Traffic Congestion in Buenos Aires: Diagnosis and Public Policy Recommendations for a More Sustainable City

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Abstract

In recent decades, traffic congestion has had a central place on the transportation agenda in the City of Buenos Aires. Despite imposing works that benefited -in the short term- the traffic flow, traffic jams are persistent, and the phenomenon has even spread beyond the city center, reaching different points of the suburbs. The mere fact of traveling with a telephone throughout a city generates endless data that can be collected and analyzed to make investment or public policy decisions. In this work, the cost represented by the existence of congestion in Buenos Aires will be estimated and studied through a characterization approach of the variables, thoroughly investigating its causes and its consequences using programming tools and emphasizing the importance of Big Data in building a more sustainable city. Tentative public policies will also be proposed to mitigate the effects of congestion in the city, based on the data observed in the first instance and considering the new paradigm of smart cities, ecological infrastructure, and empowerment of public transport.

Keywords: traffic congestion; smart cities; sustainable, transportation

1. Introduction

Traffic congestion is a phenomenon present in most medium-sized and large cities around the world. This implies the constant generation of negative effects in socioeconomic, environmental and development aspects. Various studies present the costs of congestion at an aggregate level, such as in Europe, where the cost of time lost in traffic in 2016 was estimated at €200 billion, which is equivalent to 1.4% of the GDP of the European Union (European Commission, 2020). In the United States, studies show that congestion generates losses of approximately 0.7% of GDP and that this is a number that is growing along with the total of vehicles (Cebr, 2014). Although this latest study considers the costs of congestion as only the value of lost time and fuel consumption in situations of speed irregularity, congestion is also associated with higher levels of fatigue, anxiety, and depression, with variations in the rates of road accidents and with barriers to the positive effects of urban agglomeration —for example, in terms of productivity and the labor market—, ultimately hindering the sustainable development of societies (IDB, 2021).

Traffic congestion has been increasing in both developed and developing countries, and everything indicates that it will continue to worsen, representing an undoubted threat to the quality of urban life. The congestion is mainly due to the intensive use of cars, the ownership of which has spread massively in Latin America in recent decades. Private cars have advantages in terms of facilitating personal mobility and giving a sense of security and even higher social status. In Argentina, and especially around the Buenos Aires Metropolitan Area (BAMA), this scenario is aggravated by a deficit in the quality of public transport modes. The BAMA includes the City of Buenos Aires and 40 municipalities of the Buenos Aires Province, totaling 15 million inhabitants. Around two million people enter the City of Buenos Aires daily, with the private vehicle being the mode of choice for approximately 25% of trips in the Metropolitan Area (ENMODO, 2009). These characteristics, including the low occupancy of the vehicles (approximately, each vehicle carries 1.2 people on average) and the disjointed public transport system in the BAMA, led to the creation of congestion hotspots in the city and in the suburbs, meaning an extra cost of transportation and a problem that must be addressed from public policy and planning.

This paper aims to be the first antecedent of a comprehensive analysis of the situation of vehicular congestion for the BAMA, highlighting the use of public and homogeneous databases that can be replicated in other cities with the same possibilities of access these sources of information. In this framework, this paper will be useful to implement congestion cost methodologies that include implicit factors such as the carbon footprint with the help of open programming tools and Big Data.

2. Sources

The mere fact of moving around a city with a phone generates endless data that can be collected and analyzed to make investment or public policy decisions. The study of mobility had a leap in quality thanks to cell phone GPS and Geographic Information Systems (GIS). The combination of these tools makes it possible to analyze flows of people, their origins, their destinations, the routes they have used, and even the speeds at which they have circulated. In this context, the production of massive data opens interesting possibilities in the field of mobility management and urban transport planning. For the development of this work, Waze congestion data, TomTom car flow data and different public databases will be used. One of the fundamental ideas of this paper is the possibility of replicating the methodology used in it for other cities. The data partnerships that the mentioned companies have make it easy to obtain the same information that was used for this research for local governments, universities, or NGOs. For processing, R programming language and open-source libraries were used. It should be noted that the entirety of this study is based on data from the year 2019, since it can be considered the last "normal" year before the COVID-19 pandemic. It will be interesting for the investigative continuity of this work to recalibrate the model with post-pandemic parameters to identify continuities and differences.

3. Transport decisions in the Buenos Aires Metropolitan Area

Every day, thousands of people move between different geographical points of a city to carry out their daily activities. For this reason, everyone must choose the mode of transportation that best suits their desires and availability. In the case of urban passenger transport, users decide regarding which transport mode to take based on all their temporary, physical, and budgetary reasons (de Rus, 2009). This is how transport users make the decision of the mode of travel based on certain parameters such as travel time, fare, convenience, comfort, and safety.

In recent times, there has been in the country an almost uninterrupted government promotion of the purchase and use of private vehicles. Although road works were carried out to provide more security and reduce travel times, reality shows that the supply of "streets space" has grown at a much lower level than the demand, reaching saturation in certain parts of the region. In a dynamic of interjurisdictional trips generated mainly between the City of Buenos Aires and the rest of the metropolitan region, this increase in the use of private cars created certain sources of congestion related to excess vehicle demand.

The meager attempts to revitalize public transport with works that could barely ensure a minimum level of safety and comfort, in part due to the distorting financing system and subsidies to the supply of the system, could not prop up the transition from private to shared or sustainable modes of transport (Barbero et al., 2019). Not even one of the lowest fares in Latin America for rail or bus transportation managed to discourage the use of private vehicles. The policy of indiscriminate subsidies to motor transport (buses) with a minimum level of auditing has generated countless distorting situations in the market. The most relevant was the disincentive for companies to gain users, since the subsidies were granted according to the kilometers traveled and the affidavits of the owners of the companies. In this way, a "non-competition" and strong regulation scheme was generated in the context of a progressive aging of bus routes. The fall in the real rate of public transport graphed above was not configured as a public policy to promote public transport, but rather was the result of a mismanagement of federal subsidies that had an impact on other areas besides mobility (electric power, water), generating a progressive deterioration in the transportation system.

Regarding the transport offer, there is a strong concentration in the center of the city. This has remained relatively constant over the years, since the center has principal offices of the national and municipal public administration, central offices of banks and different companies, which generates a logical flow of movement towards it. It is also true that there is a higher population density in that area compared to the outskirts of the city.

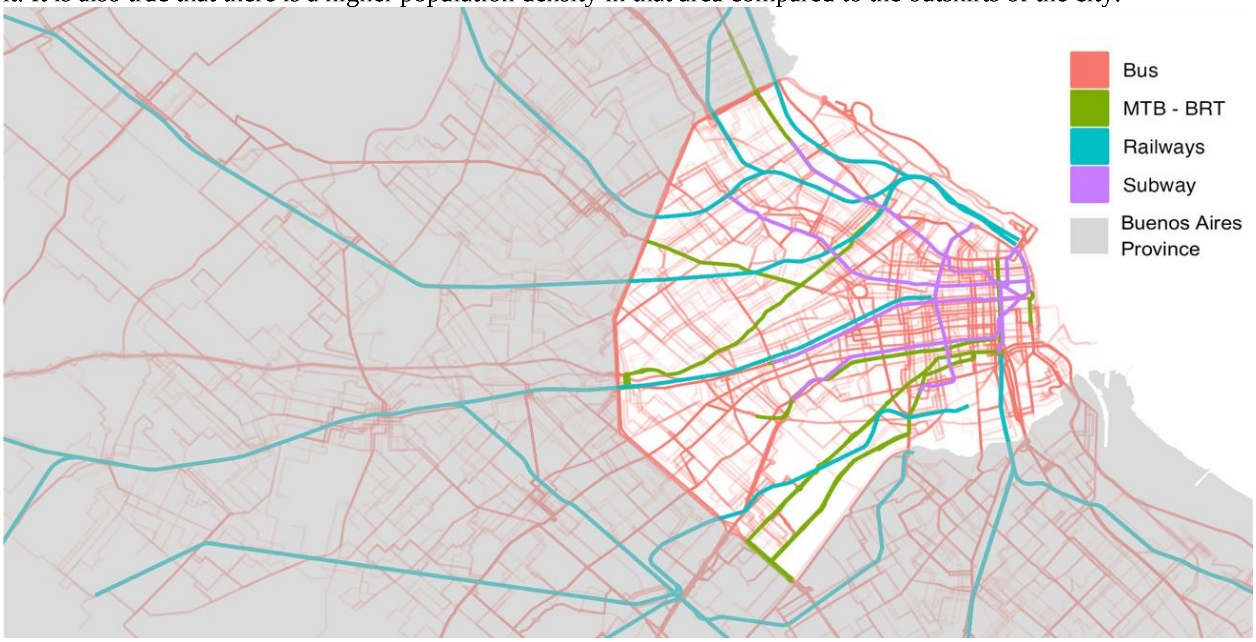

Fig. 1. Public Transportation Supply in the BAMA.

The entire public and private transport system in the region seems oriented towards this centrality, in fact, the accesses and highways point towards the Obelisk and the van and charter terminal (important players in trips from the suburbs) are located there, as seen on Fig. 1. The subway is shown as a complementary system to the railways since the latter attract passengers from the Buenos Aires suburbs to the terminal stations where it is easily connected with the subways to reach a more particular destination (in the macro / microcenter). Parallel to this phenomenon of public transport, many parking lots have been built in the center (where there is a limited supply of parking on public roads) to absorb the demand for the transition from the private vehicle mentioned above.

4. The dynamic of traffic congestion in the area

For many decades, vehicular congestion was a problem that was in the center of the City of Buenos Aires. The hundreds of thousands of vehicles that entered the city daily were largely located in the Plaza de Mayo area (fundamentally the neighborhoods of San Nicolás and Monserrat). From the urban expansion suffered by the entire BAMA, the phenomenon of congestion has spread to other points not only in the city (such as the commercial part of the Belgrano or Flores neighborhood) but also outside the city. General Paz Av., reaching the urban centers of the largest cities in Greater Buenos Aires such as Morón, San Justo, Caseros, Avellaneda, Quilmes, or Vicente López. This is how, during the year 2019, vehicular congestion had its epicenter in the area between four avenues: del Libertador, Independencia, Pueyrredón and Leandro N. Alem, with a continuation towards the west and north closer with Rivadavia (neighborhoods of Caballito and Flores, essentially) and Santa Fe (Palermo and Belgrano). Arriving in Greater Buenos Aires, more frequent congestion is perceived in the centers of economic activity of the localities, but also in the accesses and highways that derive traffic to the city.

Congestion can be represented from a geographical point of view. In this map, congestion is represented by lines that imply congested sections, that is, sections where the operated speed is less than the free-flow speed, throughout the entire year 2019. An opacity factor was applied by which the sections with fewer repetitions of congestion appear lighter, while the streets with the highest number of occurrences of congestion in the year appear darker and more defined. To have a clearer detail of the most important sources of conflict, not all metropolitan area is shown. As mentioned before, Waze generates data only when there is a congested section, that is, when the operated speed consistently differs from the historical free-flow speed. During this period, Waze clusters cars that are geographically close and at a statistically similar speed. Subsequently, the programming algorithm segments the corresponding geometry with its correspondent characteristics.

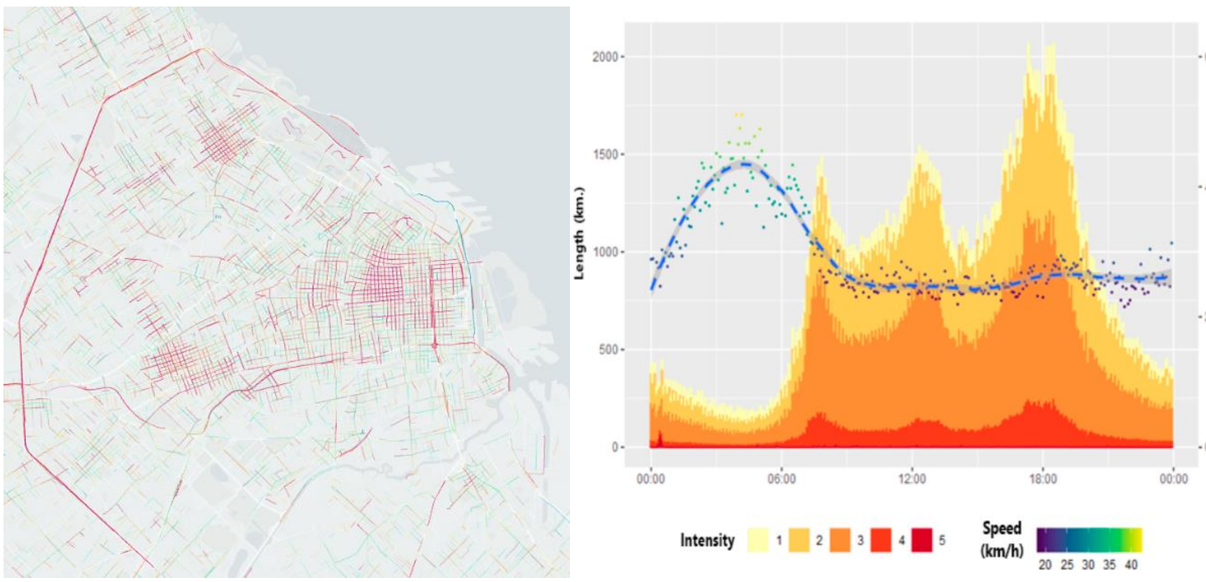

Fig. 2. Geospatial (left) and temporal (right) representation of traffic congestions in Buenos Aires.

The previous graph (Fig. 2) represents the length of average congestion for the BAMA according to its intensity and the points referring to the average speed operated by the vehicles in each TomTom dataset. At first, the three peaks of congestion that exist in the BAMA can be clearly observed: between 8 and 9 in the morning, at noon and in the afternoon, around 6 pm. These three times coincide with the entry and/or exit times of most jobs and educational establishments. In addition, the growth of the speed operated by the vehicles at dawn is notable. This is not due to less congestion, but rather that in proportion the congestion that exists at those times is not as intense as during business hours. Waze does the calculation of the delay of each congestion section from its own algorithm, computing the seconds that are added to the trip to travel on that particular congested stretch. Taking into account the differential of the speed that is operating at that moment with respect to the free-flow speed and knowing the total congested distance of that part of the route, those extra seconds are computed as delay time.

5. Estimation of congestion costs

In the first place, some assumptions and descriptions will be made about the process of generating vehicular congestion. Following the guidelines of Mun's (1994) bottleneck model, congestion will be considered a phenomenon with the following behavior:

$$T(t) = \begin{cases} 0, & if\ Q(t) \leq C_b \\ \dfrac{Q}{(C_b - 1)}(t - t_a) & if\ Q(t) > C_b \end{cases}$$

Where T(t) is the extra travel time, t_a is the time needed to travel the remaining path before the destination under normal conditions, t is the waiting time in congestion, Q is the number of vehicles in the traffic jam, and C_b is the load capacity of the artery. Adding to the analysis the value-time v (Berechman, 2009), the marginal cost of congestion is defined as the differential of the time necessary to make a certain trip in conditions of vehicular congestion multiplied by the number of people who suffer from that congestion (both drivers and companions) and weighted by the monetary value of time. In this way, the total cost of congestion from the point of view of the time value of users is determined by the number of users involved in a congested section, the associated time value, and the delay time on the congested road. It should be noted that, as there are cases in which cars transport more than one person, the number of companions will be weighted according to the calculation of average people in a car according to ENMODO. With respect to the number of vehicles affected by congestion, the following assumptions apply:

a) the characteristics of the bottleneck remain constant during the two minutes that there is a gap between data and data. This means that the delay, speed, length, and number of vehicles are considered equal throughout this interval.

b) the flow of cars in a traffic jam is infinite. This is a logical consequence of assumption a). It is necessary that for the number of vehicles involved to remain constant in these 120 seconds, the number of cars leaving the congestion are the same as those entering, that is, each vehicle that leaves the congested section is replaced by another.

As a result of these two assumptions, it can be established that the vehicles entering the traffic jam as a flow are symmetric in terms of added delay to those leaving the stock, the added delay can be calculated as the sum of the maximum delay for each vehicle in stock.

To calculate the cost of the loss of efficiency due to higher fuel consumption, the methodology of Posada Henao and González Calderón (2013) will be followed. These authors put together a compilation of a series of vehicles and did tests at different speeds on the consumption of different types of fuel. In Argentina, the production of diesel vehicles has been in sharp decline in recent decades, reaching levels of 3% and there are no specific and updated data on the existing vehicle fleet powered by this fuel, so it will be assumed that all vehicles use “super” gasoline. Bearing in mind that the weighted average free-flow speed is 41.53 km/h and the speed operated in weighted congestion is 15.35 km/h, it can be concluded that, at an aggregate level, congestion in the city generates that cars that used to go at 41.53 km/h now go at 15.35 km/h and from there calculate the data of the extra gasoline consumed for all the length sections, knowing the specific difference for each street.

In what has to do with environmental costs and having the data of the aggregate consumption of gasoline due to the existence of congestion, it is possible to obtain the carbon footprint left by this excess fuel consumption. The carbon footprint is an instrument that allows estimating greenhouse gas (GHG) emissions emitted by an individual, organization, event or product and consists of collecting data referring to direct and indirect consumption of material and energy inputs and translating them in equivalent CO2 emissions. The Department of Sustainability, Environment and Climate Change of the Ministry of Agroindustry of the Province of Buenos Aires (2018) established a methodology for the calculation and obtained that, for each extra liter of gasoline, the carbon footprint is 2.37 kg CO2 equivalent. At the same time, the ECLAC document entitled "The social cost of carbon: an aggregate view from Latin America" allows us to obtain the monetary social cost of these equivalent kilos of carbon dioxide. The cost is, on average, 25.83 dollars per ton of CO2 equivalent, that is, 0.02583 dollars per kilo. So, a liter of gasoline generates an extra social cost for the equivalent carbon dioxide of 0.0612171 or 2.978 pesos per liter according to the average exchange rate for the year 2019.

Table 1. Composition of the socioeconomic cost of vehicular congestion in the City of Buenos Aires, year 2019.

Cost (time value)	Extra consumption of fuel	Carbon footprint	Total
Medium wage (hourly, 2019) = \$351 v = \$175.61 $Q.v.\frac{t - t_a}{C_b}$	“Super” gasoline (2019) = \$43.59 Extra liters = 67,421,638	CF per gasoline liter = \$2,978 Extra liters = 67,421,638	
\$ 23,092,024,198	\$ 2,938,909,209	\$200,781,639	\$ 26,231,715,046

Table 1 distinguishes the components of the socioeconomic cost of congestion. The first column establishes the cost of the added time. This data was calculated by multiplying the aggregate travel time of each of the drivers involved in congestion (for each of the congested sections throughout 2019) by the monetary value of the time obtained with the previously explained methodology. In the second column of Table 1, the extra gasoline consumption caused by the existence of lower average speeds than the "free-flow" speeds is calculated, which generates a more intensive use of energy by the engine and this translates into an additional cost to the car user, and, therefore, to society. Lastly, the third column describes the socioeconomic cost derived from the carbon footprint of these extra liters of gasoline that vehicles consume in a situation of vehicular congestion.

Comparing the total magnitude of the monetary cost of congestion with the Gross Geographic Product of CABA for the year 2019 ($2,490,660 million at current prices according to the General Directorate of Statistics and Censuses of the Government of the City of Buenos Aires), it is concluded that the congestion cost represents approximately 1.1% of GDP. When this index is broken down, it is observed that the cost due to loss of time value is the most preponderant of the three costs studied in this work, representing 88% of the costs of congestion, followed by the extra cost of gasoline consumption, meaning 11.2% and having in last place the cost per carbon footprint of gasoline consumption, implying a 0.8% of the cost of congestion. It is also interesting to compare the cost of congestion with the socioeconomic cost of road accidents, which is approximately 1.8% of GDP (Fulponi, 2021). This means that, if the two strongest externalities of private vehicles are added, productivity losses of almost 2.9% of the City's Gross Geographic Product are estimated, which is a fact that must be considered when to establish public policies.

6. Public policy recommendations

This study shows the relative importance of congestion in the lives of the inhabitants of the City of Buenos Aires. The result of the congestion cost level reaches 10,000 pesos per capita, equivalent to a monthly minimum wage. These socioeconomic losses must be contemplated when drawing up public policies.

For many decades it was mistakenly believed that adding road infrastructure to cities always generated positive effects and places with respect to the phenomenon of congestion. There are still many policy makers who think this way. However, the scientific evidence that shows that the phenomenon of induced demand exists and is increasingly important when planning transport development. Therefore, the generation of new infrastructure can be an option to mitigate vehicular congestion only if certain additions are considered, such as modal segmentation or the type of vehicles that travel along the route. An example of this case can be the Paseo del Bajo. The lower area of Buenos Aires was a historic congestion zone, however, the construction of the Paseo del Bajo made it possible to ease the traffic jams in the area by differentiating vehicles. It had been determined that the main culprits of congestion in the area were trucks, so exclusive lanes were built for them and for long-distance buses, generating a much more direct shortcut and enabling a fast north-south connection of the city, previously necessarily given by Ing. Huergo Avenue or, in the worst case, 9 de Julio Avenue.

Other highly necessary policies to reduce congestion are traffic calming policies. They are a series of strategies for road design that promotes attentive and responsible driving. It uses sensitivity-rich environments to slow down vehicles and encourage safe habits among all road users. The design of traffic calming policies forces drivers to pay attention to their general driving environment to determine their driving behavior. Factors such as road conditions, obstructions, sight distance, and the presence of pedestrians can seriously affect road safety. In this way, traffic calming policies fulfill a double function: improve road accident rates while reducing vehicle volume. If the vehicle volume is reduced, there is less possibility of the existence of congestion through bottlenecks and the standard deviation of the speed is reduced to a minimum. It should be noted that this policy can be implemented on medium flow avenues or streets, not on large highways or routes. In addition to these measures, certain road lanes can be assigned for the exclusive circulation of cars that carry more than one person, to prioritize vehicles that have the greatest potential loss of productivity by carrying several people and not a single drive.

All the policies mentioned above would not be possible if there is not a monitoring center that has a partnership with Waze, TomTom, Google, Here and all the companies that provide traffic information in real time to know and deeply understand the phenomenon of vehicular congestion. Although the of Buenos Aires already has a General Center for Urban Monitoring, it is necessary for the Province of Buenos Aires to also have a similar one to manage the traffic of the main accesses to the City, where it does not have authority, simultaneously providing support and information to the municipalities of Greater Buenos Aires so that the various local police forces can exercise traffic control in a more dynamic and efficient manner.

There are various general policies to discourage the use of a private car in a particular area. In the first place, restrictions can be established on the passage of vehicles in certain areas or at certain times. In the City there is an "Environmental Area" in which you cannot enter with a private vehicle on business days. This area represents the streets of downtown Buenos Aires where cars can circulate on the avenues. This policy, added to different interventions and pedestrianization of the streets belonging to the indicated area, generated a strong reduction in congestion. These restrictions may also involve bans on public parking, charging parking fees, or limiting parking hours and certain zones in the most congested areas to reduce the desire to drive to those places.

Different forms of road pricing have also been developed around the world to internalize the cost of congestion. Ideally, vehicles should be charged for the cost of road use for each trip, so that only cost-justified trips are made. This premise is perfectly developed by one of the mentors of the best estimate of road pricing, David Newbery. In his paper "Pricing and congestion: Economic principles relevant to pricing roads", the initial situation and the optimal situation of car travel are explored. In practice, the imposition of a congestion charge will reduce the flow of cars to the area, especially if the charge is significantly important for the income of motorists. The dynamics of pricing and the change in habits of private car users will tend, in the long term, to generate "subsistence" car consumption, so that the only trips made by car will be those in which it is really its use necessary, the rest will be replaced by other modes of transport or will not exist directly as trips in themselves. Based on this premise, it is quite interesting to analyze the paradox in the collection of this rate or charge, since initially it will be maximum and, ideally, it will be null in the long term, since it is understood that the necessary trips in car must be exempted (as well as trips with a Certificate of Disability, carriers, suppliers, etc.). However, the policy will continue to be financed through the positive externality represented by the mitigation of congestion zones.

This policy implies the collection of a pass or "entrance" to the congested area, like a toll, through some collection technique such as cameras that detect license plates. In the City of Buenos Aires there is no type of policy of this style beyond the "flat" collection of the ticket and the distinction between peak and non-peak hours. However, the most preponderant purpose of urban tolls is currently not the reduction of the volume of cars in a specific area. A probable congestion charge policy would be to charge the entrance to downtown through LPR cameras, and the fare could be calculated in real time with the Waze live feed data. According to calculations by TomTom users, Waze congestion and the calculation of costs made in this work, a fee of $150 (2019 price) for each vehicle that enters the perimeter could internalize 80% of the costs of the congestion. Of course, various assumptions are being made, such as an optimistic 40% reduction in volume of cars in the area. In addition to the political difficulty of facing a policy of this magnitude, it is necessary to emphasize that this congestion charge proposal requires a large initial investment and at the same time must be complemented with other policies that encourage the use of public transport or non-motorized vehicles (investment that will probably have to be made before obtaining the desired results from the fare collection, which can also generate planning conflicts).

A fundamental and central policy to reduce urban congestion is to encourage the transition to public transport. Compared to other modes of transportation, public transportation has the capacity to move many people due to the load capacity of its vehicles, providing effective and efficient solutions for traveling in large cities. With a framework of investments and reasonable rates, an efficient scheme of subsidies and works that improve the level of public transport services, motorists who can access it will progressively adopt it as their preferred transport modes. The fundamental thing is access to competitive travel times, full comfort, and predictability in the transport supply. The Metrobus (BRT) in the city has generated improvements in these aspects, the most palpable being the improvement in the speeds operated by the groups in those sections.

A good complementary policy to the regulation of public parking could be the construction of parking lots at railway stations far from the city center and located near accesses (such as Liniers, Avellaneda or Rivadavia), so that the person who is not encouraged to access public transport from Greater Buenos Aires due to the lack of quality and supply of the same may have one more reason to leave the vehicle on the outskirts of congested areas, reducing the level of congestion without having to generate new roads for transportation in the suburbs, a policy that can generate budget mismatches due to the lower population density.

Finally, it is necessary for cities to begin to set green mobility objectives to reduce congestion and everything related to the environmental pollution of the private car. For this, the promotion of the creation of cycle paths, the promotion of the use of the bicycle and the generation of bike-sharing models or public transport systems by bicycle are central on the agenda. In addition to mitigating the negative externalities mentioned, positive externalities are generated such as economic growth in the areas, improvements in productivity and greater care for health and personal well-being. In this aspect, the integration of the bicycle in general urban transport is a necessary step to radically transform the transport offer. There are several possibilities to achieve this, such as parking in large stations, allowing bicycles to travel by metro and generating benefits in fares if this transport is used.

7. Conclusion

Throughout this work, it was highlighted that congestion is not an isolated phenomenon that appears and disappears through the streets of Buenos Aires without any cause, but that congestion has its reason for being in the scarce territorial planning, in the indiscriminate expansion of the urban sprawl beyond the sustainable limits for a region and in the poor real investment in public transport beyond the subsidies. It was emphasized that it is useless to have a cheap but uninvested public transport system, since, with extremely low real fares, the use of private vehicles continued to grow. This was because people not only value the cost of the trip as the fare to pay, but there are also objective issues (such as travel time) and subjective ones (the comfort of transportation, the possibility of taking the means of transportation every day at the same time, predictability) that make people buy a vehicle due to the distrust and fear that exists regarding public transport.

It is essential that both local and national transport authorities understand that this problem cannot be solved with superficial and short-term measures such as reducing pedestrian zones to expand lanes for cars, but that a very important planning effort is necessary with a view to long term and the sustainability of the transport system. Policies should be efficient, and evidence based. In the world of Big Data, programming and real-time analysis, governments cannot ignore hard and factual analyzes to understand phenomena like this one. It is necessary to generate, share and process information to create cities for people and not for vehicles, leaving jurisdictions and political sectors aside to join efforts to efficiently coordinate policies throughout the entire territory and minimize all possible externalities, considering mind the well-being of the population, the sustainability of the environment and the economic development of the region.

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