Geographic patterns of Annual Average Daily Traffic in Mallorca

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Abstract

Annual Average Daily Traffic (AADT) is a relevant indicator of territorial sustainability. The territorial analysis of the special distribution pattern of AADTs allows users to know the level of anthropic pressure in a territory and the urban growth trends. An analysis of the evolution of AADTs has been made in the Island of Mallorca for the period 2005-2016. An evaluation of its spatial distribution pattern and its relationship with other territorial variables is possible using spatial autocorrelation techniques. The results allow identifying the main factors linked to the urban expansion of the island and to propose a territorial zoning based on mobility and settlement. The factors generating a greater mobility on the island are the proximity to the city of Palma, the topography and the population density. The peri-urban area of Palma shows the greatest pressure in terms of traffic. The development of tourist zones on the coast promotes an increase in mobility to these areas expanding the negative effects of traffic.
Keywords: AADT, Mobility, Vehicles, Traffic, Fragmentation, Territory

1 Introduction

Mobility is one of the most relevant activities of human action and it is responsible for the consumption of a vast quantity of energy and natural resources that can reach 25% of the global energy expenditure of the planet (Meekan et al., 2017). Annual Average Daily Traffic (AADT) is a mobility indicator that expresses an average of the number of vehicles driving on a certain road. AADT Values are obtained by an experimental count of the number of vehicles passing through a certain road section where a gauging system is installed. Specific methodologies can also be developed for its calculation (Fu et al., 2017; Gastaldi et al., 2014). The indicator is expressed in an average annual traffic value (AADT=number of vehicles throughout the year/365 days), even though roads do always experience a marked variation in traffic on a monthly, daily or hourly basis. (Crawford et al., 2017).

The distribution of the population respecting the traffic level is a question that is being analysed in the framework of environmental justice (Gaffron, 2012; Gössling, 2016). A relation between traffic exposure and income level of the population, ethnicity (Pirdavani et al., 2017; Rosenlieb et al., 2018) or diseases can be found (McGuinn et al., 2016).

AADT is frequently related to studies regarding infrastructure capacity to absorb traffic. High values of AADT justify the construction of new infrastructures. The construction of roads and the increase of vehicles circulation mean an increase of the negative effects on the environment, among those who stand out: atmospheric pollution, direct occupation of land, habitats fragmentation, loss of biodiversity, a barrier effect of the infrastructure, an increased risk of vehicles and people/wildlife collision, etc. (Coffin, 2007). Thus, in a sustainable transport system framework, it is advisable to battle congestion with the encouragement of more sustainable means of transport, and the reduction of the private vehicle use.

Territorial fragmentation is one of the main effects induced by a road network deployment within a territory. This fragmentation produces an alteration of the territorial structure and it also originates different geographical units in terms of shape and size. The effects on habitats ecosystems and landscapes are devastating. There is a transformation of large patches into small fragments that produce an isolation of communities and loss of habitats. Those fragments may have inherited features, but they also possess their own characteristics as a consequence of the shape and size. (Forman, 1995). Each part will be affected by the traffic intensity of the surrounding roads. Generally, small areas with high AADT values suffer to a greater extent the negative effects of road traffic; oppositely, big areas feature a scarce circulation level. (Jiang and Kang, 2016; Mancebo Quintana et al., 2010; Nega et al., 2013, 2012). A constructive structure of urbanized areas may have an impact on the attenuation or on traffic effects (Weber et al., 2014). Sustainable planning is currently aimed at reversing the negative effects of infrastructures by promoting defragmentation actions and eliminating road sections in order to recover territory.

This study analyses the effect of fragmentation caused by road infrastructures on the territory of the island of Mallorca and the role of AADT over the fragmented territory. This analysis will allow users to know the underlying causes that determine the distribution of AADT throughout the island in order to guide the planner to reduce the negative effects of traffic. An analysis of AADT distribution is proposed, using as geographical units the fragments of the territory generated by the deployment of transport networks. The goal of this line of research is to investigate the spatial autocorrelation of the distribution of AADT and its relations with different territorial variables. The final objective is to understand the existing territorial expansion dynamics produced by roads deployment and traffic effects to propose tools to reduce their negative effects.

2 Study case

The island of Mallorca (Spain) was considered as a study case. Mallorca has an area of nearly 3,600 square kilometres, an approximate population of 800,000 people and it receives around 12 million tourists per year. The island is composed of 53 municipalities and has a wide network of roads that are radially deployed from its capital (Palma) to other regions of the island. Most of the infrastructures and basic services are located in Palma. Mallorca has a very high motorization rate (1125.14 vehicles/1000 inhab.) including 80,000 tourist rental vehicles. The public transport lacks coverage in terms of lines and frequencies, this makes the private vehicle the usual mode of transport. Tourism is mainly developed along the coastline; this produces a continuous flow of vehicles from the city of Palma to the inner and coastal population areas.

Road infrastructures on the island have undergone an intense development in recent decades causing a huge increase in vehicle traffic. The roads cause a territorial fragmentation that can be considered as critical due to the size of the island and the quality of its natural resources. Nowadays, Mallorca features obvious symptoms of traffic congestion during peak hours and especially during the tourist season.

The land occupation has also undergone a considerable transformation in recent decades. Urban areas have especially spread over Palma's periphery and over the coastline.

Previous studies regarding the fragmentation of island habitats derived from road networks have been published (Martín, 2006, Rossello-Melis, J., Lorenzo-Lacruz, 2017), but global studies of the effect of the road network and the effect of the AADT are inexistent.

The island possesses a high landscape value since its main mountain range was awarded World Heritage Status by UNESCO as an area of great physical and cultural significance. Mallorca can also be considered as an integral territorial unit due to the fact of being an island. Its level of territorial protection makes possible the consideration of the island as a great integral ecosystem. Therefore, we can focus on the fragmentation of its territory in a global extent.

3 Methods

The base information corresponds to a total of 172 gauging stations, for which information of annual data of traffic is available by sections and it is provided by Mallorca Insular Council.

The main performed tasks were as follows:

3.1. Analysis of AADT's distribution and evolution.

The information of the gauging stations is transferred to the arcs of the road network. The evolution of the AADT's for each road segment is assessed.

3.2. Evaluation of territory fragmentation derived from the deployment of the road network

The road lines map is transformed into a polygons map. Moreover, population centers are included as entities that allow roads to be adjusted to shorelines. The final result is a map of territorial fragments that we will consider the geographical units of analysis.

3.3. Diagnosis of AADT distribution and its relationship with other territorial variables.

In order to estimate the traffic values of each polygon, it is necessary to apply an interpolation method. In this case, Inverse Distance Weighting (IDW) interpolation was chosen for the reason that it uses the measured values surrounding the prediction location, to predict a value for any unmeasured location. Later, a global and local spatial autocorrelation analysis is performed to determine the patterns of spatial distribution.

Basic territorial variables are obtained from different base layers for each geographical unit (topography, population, number of tourist places, proximity to Palma, etc.), and a bivariate autocorrelation analysis of each variable with AADT values is performed

Subsequently, in order to analyze the relationship between AADT and the rest of the territorial variables, regression models OLS and GWR must be applied. AADT is used as a dependent variable and the rest of the variables are considered as independent.

The applications used for the assessment are ArcMap vers 10.4 (ESRI, 2017) and Geoda vers 1.2.

4 Results

The AADT distribution reproduces the radial model of the transport network of the island of Mallorca. The highest values are located in the center and in the periphery of Palma. Significant values stand out in the different ring roads of the city and in the main arteries that leave from Palma to the inner cities or tourist areas. The peri-urban area of Palma and the Bay form an area of maximum transit level, followed by coastal areas of the northeast of the island and the eastern shore (Figure 1).

There is a generalized growth of traffic on every road within the decade 2006-2016. The results show an average growth of 22% for all roads. The roads connecting the city of Palma to the tourist areas of Alcúdia, Capdepera, and Sóller experience the greatest growth. It is also noteworthy the section that connects Palma with Valldemossa, located in the Serra de Tramuntana.

The territorial fragmentation caused by the road network is very significant (Figure 2.1). Greater fragmentation is observed in areas with urban uses but less in agricultural and natural areas. It is important to highlight the increase in fragmentation along the coastline and in areas next to the city of Palma (De Montis et al., 2017; Pirdavani et al., 2017).

Figure 1. [1.1] AADT vectorial distribution (2016). [1.2] AADT Evolution (2005-2016-% growth)

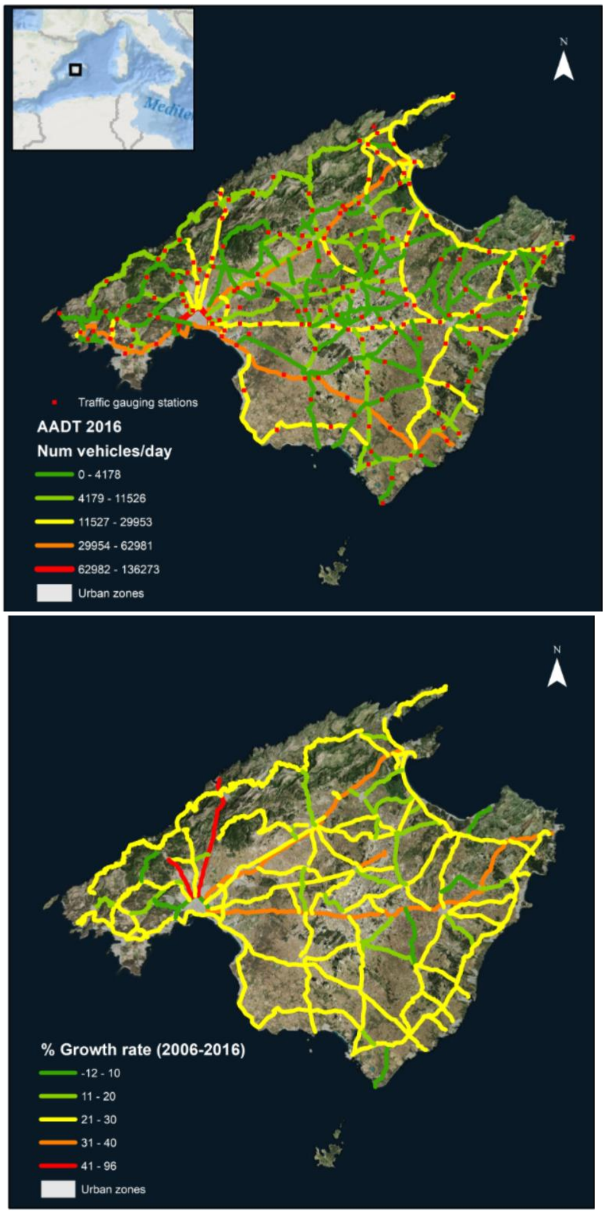


Figure 2. [2.1] Territorial fragmentation (AADT 2016) Territorial fragmentation caused by roads. Each polygon represents an AADT mean [2.2] AADT 2016 Local Autocorrelation

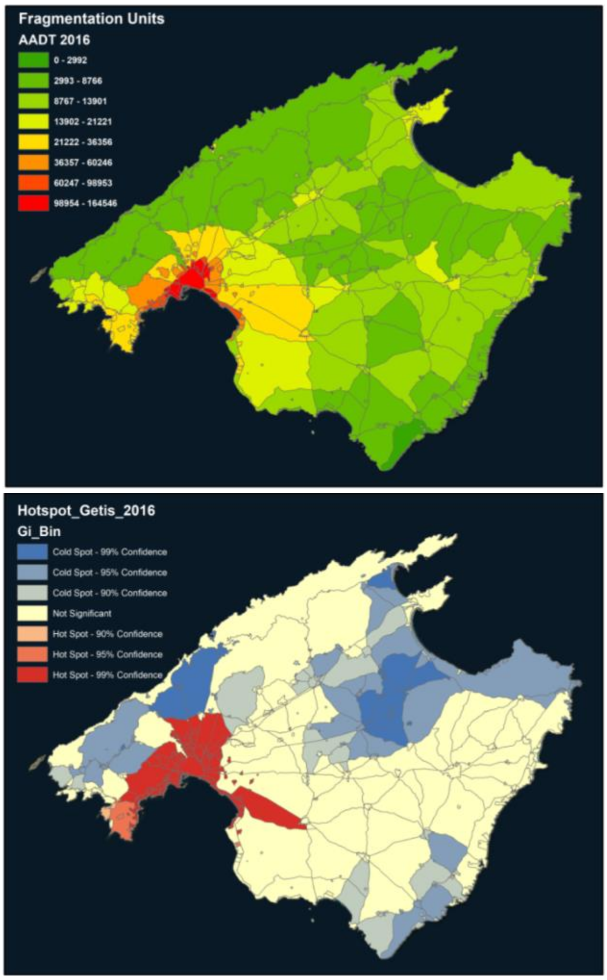
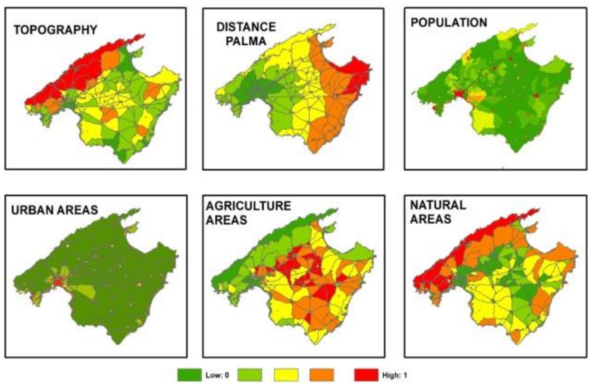


Figure 3. Territorial variables considered for the study



The global spatial autocorrelation of 2016 AADT reaches a value of 0.765, which proves a marked zoning. The local autocorrelation shows the area of Palma and its periphery as the areas responding better to the concentration of high values (Fig. 2.2). The lowest values of traffic appear in the Northeast and South East coastal areas. The areas with high slope near Palma also show low values.

Five territorial variables have been considered as an explanation of the AADT values and distribution. These are, topography, distance to Palma, size of the territorial units cause by fragmentation, population and land occupation (Fig. 3).

The bivariate autocorrelation analysis of the studied variables with the intensity of the 2016 ADDT (Table 1) shows the relationships previously outlined. The results show a positive relationship between traffic intensities, proximity to Palma, flat topographies and urban uses. On the other hand, a negative relationship between AADT, the topography, the size of the geographical units, the agricultural and natural uses was detected. Palma, as the capital of the island, concentrates a large amount of population, infrastructures, and equipment. The city is a great travel generator, which means there is a significant correlation between AADT and the proximity to the city. The topography plays a reverse role. Areas with significant slopes have the lowest values of AADT. This confirms that the difficulty of access to the mountains and the type of road causes a significant reduction in traffic.

Table 1: Autocorrelation analysis of territorial variables. Bivariate Moran's coefficient

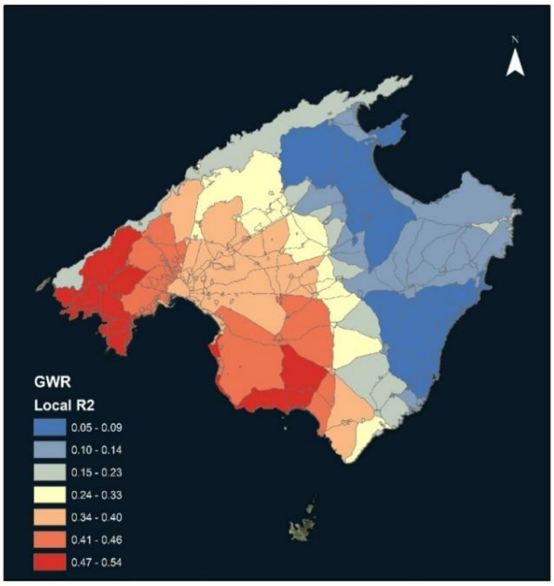
	AADT 2016	Area Fragment
Surface of fragment	-0.387	
Perimeter of fragment	-0.356	
Topography	-0.229	
Distance to Palma	-0.452	
Natural Areas	-0.464	+0.351
Agricultural Areas	-0.214	+0.219
Urban Areas	+0.447	-0.440

The OLS regression analysis, taking AADT as a dependent variable and the rest as independent, shows an R coefficient of 0.3 (Table 2). This suggests a limited explanatory capacity of the set of variables. However, there is an evidence of a certain lineage.

Table 2: Results of OLS regression.

OLS Diagnostics	
Number of Observations	94
Multiple R-Squared	0,324935
Joint F-Statistic	87,411050
Joint Wald Statistic	232,032108
Koenker (BP) Statistic	123,728209
Jarque-Bera Statistic	2957,616737
Akaike's Information Criterion (AICc)	20862,700765
Adjusted R-squared	0,321217
Prob(>F), (5,908) degree of freedom	0,00000
Prob(>chi-squared), (5) degree of freedom	0,00000
Prob(>chi-squared), (2) degree of freedom	0,00000

Figure 4. Local r2 distribution of GWR Dependent variable AADT 2016



The GWR regression analysis reaffirms the signs of correlation identified by the OLS analysis, obtaining an R-value of 0.58. This confirms an OLS dependence with the territorial variables. The highest values can be found in the areas near Palma.

Table 3: Results of GWR regression

Varname	Variable
Bandwidth	15468,276818
Residual Squares	274219585034,41644
Effective Number	41,230693
Sigma	17725,541124
AICc	20500,842524
R2	0,570857
R2Adjusted	0,551075
Dependent Field	AADT 2016
Explanatory Field	Topography
Explanatory Field	Distance to Palma
Explanatory Field	Urban areas
Explanatory Field	Natural areas
Explanatory Field	Natural-Agricultural areas

5 Discussion

Annual Average Daily traffic constitutes a significant indicator of the anthropic pressure level of a territory caused by road traffic. The use of spatial units, derived from the fragmentation of the territory produced by the road network, shows a remarkable applicability.

During the last decade, AADT values in the island of Mallorca have experienced an intense increase causing the perception of difficulty in access to Palma and various tourist areas. This situation occurs especially in high tourist season (Saenz-de-Miera and Rosselló, 2012) when a fleet of more than 80,000 vehicles is incorporated into the road network.

The proximity to Palma causes a collapsing effect in a chain that could progressively be infecting the rest of the island through the radial routes in the direction of Palma-Coast areas. The mountainous zones of the Serra de Tramuntana have remained somewhat outside this dynamic, but some indications show that the situation could increase.

The smallest geographic units with the largest AADT values are the most vulnerable to increase urban uses and therefore vehicle traffic.

A situation close to a circulatory collapse in Palma and the main access roads in the coming years is intuited if the current trends in the increase of AADT and territorial fragmentation follow the last decade dynamic.

The main solutions to this problem should be oriented to improve public transport and optimize the urban model of the island. Some sectors also think that it would be appropriate to limit the number of rental vehicles that circulate in high season and penalize the use of vehicles with higher taxes.

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