

XII Conference on Transport Engineering, CIT 2016, 7-9 June 2016, Valencia, Spain

Stage of historical evolution of private vehicle ownership in the city of Barcelona

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Abstract

Transport demand and private motor vehicle ownership (cars and motorcycles) are generally related to the socio-economic development, increasing urbanization, public policies and rising per capita income.

Private motor vehicle ownership varies between countries and geographical regions. However, it tends to have some common patterns in its historical evolution. So that during the early stages of development, the rate of motorization increased mainly by acquisitions of PTWs (mopeds and motorcycles). As the economy grows, the increase in per capita income stimulates a shift from PTWs to cars, which are preferred for their safety, versatility, comfort and social status. The increasing use of cars contributes to raising travel costs (congestion, parking constraints, accidents, pollution), that coupled with public policies to discourage car use, tends to favor modal shifts from cars to public transport and in some regions also to PTWs.

This study analyze the historical evolution of private motor vehicle ownership in Spain (cars and motorcycles), and identify the stage in which is the city of Barcelona, characterized by the high use of PTWs. The increase use of PTWs is a common phenomenon in some major European cities and suggests a continuous future growth in developed countries and congested urban areas, that is not in line with the assumptions of some models, which predict that in the long-run there will be a decrease in use of PTWs in areas with high income per capita levels.

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Peer-review under responsibility of the organizing committee of CIT 2016

Keywords: PTW, vehicle ownership; motorcycle; rate of motorization

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1. Introduction

Mobility provides access to people, goods, services and information, favoring human development and socio-economic activities. The more efficient mobility becomes, the greater socio-economic prosperity and quality of life tend to be.

Understanding the patterns of the historic evolution of motor vehicle ownership is useful to forecast and manage transport demand, planning infrastructures, urban design, implementation and assessing of transport programs and policies, so that social welfare is maximized.

Private motor vehicle ownership varies between countries and geographic regions. However it tends to have some common patterns in their historical evolution. Much of the existing literature shows the impact of changing levels of economic activity on mobility rates and traffic volumes. Policymakers should consider the effects of economic cycles on mobility evolution to manage the effects.

Knowledge on the socio economic variables that shape private motor vehicle ownership evolution and the interactions among different types of vehicle ownership is useful in transport management, infrastructure planning, road safety and public policies, helping to maintain consistent perspectives on dealing with urban transportation problems. Knowing how other similar urban areas have gone through the stages, the kind of policies implemented and their results can be a useful reference when deciding what kind of measures should be implemented.

This study has been conducted to identify the stage of historical evolution of private motor vehicle ownership in which the city of Barcelona is at, identifying factors underlying the mode choices behavior, characterized by the high use of the powered two wheelers.

2. Patterns of historical evolution of private vehicle ownership.

The historical evolution of private vehicle ownership is determined by different types of variables that have relative importance according to the stage of evolution. Motor vehicle ownership determines travel behavior. There are several patterns that allow study, model and even forecast car and motorcycle historical evolution, mostly related with socioeconomic factors. (de Jong, G et al. 2004).

Economic factors and evolution of per capita income are closely associated with a rise in traffic volumes and vehicle possession and use. In the literature of mode choice modeling, several studies have emphasized the influence of income and household car and motorcycle ownership. The income level changes consumer preferences over modes of transport. (Pongthanaisawan, J. and Sorapipatana, Ch. 2010).

Many factors affect the evolution of vehicle ownership, such as income (total expenditure), the level of urbanization, and alternative means of transport. Economic growth leads to an increase of mobility demands and vehicle ownership, car ownership tends to increase as per capita GDP grows (Schafer, A and Victor, D.G., 2006). Walking is the world's dominant mode of transport, until a certain threshold of individual wealth is reached; people can afford to buy vehicles encouraging shifts from non-motorized to motorized transport modes (Schafer, A., 2006). At an early stage bicycles are used for short trips, being replaced by PTWs that allow making longer trips. After personal income grows up to a certain level, people will shift from motorcycle to car ownership.

The first stages of evolution of urban mobility and hence private vehicle ownership, tends to accelerate when societies develop their industrial sectors and the demand of workforce pushes the phenomenon of migration from rural to urban industrialized areas. Economic growth tends to stimulate higher levels of consumption. When the gradual increase in per capita income reaches a threshold level, a car is an asset that people want to buy once they have covered their basic needs. The affordability of buying cars encourages a shift of use from motorcycles to cars. The substitution effect from motorcycles to cars is possible because the overall income increase reduces the costs of buying and running a car. (Law, T. H. et al. 2015).

Income rising favors a switch from PTWs to cars. When income per capita growth trespasses a certain level over the car owning threshold, a decline in motorcycle ownership is therefore expected. Nishitateno, S. and Burke, P.J (2014) analyzed data from 153 countries for the period 1963-2010 and found that the number of PTWs per capita increases as income per capita grows until it reaches a threshold of around \$8,000 per person per year. From this threshold on, in spite of income increase, the possession of PTWS decreases. Cars tend to be preferred due to the independence that they provide as well as mobility, safety, versatility, convenience, comfort and because cars are

regarded as a symbol of status or a badge of social welfare (Goodwin, P.B. 1997; Stradling, S. G. et al 1999). Their high utility and symbolic appeal stimulate car ownership, even if public transport is well prepared as an alternative. (Wu, G et al. 1999; Steg, L. 2003).

In advanced stages of development, the rate of motorization tends to reach a saturation level, shifting from an expansion market to a mature one. When this stage is reached in dense urban areas, modal split is increased, and motorization stabilizes while car ownership is reduced (Mogridge, M. J. H. 1967). The saturation level can be measured by the number of car ownership per 1,000 inhabitants, and varies depending on the type of society, level of development and geographical and urbanization factors. Whelan et al. (2000) analyzed the limits to car ownership growth. Some other studies consider that vehicle saturation levels may be different across countries, as a function of population density, and then it is possible to estimate empirically the saturation rate for different countries, considering income elasticity. (Dargay, J. and Gately, D. 2001; Dargay, J. et al. 2007).

The pace of motorization tends to be faster than the capability of infrastructures and facilities to improve the efficiency of transport systems, resulting in a problem of congestion and an increase in travel times. In dense urban areas massive car use is related with pollution, problems in the interactions between vehicles and pedestrians and parking restrictions. To attenuate these problems several kinds of policies are implemented to discourage car use: restricting traffic in the center where large pedestrian zones are created and taxes to car access to different urban areas. Different levels of vehicle taxation affect the choice of vehicle type (Birkeland and Jørgensen 2001).

At the last stage of motorization evolution, the increased use of PTWs in dense urban areas is based on three factors: motorcycles are more economical in areas with traffic and parking restrictions, the incorporation of women increases the use of PTW and finally in areas with high purchasing power and enough leisure time, recreational use motorcycle appeared with a renewed interest, mostly at weekends and spare time (Haworth, 2012).

3. Modeling private vehicle ownership evolution

The rapid increase of motorization in the world improves transport and economy, but it is also associated with negative externalities (accidents, pollution and congestion). Modeling vehicle ownership is a powerful tool useful to analyze and predict scenarios that assist decision-making and transport planning.

There are different model approaches, among others: aggregate, disaggregate, heuristic, discrete-continuous, pseudo-panel methods, and dynamic (de Jong, G. et al. 2004). Many vehicle ownership aggregate models, mostly by country, have been carried out attempting to model the demand as a function of socio-demographic, economic, transportation system, and land development characteristics. (Tanner 1962); Beesley, M.E. and Kain, J. (1964); Button, K et al (1993); Whelan et al., 2000, Whelan, 2001), Dargay and Gately 1999. Ingram and Liu (1997) found a significant relationship between number of vehicles and road lengths and estimate the quantitative relationship with income, population, urbanization and fuel prices.

When income increases people can afford to buy cars, that are globally preferred for its versatility, security, comfort and status, a substitution effect appears in the election between cars and PTWs. At higher levels of per capita income, the substitution effect decreases due to the possibility of owning several types of vehicles. In this way a relationship between motorcycle and car ownerships differs depending on level of the economy and other factors also gain relevance, such as urbanization, transport policies, security and leisure.

3.1. Modeling car ownership

There is a long tradition of studies that model the evolution in the level of car ownership and relevant variables. Car ownership models are based on one or several independent variables related to economic evolution, urbanization form and transport policies.

The relationship between measured economic values and car ownership variables is nonlinear in the long-term. It is usually assumed that the equation that well describes the data is a sigmoid-shape function, an S-shape curve. (Tanner, J.C. 1958; Mogridge, M. J. H. 1967). Some processes and dynamics of complex systems show a temporal evolution, starting from low levels, progressing at a stable pace until reaching a point characterized by a strong intermediate acceleration from which it rises until approaching a saturation climax. The sigmoid function with the typical form of "S", allows this kind of evolution to be described. The Gompertz curve is a sigmoid function used to

model systems that tend to evolve in time until an asymptotic value showing saturation when the explanatory variable reaches large levels, being the formula:

$$y(t) = ae^{-be^{-cT}} \quad (1)$$

Where:

a: is an asymptote that sets the saturation level.

b: is a positive number that sets the graph displacement along the x axis

c: is a positive number that sets the growth rate

The flexible Gompertz function allows vehicle/population ratio with an economic variable to relate (Zachariadis, T. et al 1995; Talukdar, D. 1997). Examples are the studies done during a long period in UK and 18 industrialized countries from 1958 to 1980, finding a strong relationship between car ownership and the rate of economic and of income levels on the number of cars, and how income elasticity decline as a country's income increases (Tanner, J.C 1983).

Dargay, J. and Gately, D. carry out international comparison studies analyzing the relationship between car ownership and income levels using data, in a previous study from 26 countries (1999) and extending the range to 82 countries (2001). They used a Gompertz function to represent the long-run equilibrium level of the vehicle/population ratio V_t^* (Vehicle ownership in year *i*) as a function of per capita income GDP, allowing prediction of the motorization rate (the number of cars per 1,000 persons). The equation can be written as:

$$V_t^* = \gamma e^{\alpha e^{\beta GDP_t}} \quad (2)$$

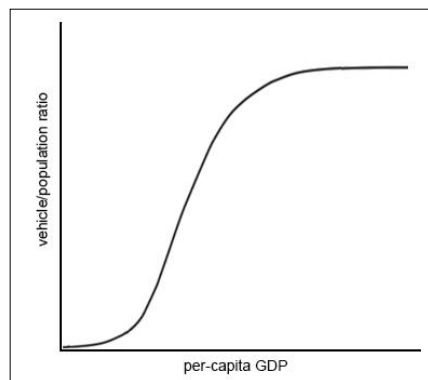


Fig. 1. Gompertz function

Different income elasticity must be considered depending on population density, urban structure and transport policies. As population density increases tends to declining saturation levels of vehicles per capita. The curve has a similar shape but there are four different patterns depending on the geographical area: North American & Australia, Europe, Asia and Countries with lower vehicles ownership (Huo, H., et al. 2007).

3.2. Modeling PTWs ownership

In a long-term perspective, the relation between economic prosperity and motorcycle possession is less strong than car ownership. Motorcycle use is influenced by many different factors from car use, implying a different type of ownerships evolution. The relationship between income and PTWs possession appears to be non-linear: at the beginning, economic growth leads to a growing number of PTWs, but later more prosperity tends to mean fewer motorcycles and more cars.

Otherwise, in some advanced countries, driving motorcycles has a high recreational purpose, influenced by factors such as culture, spare time available, weather, risk-perception and demographic structure, more than economic factors. This fact subtracts weight to the purely economic variables and adds a wider range of explanatory variables. Since the mid-1990s, notable increases in motorcycling use in developed countries are related to a wide range of activities for commuting and recreation (Jamson, S. and Chorlton, K. (2009); McCartt, A. T., et al. (2011); Haworth, N. (2012). Therefore as income rises and per capita wealth exceeds a certain threshold that allows people to buy cars, people shift from motorcycles to car ownership, declining not the global but the relative number of PTWs in relation to cars. In dense urban areas an increase of motorization and massive car use produces congestion and parking problems. PTWs use can help reduce traffic congestion, giving opportunities to cities to use less area for motor vehicles and parking. In this specific situation and areas in developed countries, where car motorization expands, it tends to get reduced and there is an increase in the use of TPWs.

The S-shaped Gompertz function valid to represent car evolution does not provide a statistically fitting representation of the relationship between evolution of GDP per capita and number of PTWs. Research studies suggest that the relationship between motorcycle ownership and per capita income growth follows a long-term inverted U-shaped curve. The function was formulated by Simon Kuznets (i.e., the Kuznets curve) (1955) in the framework to represent the relationship between environmental pollution and per capita income (Grossman, G.M., and Krueger, A.B. 1995).

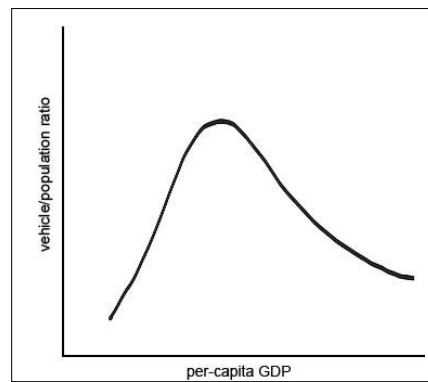


Fig. 2. Kuznets function

Over time, the scale of the socio-economic activity entails negative impacts of PTWs (mainly an increase in accidents), and such urban structural transformation may, reverse the expected positive relationship between economic development and PTWs use (Hsu, TP. 2007). Different models of PTWs ownership have been formulated with some type of inverse U-shape curve. Sillaparcharn, P (2007) formulated for Thailand a model where motorcycle ownerships increase until they reach a threshold, after that motorcycle ownership declines replaced by car ownership. Taking into account the former model, Pongthanaisawa, J. and Sorapipatana, Ch. (2010) consider that Sillaparcharn, P. (2007) underestimated the motorcycle ownership after trespassing the peak; formulating a new model based on a logistic function.

Duffy, M. and Robinson, T., 2004 made an econometric analysis of motorcycle ownership in the UK and concluded that motorcycle use will not decrease in the long-term, on the contrary, the future growth prospects may be quite good. In dense urban areas, cars will experience an increase in cost of running because of further tolls, taxes and environmental restrictions, favoring a substitution effect from car to motorcycles. The conclusion of the analysis implies questioning that in the long run high incomes are related with declining use of motorcycles and therefore that the model of PTWs ownership fits an inverted U-Shape.

4. The stage in which the city of Barcelona is at

Barcelona is one of the densest cities in the world. One million six hundred thousand inhabitants are distributed in a small area, which also attract a high number of journeys, generated by a substantial socio-economic activity. In addition, in the last 10 years the surface for private vehicle-circulation has been reduced by 10%, there have been restrictions to private car use, increasing length of lanes exclusively devoted to bus and bikes and regulating car parking on the road.

Despite the high density, Barcelona does not lead the rankings of European urban congestion areas (TOMTOM 2015). One of the factors that allow a daily significant volume of motor-vehicle journeys in such a dense space is that a large percentage of internal journeys are made by motorized two-wheelers. PTWs account for 17.4% of mobility in private vehicles in the city of Barcelona (Ajuntament de Barcelona 2012).

The evolution by types of vehicles shows a tendency of decrease in cars fleet, whereas those PTWs tend to rise. People travel less by car, changing and increasing the use of PTWs. The use of motorized two-wheeled vehicles is a growing phenomenon. Small dimensions, high maneuverability and free parking on streets, have made PTWs a competitive mode of transport in terms of cost and time, and have additionally contributed to relieve traffic conditions. In 15 years (1996-2014) the number of PTWs per 1000 inhabitant has increased by 21%, while cars have decreased by 15%. In 2012 34% of non-commercial vehicles in Barcelona were motorized two-wheelers.

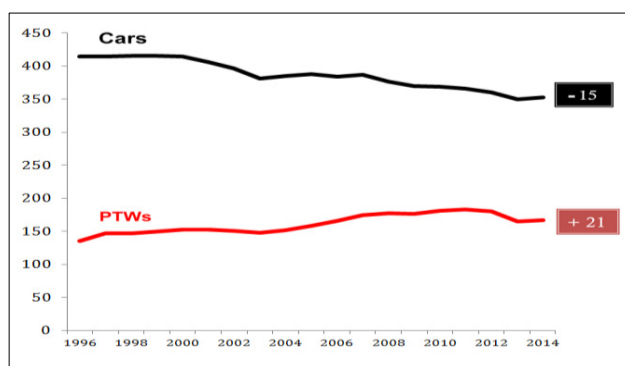


Fig. 3. Cars and PTWs per 1000 inhabitant in Barcelona from 1996 to 2014 (%)

Like many European metropolitan areas, Barcelona experiences a double trend: major tertiarization of the center city and increasing journey attraction and population decentralization from center city to peripheries. The implications are that major population living a certain distance from working centers led to more car dependence to access their work (Matas, A. et al. 2009).

In Barcelona, congestion pricing has been introduced in an indirect way. Instead of implementing urban toll schemes, the main set of measures to price car use has been through regulatory parking policies and increasing cost of street car parking. Unlike car parking pricing implantation, on street motorcycle parking has no cost, and it is allowed and free on sidewalks. In addition, the numbers of on street motorcycles parking places are in augmentation. Congestion pricing has a significant effect on encouraging motorcycle use, assuming motorcyclists are not charged for parking.

These traffic-calming schemes have discouraged the use of cars, partially shifting the use of cars for motorcycles. Besides, governments have taken actions to discourage car use, and measures to favor PTWs such as increase parking spaces for motorcycles, creation of advanced Stop Lines at traffic lights, improved traffic safety of motorcycles using anti-slip paint for road markings and reducing the crosswalks painted area. Altogether it has favored the reduction of the inefficiencies associated with traffic congestion and increased attractiveness for PTW use.

As in Barcelona, many European local governments in major cities implement policies to inhibit and reduce car use, targeting to relieve congestion and emission of greenhouse gases. In this sense they have implemented actions to restrict car use that intentionally, or unintentionally, have favored PTW and bicycle use because the small size and nimbleness of those vehicles reduces congestion. The high density of Barcelona and saturated streets increase safety

conditions, because congestion diminishes the probability of suffering severe injuries, finding a negative relationship between traffic flow and injury severity of PTW (Albalate, D. and Fernández-Villadangos, L. 2010).

Increase use of PTWs is a common phenomenon among major European cities. Since the mid-1990s there has been a continuous increase in PTWs ownership and their use in large European cities. In Paris in the period 2000-2007 PTWs have experienced an increase of 36 % and private cars a decrease of 23% (Kopp, P. 2009). Motorcycle traffic appears to have been increasing notably in Greater London since the introduction in 2003 a pricing scheme “The Congestion Charge”, granting exemption to PTWs, which has benefited a notable increase of use and possession of PTWs in the London Area. In Rome motorcycles represent 16% of vehicles in circulation and have increased by 60% between 2002 and 2014 (Automobile Club D’Italia 2014).

These trends suggest a continuous future growth of PTW use in urban congested areas, showing a relevant income elasticity of demand for motorcycles and substitution effect from cars, and even from public transport to PTWs in stages of high economic levels. The increasing use of PWTs in developed countries congested urban areas may contradict the models interrelating economic growth and the use of motorcycles.

5. Conclusions

Transport systems provide mobility necessary for human socio-economic activities. Journeys made by private vehicles (mainly cars and powered two wheelers PTW) make up an important part of mobility. Understanding about patterns of the historic evolution of motor vehicle ownership is useful to forecast future transport scenarios.

The historical evolution of private vehicle ownership is determined by different types of variables, mostly related with per capita income, urbanization, public policies and alternative means of transport.

Vehicle ownership models are a useful tool for analyzing and predicting scenarios that assist decision-making and transport planning. The relationship between measured economic variables and car ownership is non-linear in the long-term, fitting a sigmoid-shape function. The Gompertz function represents the long-run equilibrium level of the vehicle/population as a function of per capita income. The S-shaped Gompertz function that is valid to represent car evolution doesn’t provide a statistically fitted representation for the PTWs. Studies suggest that a long-term inverted U-shaped curve (i.e., the Kuznets), fits better for the relationship between PTWs and per capita income. The double slope shapes the PTWs increase at early stages of economic growth ownership and once a threshold level is surpassed, higher incomes produces the inverted effect, declining the use of PTWs. Some other studies and this one, suggest that in advanced European countries PTWs use will not necessarily decrease in the long-term. In dense urban areas, cars experience increasing operational cost because of tolls, taxes, parking and environmental restrictions, favoring a substitution effect from car to more convenient PTWs. Those future growth prospects, questioning the inverted U-shaped model consider that in the long run high per capita incomes are related with declining use of motorcycles. This study also notes that in a high-density city like Barcelona the trend is an increase in the use of PTWs.

Barcelona is one of the densest cities in the world. Mobility policies are characteristic of an advanced society, addressed to promote public transport and bicycles. Barcelona is a city that is highly dependent on motorcycles. Small size, high maneuverability, low operational costs and free on-street parking made PTWs more convenient for inner city trips. In 15 years (1996-2014) the number of PTWs per 1,000 inhabitant increased by 21%, while the number of cars has fallen by 15%. Increase use of PTWs in Barcelona is a common phenomenon in major European cities. These trends suggest a continuous future growth of PTWs use in urban congested areas, showing a relevant income elasticity of demand for motorcycles and substitution effect from car and even public transport to PTWs.

The increasing use of PWTs in developed countries and congested urban areas is not in line with the assumptions of the U-inverted curves models, which predict that in the long-run there will be a decrease in use of PTWs with high income per capita levels. These results may suggest that conducting further research might be helpful in analyzing possible functions that improve modelization of PTWs ownership in advanced stages of socio-economic development, considering that the curve shape can acquire a growing slope.

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