribute to highlighting the different nature of both variables. As indicated above, from the point of view of the operating cost of services "to property" per unit area, the housing density represents the "amount of supply" - either in the form of water or garbage, more closely linked to the amount of population that to its distribution on the analyzed area -, while the relative length of road essentially represents the "amount of infrastructure" deployed in the territory, closely related to the length of pipelines or the distance between waste collection points. Given the mixed nature of most services, the study shows which of the two factors is preponderant in the total operating cost in each of them. This confirms that when an urban area is characterized by a set of urban parameters in order to analyze the influence of its urban pattern on the operating cost of its public services, both in the case of engineering multi-variate or econometric analyses, it is necessary that two of the regressors considered be the housing density and the relative length of road, since no equivalence between them can be established except in a few cases. This is highlighted if for the sample of cities analyzed it is observed how the correlation values improve when the two variables are used in a multi-variate analysis and they are compared to the individual correlation values arising from Figure 7. The results are shown in Table 4:

SERVICE	CORRELATION COEFFICIENT (R^2)		
	Uni-variate analysis		Multi-variate analysis
	f (L)	g (D)	h(L, D)
Road Maintenance	0,05	0,19	0,31
Street Lighting	0,06	0,01	0,09
Water Cycle	0,39	0,01	0,47
Waste/Street Cleaning	0,45	0,01	0,48
Parks Maintenance	0,06	0,19	0,32

Table 4. Correlation coefficients

Source: Author

As can be observed, significant correlation coefficients (R^2>0.30) are obtained from the combined effect of both variables for all services except for public lighting, which remains low. Probably, higher correlation coefficients could be obtained had it been possible to break down water cycle services into supply, sewage and sanitation, and to examine waste collection, disposal and street cleaning services separately; still results denote the intrinsic complexity of all set and services analyzed, where many factors appear to influence. Nevertheless, it seems clear that consideration of linear efficiency and housing density, not only independently but also simultaneously, allows for a reasonable approximation to operating cost per unit area of services to “the property” in terms of urban variables.

CONCLUSIONS

The analysis has shown that regardless of the characteristics of the urban morphology, the studies which examine the relationship between the urban pattern and the operating cost of public services usually tend to establish an equivalence between the roles of population or housing density and the relative length of road, when these two urban variables are only proportional in homogeneous developments exclusively based on single-family dwellings. What is more, even in cases where both variables are proportional, it is necessary to take into account that while the road network usually has little variation over time, population is variable, which together with the mixed character of the operating cost of the urban public services, makes it imperative that their role be adequately differentiated.

The statistical analysis carried out on a set of Spanish cities with population between 100,000 and 300,000 inhabitants has shown, even with the limitations due to the small sample size, the different role of both urban variables as determinants of the operating cost of the public services more closely related to the territory. Although in all the services considered, moderate correlation coefficients show some influence of other variables (urban and non-urban), linear efficiency is more strongly correlated with the operating cost of linear services such as water supply, sewage and sanitation (R^2=0,39), waste collection and disposal and street cleaning (R^2=0,45), showing the greatest influence of infrastructure maintenance in these services (or length of waste collection), which is usually a function of the relative development of the roads. In addition, housing density is more correlated with pavements (R^2=0,19) and parks and gardens (R^2=0,19) maintenance, which shows more influence of the amount of population per unit area than its internal distribution. The cost of street lighting service is weakly related to both variables. Logically, despite the difficulty of collecting data on the operating cost of public services, either when they are provided by public administrations (lack of adequate cost accounting) or by private contractors (revelation of potential benefits), it would be necessary to extend the study to other population ranges and different urban environments of the Mediterranean city, inherently compact and diverse. Similarly, regardless of the size of the sample, more consistent results might be obtained if the study could be carried out exclusively for the residential area of the city (considering net housing density), but this would require a differentiation between the operating costs of services for each use, data not available and an aspect still not adequately solved in the planning research.

For these reasons, since housing density can be associated with different levels of linear efficiency and each of these variables has a clearly differentiated impact on public spending, studies that analyze the influence of a set of urban factors on the operating costs of public services must consider both factors independently but simultaneously, which would improve the understanding of the relationship between the urban form and the economic management of the city as well as the right design or redesign of future developments. This requires that the public databases used in broad spectrum studies include not only the population or the total urbanized land as variables characterizing the built environment, but also that the length or area of roads of the settlement, as well as all other urban variables influencing the operating cost of public services the economic sustainability of the urban area be available. In this respect, an adequate understanding of the economic long-term role of most physical variables that can define an urban area is still necessary, without meaning that the design or redesign of the new urban areas are exclusively based on the economic side of sustainability.

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