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INCREASE IN THE VEHICLE FLEET AND ITS EFFECTS ON URBAN MOBILITY IN SMALL TOWNS[1]

AUMENTO DA FROTA DE VEÍCULOS E SEUS EFEITOS SOBRE A MOBILIDADE URBANA EM PEQUENAS CIDADES

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Gabriela Senra Amaral*
*Universidade Federal do Espírito Santo (UFES), Vitória, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/8051591619167715
Orcid: https://orcid.org/0000-0003-4000-4375
gabisenra@hotmail.com

Calvin da Silva Candotti**
**Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Amazonas, Brasil
Lattes: http://lattes.cnpq.br/4553810105127855
Orcid: https://orcid.org/0000-0001-7356-6548
c4lvin1989@gmail.com

Fabrícia Benda de Oliveira*
*Universidade Federal do Espírito Santo (UFES), Alegre, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/9513837515797451
Orcid: https://orcid.org/0000-0002-4456-0275
fabricia.oliveira@ufes.br

Carlos Henrique de Oliveira***
***Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo (IFES), Alegre, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/1293627013882628
Orcid: https://orcid.org/0000-0003-4829-8005
carlos.oliveira@ifes.edu.br

José Luiz Louzada*
*Universidade Federal do Espírito Santo (UFES), Alegre, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/6631032721471650
Orcid: https://orcid.org/0000-0003-4285-9983
jlslouzada@gmail.com

Pâmela da Silva Purificação*
*Universidade Federal do Espírito Santo (UFES), Vitória, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/3622662159541819
Orcid: https://orcid.org/0009-0005-0962-6688
pamela.purfificacao@edu.ufes.br

[1] The work was carried out in a small mountain town called Alegre, in the Caparaó region, southern Espírito Santo state, Brazil.

Gabriel Soares Lopes Gomes*
*Universidade Federal do Espírito Santo (UFES), Alegre, Espírito Santo, Brasil
Lattes: http://lattes.cnpq.br/4736378013018937
Orcid: https://orcid.org/0000-0002-3211-3929
gsoares.flo@gmail.com

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Abstract
The increase in the vehicle fleet negatively impacts Brazilian municipalities. Understanding how it impacts Alegre, a virtual public survey was held with its licensed drivers in 2019. In 10 years, its fleet of cars and motorcycles grew faster than its stagnant municipal population growth and faster than municipalities almost four times more populous than it. In mid-2019, of about 104 respondents, 90% had cars and 44% had motorcycles, relative percentages above obtained in a similar survey in Londrina, which has 20 times its population. About 86% of interviewees considered the lack of parking to be a problem and 80% believed that limited waiting could improve urban mobility in Alegre if it had affordable prices. The increase in the vehicle fleet in Alegre causes urban mobility problems. However, its population receives the implementation of a limited waiting system well, contributing to the implementation of public management practices. However, implementing limited waiting alone is insufficient; some Brazilian municipalities combined the implementation of the system with awareness-raising and (re)education of drivers and education of children.

Keywords: Management. Mobility. Consultation. Accessibility. Awareness.

Resumo
O aumento do parque automotivo tem um impacto negativo nos municípios brasileiros. Para compreender como isso afeta Alegre, foi realizada uma pesquisa pública virtual com seus motoristas habilitados em 2019. Em 10 anos, seu parque de carros e motocicletas cresceu mais rapidamente do que o crescimento populacional municipal, que se manteve estagnado, e mais rapidamente do que em municípios com quase quatro vezes mais habitantes. Em meados de 2019, dos cerca de 104 entrevistados, 90% possuíam carros e 44% possuíam motocicletas, porcentagens relativas superiores às obtidas em uma pesquisa semelhante em Londrina, que tem 20 vezes a sua população. Cerca de 86% dos entrevistados consideraram a falta de vagas de estacionamento um problema e 80% acreditavam que o sistema de espera limitada poderia melhorar a mobilidade urbana em Alegre se tivesse preços acessíveis. O aumento da frota de veículos em Alegre causa problemas de mobilidade urbana. No entanto, sua população aceita bem a implementação de um sistema de estacionamento com tempo limitado, contribuindo para a adoção de práticas de gestão pública. Contudo, a implementação do estacionamento com tempo limitado por si só é insuficiente; alguns municípios brasileiros combinaram a implementação do sistema com a conscientização e (re)educação dos motoristas e a educação das crianças.

Palavras-chave: *Gestão. Mobilidade. Consulta. Acessibilidade. Conscientização.*

1 TRAFFIC PROBLEMS

The increase in the vehicle fleet indicates economic development; but negatively affects urban mobility by increasing congestion and placing pressure on the availability of public parking spaces (Cassiano, 2014; Ronquin *et al*., 2012; Câmara dos Deputados, 2015). In commercial areas, competition for parking spaces generates conflicts between users, interfering with traffic and urban mobility (Elias, 2001; Feder, 2006). Urban

mobility encompasses the movement of people and goods from an origin to a destination and involves private vehicles, public transportation, pedestrians, and cyclists, as well as the urban infrastructure that supports them (Silveira, 2004; Franco, 2008). It is related to sustainable development, as it concerns the right of individuals and products to circulate freely and efficiently within urban spaces, contributing to social inclusion, economic activity, and service provision (Campos, 2006).

Ensuring adequate mobility requires encouraging the rational use of private vehicles, strengthening public transportation, and promoting alternative modes of travel (Rocha *et al*., 2006; Parra & Portugal, 2007; Corrêa, 2018), given that the number of private vehicles continues to grow. Cars are associated with status and comfort, while motorcycles have lower acquisition and maintenance costs and are suitable for service-related activities (Ricieri *et al*., 2017; Silva *et al*., 2021). In small municipalities, these dynamics increase mobility problems previously associated with large cities. In Alegre, located in southeastern Brazil, there has been growth in the vehicle fleet, with rates comparable to those of larger municipalities (Amaral, 2019). This growth has intensified pressure on the road system and on the availability of parking spaces in the commercial center, highlighting the need for public space management strategies.

Among the measures adopted in similar contexts, time-limited parking systems have been implemented to promote the rotation of vehicles in public parking spaces. These systems aim to democratize parking, reduce conflicts over the use of space, and support local commerce, showing positive results in several municipalities where they have been implemented. Thus, this study aimed to evaluate the perceptions of licensed drivers regarding urban mobility in the municipality of Alegre, focusing on parking conditions in the commercial center and the potential need to implement a parking rotation system. To this end, a structured questionnaire was applied to identify vehicle ownership, travel patterns, perceived traffic difficulties, and attitudes toward the implementation of parking regulation policies.

2 THE PHYSIOGRAPHY AND POPULATION AND VEHICLE FLEET INCREASE OF ALEGRE

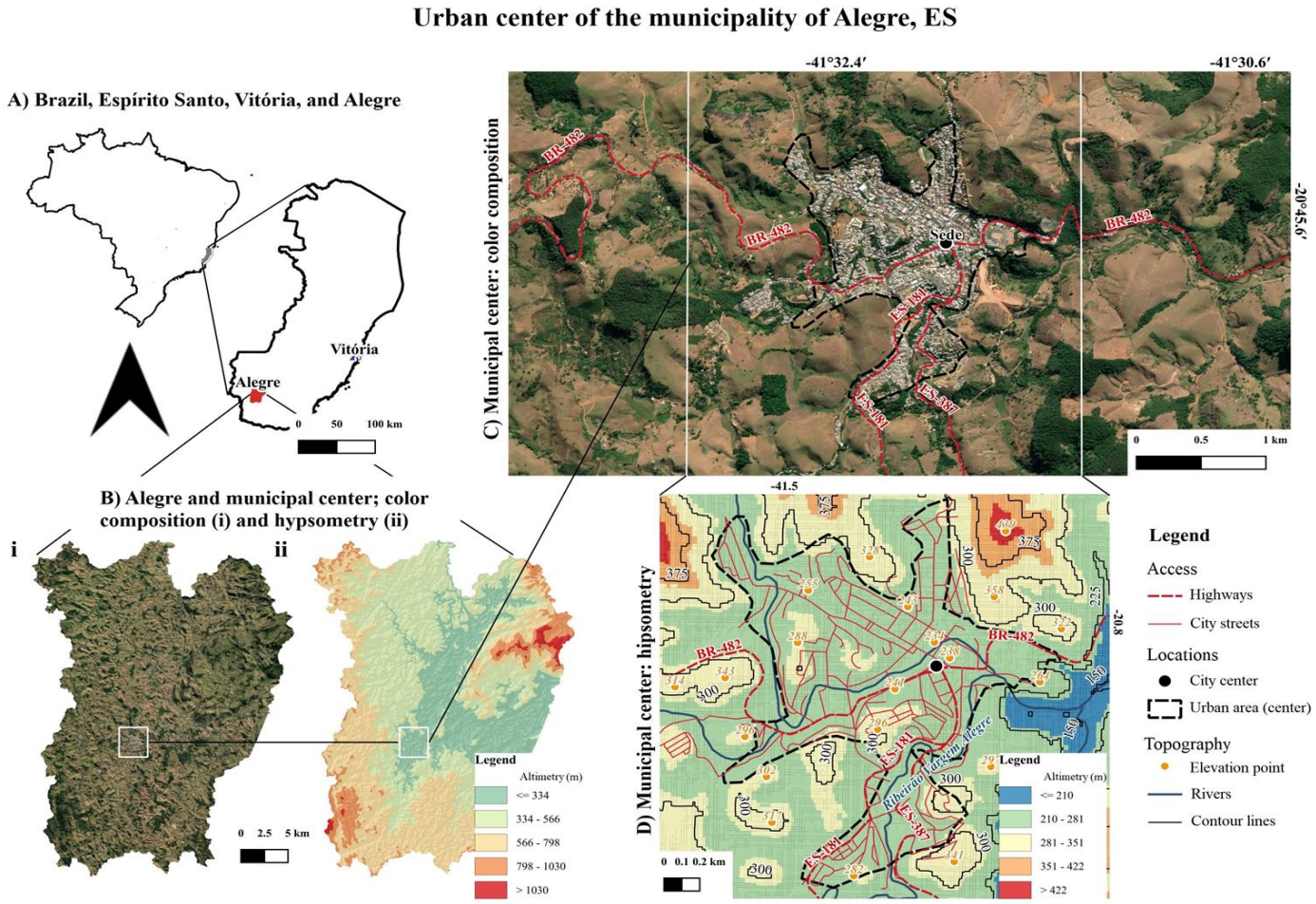
2.1 Physiography

Alegre spans 780 km² in a mountainous region in southern Espírito Santo State (Figure 1a). The elevation within the municipal limits varies from 300 to 1100 meters (Figure 1b) (IBGE, 2018). In the region housing the city hall, the elevation varies from 150 to 450 m. The surrounding "sea-of-hills" relief shows "half-orange" elevations (Figure 1c). Its urban area shows a slightly undulating relief, whereas its central portion has a relatively flat relief, the elevation of which ranges from 210 to 280 meters, surrounded by hills of up to 450 meters (Figure 1c).

It has seven districts (PMA, 2018) and its city hall (Figure 1b, 1c, and 1d); one of which has 20 neighborhoods (PMA, 2010), including its central area, the region with the largest and main evidence of the scarcity of parking during business hours (Amaral, 2019). This area contains a Universidade Federal do Espírito campus and Faculdade de Filosofia, Ciências e Letras de Alegre, indicating that it and the municipality have a significant floating population. Its physiography and population dynamics indicate future difficulties in urban and road network expansion as it will involve state roads surrounded by steep terrain.

Figure 1

Location of the municipality of Alegre and the urban headquarters (IBGE, 2023; Copernicus, 2024; NASA, 2000; Geobases, [2015-2020]).

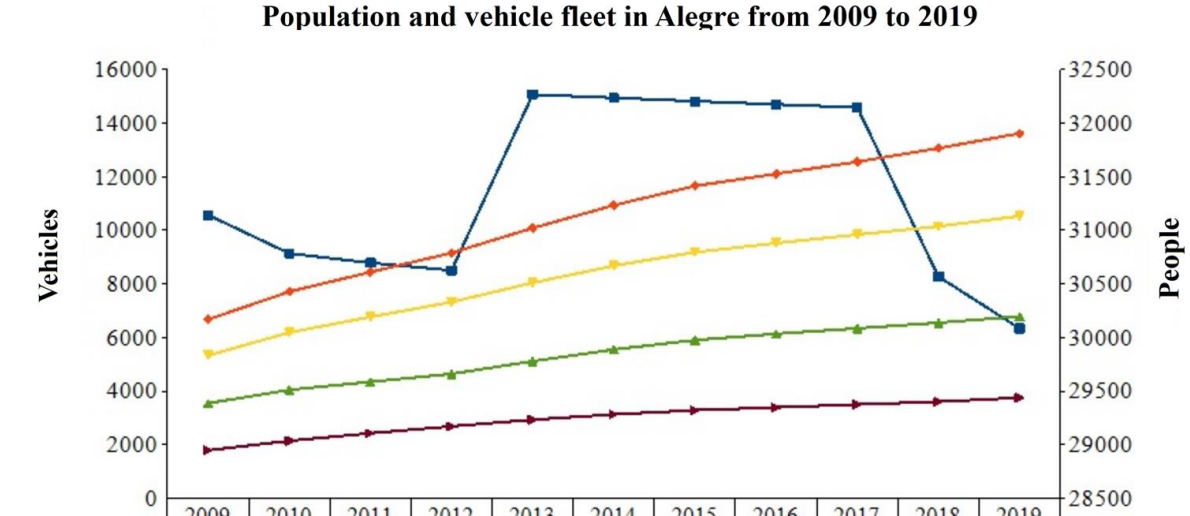


2.2 Population x vehicle fleet

Figure 2 (SENATRAM, 2019) correlates population increase with vehicle fleet growth over 10 years (from 2009 to 2019) and Table 1 shows the equations and correlation coefficients for vehicle fleets. Its population slightly decreased from 2009 to 2012, drastically increased in 2013, slightly declined up to 2017, abruptly dropped up to 2019, and grew until it stabilized in 2024 (IBGE, 2025). On the other hand, its vehicle fleet continued to increase over the years, indicating that a smaller number of people tended to acquire a greater number of vehicles.

Figure 2

Fleet of vehicles in Alegre from 2009 to 2019; reference: February (SENATRAM, 2019).



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Population	31143	30784	30696	30626	32267	32236	32205	32175	32146	30568	30084
Total fleet	6670	7707	8440	9156	10082	10935	11656	12108	12556	13061	13620
Cars + Moto.	5327	6183	6764	7321	8040	8675	9183	9521	9838	10147	10530
Cars	3541	4043	4341	4639	5112	5549	5901	6135	6339	6549	6781
Motorcycles	1786	2140	2423	2682	2928	3126	3282	3386	3499	3598	3749

Table 1

Statistics on the increase in the vehicle fleet in Alegre.

VARIATION RATES			
Parameter	**Average annual rate of change (vehicle year^{-1})**	**Overall rate of increase (%)**	**Annual rate of increase (%)**
Total fleet	695	104	7.4
Cars + Motorcycles	520	97.7	7
Cars	324	91.5	6.7
Motorcycles	196	110	7.7

EQUATIONS AND DEGREES OF CORRELATION

Parameter	Equation	R^2
Total fleet	$y = -28.7x^2 + 1035x + 5653.7$	0.99
Cars + Motorcycles	$y = -27.5x^2 + 844.6x + 4517$	0.99
Cars	$y = -13.5x^2 + 488.8 + 3047.7$	0.99
Motorcycles	$y = -14x^2 + 355.8x + 1473.4$	0.99

This study compared these variations with those in Cacoal — a 3793-km² municipality in Rondônia, in which Piassarolo (2014) developed similar research — from 2003 to 2013. Unlike Alegre, Cacoal showed a constant population increase in this interval and in the following years, as per the 2024 IBGE census. However, as in Alegre, it showed a constant increase in its vehicle fleet over the years, indicating balanced expansions or a greater number of people acquiring more vehicles.

Figure 2, based on the graph in Piassarolo (2014) — which shows the increase in the vehicle fleet from 2003 to 2013 —, and the Brazilian Institute of Geography and Statistics population statistics for Cacoal from 2003 to 2013 evince the following information and indicators on the population and vehicle fleet dynamics in the two municipalities:

1. Initial and final demographic density: number of inhabitants by municipal area at the beginning and end of the analyzed period;
2. Initial and final car and motorcycle density: number of cars and motorcycles by municipal area at the beginning and end of the analyzed period;
3. Inhabitant, vehicle, and density amplitudes: difference between the final and initial values;
4. Overall increase: percentage of increase in variables in 10 years;
5. Annual increase: annual percentage of increase in the 10 years;
6. Average annual rate of change: speed of annual increase or decrease of variables.

2.2.1. Population in Alegre and Cacoal

Table 2 shows that most of the percentage increases, amplitudes, and annual rates of change in the indicators of the number of inhabitants and demographic density of Cacoal exceed those of Alegre. The amplitude and annual rate of variation of the population of Cacoal was 12 times greater than that in Alegre and its annual and global increases about five times higher. Only the demographic density of Alegre at the beginning and end of the analyzed interval and the current one exceed those of Cacoal in 2003, 2013, and the current period. However, the other density indicators exceed those of Alegre from three to almost five times.

Alegre shows an almost stagnant trend of population growth, with a slight vacancy of its territory, whereas Cacoal has seen and experiences a more dynamic trend, with an increase in territorial occupation. The stagnant population dynamics in Alegre can contribute to minimize and/or delay the effects of future negative impacts of the increase in the vehicle fleet on urban mobility. On the other hand, the pressure from population growth and population density increase in Cacoal may require short-, medium-, and long-term urban planning and urban mobility actions.

Table 2

Comparison between Alegre and Cacoal demographic indicators.

Indicator		**Alegre**	**Cacoal**	**Cacoal/Alegre Ratio**
Population	Initial (inhab)	31,143	74,758	2.4
	Final (inhab)	30,084	85,863	2.85
	Current n (%)	30,000	100,000	3.33
	Amplitude (inhab)	−1,059	+ 11,105	11.42
	Overall increase (%)	−3.4	+ 14.85	5
	Annual increase (%)	−0.35	1.39	4.85
	Annual rate of change (inhab year-1)	−106	+ 1.100	12
Population density	Initial (inhab km²)	41	19.7	0.5
	Final (inhab km²)	39.5	22.6	0.57
	Current (inhab km²)	38.46	26.4	0.7
	Amplitude (inhab km²)	−1.5	+ 2.9	3
	Overall increase (%)	−3.65	+ 12.8	4.25
	Annual increase (%)	−0.37	+ 1.38	4.7
	Annual rate of change (inhab km $year^{-1}$)	−0.15	+ 0.29	3

2.2.2. Fleet of vehicles in Alegre and Cacoal

The amplitude and annual rate of change of the number of cars and motorcycles in Cacoal was 2.5 times greater than in Alegre and its annual and overall increases about two times higher (Table 3). Its amplitude and annual rate of change in the number of motorcycles surpass those of Alegre by 6.5 times and its global and annual increase by 1.3 times. Alegre shows a higher car density but a lower rate of variation than in Cacoal. Motorcycle density in Cacoal surpassed that of Alegre, showing ratios of 1.3 times for most vehicle quantity and density indicators.

Cacoal showed a more intense vehicle fleet growth than that in Alegre (related to greater economic dynamism, less public transportation supply, and faster urban expansion). The population in Cacoal greatly adheres to motorcycles as their individual transportation as they are economically accessible and have low maintenance costs. The density of cars in Alegre exceeds that of Cacoal, indicating that the latter tends toward a greater number of cars per person. Alegre, with its stagnant population expansion and dynamic vehicular expansion, requires the management of its fleet and mitigation of consolidated urban problems.

Table 3

Comparison between the indicators of the vehicle fleet between Alegre and Cacoal.

Indicator		**Alegre**	**Cacoal**	**Cacoal/Alegre Ratio**
Cars	Initial (cars)	3,541	4,425	1.25
	Final (cars)	6,781	12,626	1.85
	Amplitude (cars)	3,240	8,201	2.5
	Overall increase (%)	91.5	185	2
	Annual increase (%)	6.7	11	1.65
	Annual rate of change (cars year^{-1})	324	820	2.5
Car density	Initial (cars km²)	4.5	1.16	0.25
	Final (cars km²)	9.7	3.32	0.35
	Amplitude (cars km²)	5.2	2.16	0.4
	Overall increase (%)	115	186	1.67
	Annual increase (%)	52	21.6	0.4
	Annual rate of change (cars km² year^{-1})	8	11	1.375
Motorcycles	Initial (motorcycles)	1,786	8,720	4.88
	Final (motorcycles)	3,749	21,563	5.75
	Amplitude (motorcycles)	1,963	12,843	6.55
	Overall increase (%)	110	147	1.3
	Annual increase (%)	7.7	9.5	1.23
	Annual rate of change (motorcycles year^{-1})	196	1,284	6.5
	Initial (motorcycles km²)	2.35	2.3	0.97

Motorcycle density	Final (inhab km²)	5	5.68	1.136
	Amplitude (inhab km²)	2.65	3.38	1.27
	Overall increase (%)	113	146	1.3
	Annual increase (%)	26.5	33.8	1.27
	Annual rate of change (inhab km² year^{-1})	7.85	9.5	1.2

Also, different locations will prefer a certain type of vehicle; Cacoal (with about thrice as many inhabitants as Alegre) showed a 2.5- and 6.5-times greater increase in cars and motorcycles, respectively. However, Cacoal has a predominantly flat territory five times as large as that of Alegre, being able to drain its fleet to the surroundings of its municipal center. Despite its stagnant population rates, Alegre has a smaller territory, higher population density, and a mountainous relief, which will make it difficult to adopt measures such as alternative transportation and routes under great urban mobility inadequacy.

2.3 Alegre vehicle fleet dynamics and projection

Alegre and Cacoal have increasing motorization rates and differing characteristics and rhythms as Cacoal increased its number of vehicles and motorcycles per inhabitant, whereas Alegre has a higher proportion of car owners. In 10 years, the variation in vehicles per inhabitant in Cacoal was 1.3 times higher than in Alegre (and that of motorcycles per inhabitant was 4.6 times higher). However, its variation in the index of cars per inhabitant was 1.4 times higher than that of Alegre.

The trend towards motorcycles in Cacoal may be related to a more dispersed road structure, the lower average income of its population, and/or less public transportation (Vasconcellos, 2012; 2014). Although Cacoal more quickly expanded its total fleet, Alegre shows a more significant ownership of cars per person and a higher proportion of cars per inhabitant over 10 years) This may indicate a population with higher income, a more consistent and organized structure, and different travel habits, factors that favor cars instead of motorcycles (Villaça, 2001).

Although Cacoal has greater mobility dynamics, the fleet of vehicles in Alegre grows proportionally faster than its population. Its car fleet grew three times more than its population, whereas its motorcycle fleet expanded almost twice more (with the expansion of the car fleet being 1.5 times higher than that of motorcycles). The growth of the vehicle fleet in relation to

the population of Alegre was four times higher than that in Cacoal and that of motorcycles 1.5 times higher, the motorcycle fleet of which increased 1.5 times more than that of cars.

The car fleet in Alegre grows faster than its population, which may indicate an increase in its population's purchasing power, structured urbanization, lack of alternatives for public and/or alternative transportation, and the preference for cars as their main means of transportation (Vasconcellos, 2012; Newman & Kenworthy, 1999; Villaça, 2001). In Cacoal, and its more dynamic mobility, the greater growth of its motorcycle fleet suggests a lower average income of its population, greater urban dispersion, a culture favoring more accessible vehicles, and lower motorcycle acquisition and maintenance costs (Maricato, 2011; Vasconcellos, 2014).

An elitist or family motorization pattern predominates in Alegre; its significant increase in the fleet causes congestion, pressure on urban space, and increased emission of pollutants (Banister, 2008; Newman & Kenworthy, 1999; Vasconcellos, 2012). On the other hand, in Cacoal, a pattern that tends to individual fast and cheap use adaptable to scattered urban structures raises concerns for accidents, greater need for road safety, and impacts on public health (ANTP, 2017; IPEA, 2011; Vasconcellos, 2014). Such distinctions are relevant to the urban and environmental planning of each municipality given the continuous increase in the fleet of vehicles in both — which tends to be more impactful in Alegre.

Based on the equations in Table 2, Alegre will have an estimated total fleet of almost 17,500 vehicles at the end of 2025 (8,630 cars and 4,840 motorcycles). According to the Ministry of Transportation, in April 2025, Alegre had 17,195 vehicles (8,120 cars and 4,824 motorcycles), indicating, with great probability, the accuracy of the estimates this study obtained from its chosen equation. Thus, this research can predict with a high degree of reliability that Alegre will have almost 21,000 vehicles (about 10,270 cars and 5,780 motorcycles) in 2030.

However, Alegre shows a finished road structure in its central area and urbanized and mountainous surroundings (Figure 1B, 1C, and 1D), making an expansion to meet the continuous increase in its vehicle fleet unfeasible (Amaral, 2019). Its population needs mobility, and the increase in infrastructure alone fails to meet the demand for public roads. The impossibility of such increase requires other measures (such as educational actions for a more harmonious and balanced use of traffic) and the implementation of a limited waiting system (Campos, 2006).

2.4 Limited waiting system

The expansion of the supply of parking spaces in the central region of municipalities is almost impossible. Thus, many have implemented paid limited waiting systems around the world (Feder, 2006). The system interferes with the time spent in parking, preventing drivers from occupying a space beyond an established time and ensuring the rotation of lots and the democratization of the public space. This provides greater access for people who need lots for short periods (as is typical of those who go to malls to buy and consume other products).

The lack of parking spaces, especially during business hours, highlights the need for planning and implementing limited waiting projects (Elias, 2001). Article 24, item X, of the Brazilian Traffic Code (Law no. 9503, 1997) includes this measure. However, it is up to municipal traffic management to define the procedures and places to implement this system. In some municipalities, outsourced companies, after bidding, install a limited waiting system in the municipalities (Amaral, 2019).

2.4.1. Limited waiting in municipalities with less than 60,000 inhabitants

Além Paraíba, in Zona da Mata Mineira-MG (35,321 inhabitants in 2018; 2% more populous than Alegre) (IBGE, 2018b), had limited waiting on public roads — created by Municipal Law no. 985, of December 29, 1981, and consolidated by Municipal Law no. 3194, of July 26, 2014 (Law no. 3194, 2014) — that is currently administered by Associação da Guarda Mirim de Além Paraíba. The Law regulates the parking of vehicles on public roads. It is considered to have a social function due to the employability it provides to the youth of municipalities. The service charge spanned from Monday to Friday from 8 am to 6 pm and from 8 am to 12 pm on Saturdays. The fare (R$ 1.60 per hour) occurs directly to "Guarda Mirim."

In Carazinho-RS (59,317 inhabitants in 2018; twice as populous as Alegre) (IBGE, 2018c), Municipal Law no. 3,440 of September 12, 1984, instituted limited waiting. Currently, Law no. 8,366 of June 28, 2018, regulates paid limited waiting. Estimates suggest that the time spent in a same space ranged from 30 minutes to two hours (which can be fractioned every half hour). Vehicles must leave their parking spaces after this period. Payment occurred by purchasing a R$ 1.00-per-hour card. Limited waiting hours spanned from 8 am to 12 pm and from 1:30 pm to 6 pm from Monday to Friday. On Saturdays, spaces were charged from 8 am to 12 pm (Municipal Law no. 8,366, 2018).

2.4.2. Parking in Alegre

Downtown Alegre lacks parking lots in commercial establishments, which overloads public parking spaces as many owners and employees park their vehicles during most business hours, preventing the rotation of these spaces (Amaral, 2019). Most of its residential buildings lack parking spaces, although the Municipal Master Plan (which deals with the requirements regarding parking spaces for vehicles in homes) provides for them (PMA, 2008). Failure to comply with the Master Plan leads many residents to park on the streets, overloading public parking lots.

Urban planning must be based on policies that guarantee the mobility of people and the organization of transportation means as this ensures the standardized growth of the urban perimeter (Paradela *et al*., 2015) and greater efficiency of the urban mobility system of a municipality. However, management fails to ensure effective urban mobility despite policies and laws to ensure efficient urban mobility. Art. 24, § 1of the National Urban Mobility Policy, instituted by Law 12.587/2012, establishes that municipalities with more than 20,000 inhabitants and others thus required must prepare an urban mobility plan (Planalto, 2012).

3 METHODOLOGY

The survey of public perception regarding traffic conditions aimed to know the relationship of traffic users with their vehicles and the difficulties they face daily. The population has greater control over problems associated with mobility that affect their daily lives; surveying them helps local decision-makers to define short-, medium-, and long-term actions and public policies (Magagnin *et al*., 2016). Respondents' answers were assessed by simple frequency analysis on Excel. Figure 2 shows the adopted procedures in order.

3.1 Public perception of traffic conditions

An electronic questionnaire was created on "Google Docs" and applied to the residents of the municipality. The used sample population only included those who have a license in the municipality, in which according to its Annual Report of Traffic Statistics – License, made available by the State Department of Traffic of Espírito Santo – published in February 2019, 9,893 (30% of the municipal population) people had a license until December 2018 (DETRAN/ES, 2019).

The questionnaire was made available from March 7, 2019 to May 7, 2019. A total of 106 people (1% of licensed drivers, 0.3% of the municipal population) responded to it. The responses of two individuals were excluded as they had no license. The questionnaire had six questions; three that investigated the relationship between drivers and vehicle use and three that evaluated the relationship between drivers and vehicle use in traffic (Table 4).

Table 4

Questions asked to licensed drivers.

Questionnaire Questions			
Group 1		**Group 2**	
1	Know which and how many types of vehicles respondents owned.	**4**	Know the main difficulties when navigating downtown Alegre/ES.
2	Know the main means of travel (whether cars, bicycles, or walking).	**5**	Know if limited waiting was important.
3	Know the frequency of movement	**6**	Know the tolerated maximum amount to be paid for limited waiting.

3.2 Data analysis

Simple frequency analysis was performed to facilitate the understanding of patterns and trends and thus provide a clear view of data distribution. Bar graphs were created for this, which enable the quick and effective interpretation of the results. They help to clearly and concisely compare the number of variables between categories or groups.

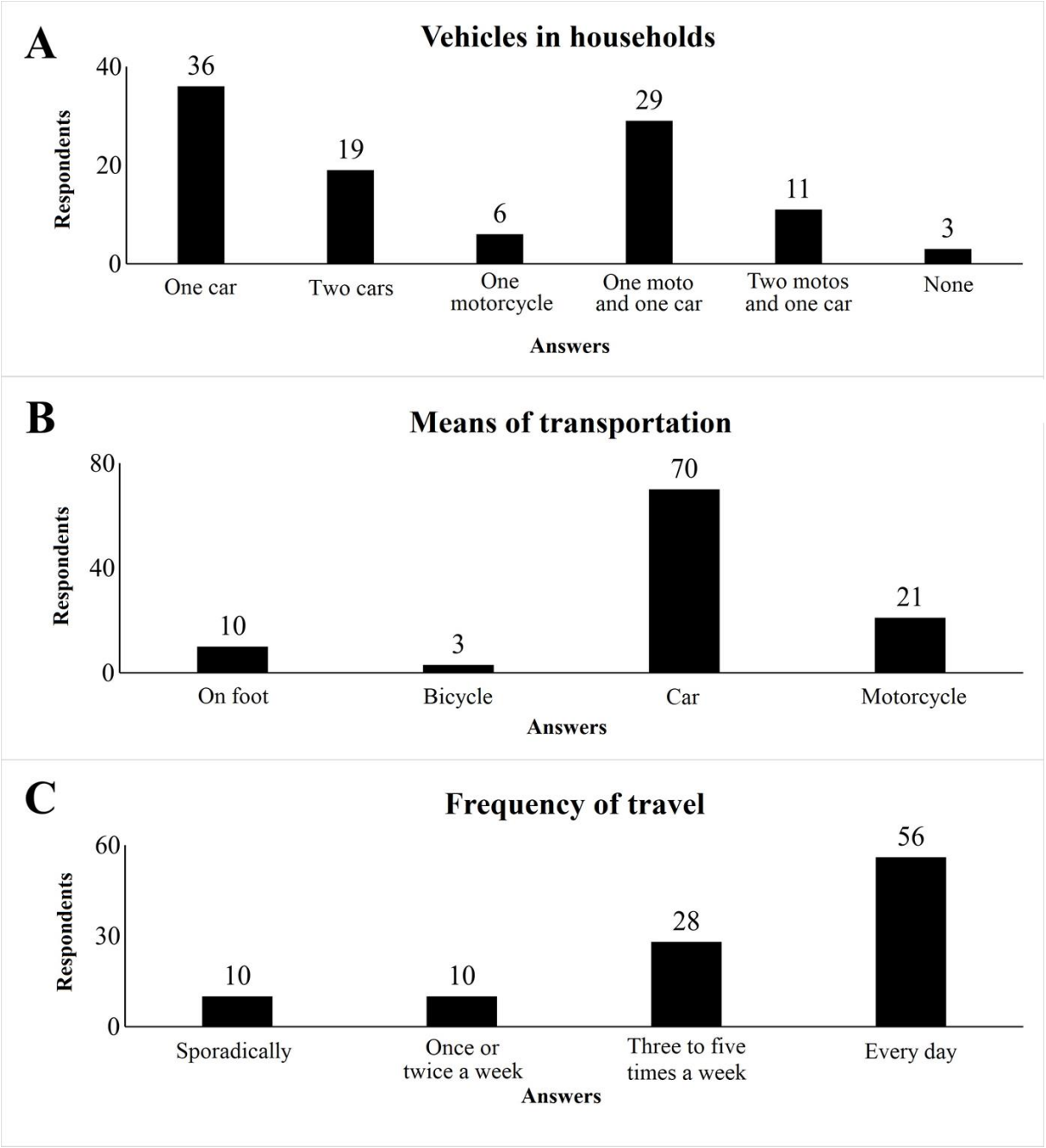
4 URBAN MOBILITY IN ALEGRE

4.1 Users, vehicles, and mobility

In Alegre, 91.3% of respondents have a car and 44%, a motorcycle (Figure 3). In Londrina-PR, a municipality with 19 times more inhabitants than Alegre, an interview in 2017 (Ricieri *et al*., 2017) showed that 73% of respondents owned cars and 26%, motorcycles. Although Londrina has a larger population, the percentage of inhabitants who own cars is lower than in Alegre (20 and 26%, respectively). In Londrina, some vehicle owners believe that cars represented social status, indicating that correct policies will make bicycles viable (Ricieri *et al*., 2017) if they disclose their benefits.

Figure 3

Answers for A) vehicles in homes; B) means of travel; and C) frequency of travel.



At first, in Alegre, such status manifests itself in people who own multiple vehicles, although such ownership may indicate that a residence contains vehicles for leisure and family entertainment and others for work. In municipalities in inner Espírito Santo, people often own multiple vehicles; the additional ones are important for travelling to the countryside (which usually takes place on low-quality side roads). About 34.6% of respondents owned a car; 25%,

a motorcycle and a car; 18%, two cars; 10.5%, two motorcycles and a car; 5.8%, a motorcycle; and 3%, no cars (Figure 3a).

The main means of transportation in Alegre refer to cars (67% of respondents), followed by motorcycles (20%), walking (9.5%), and bicycles (3%) — one of the most sustainable ones together with walking (Figure 3B). In Manhuaçu-MG (thrice as populous than in Alegre), about 55.7% of respondents to a 2018 survey stated using private vehicles as their main means of transportation, and 10.1% used motorcycles (Louback *et al*., 2018). Regarding vehicle use frequency survey in Alegre, 54% of respondents commute downtown every day of the week; 27%, from three to five times a week; 9.6%, from once to twice; and 9.6%, sporadically (Figure 3c).

The choice for vehicles instead of sustainable transportation and travelling frequencies are directly related to the increase in population, purchasing power, and the fleet of vehicles in Alegre, added to people's need for street locomotion (Amaral, 2019). The hot climate, rugged terrain, and precarious public transportation in Alegre also contribute to individuals choosing motor vehicles, generating traffic problems and contributing to the scarcity of available spaces. Walking on the streets constitutes one of the main difficulties in Cacoal (Piassarolo, 2014), Manhuaçu (Louback *et al*., 2018), and Alegre. However, such difficulty depends on the state of sidewalks, structures municipal management often ignores (Magagnin *et al*., 2016).

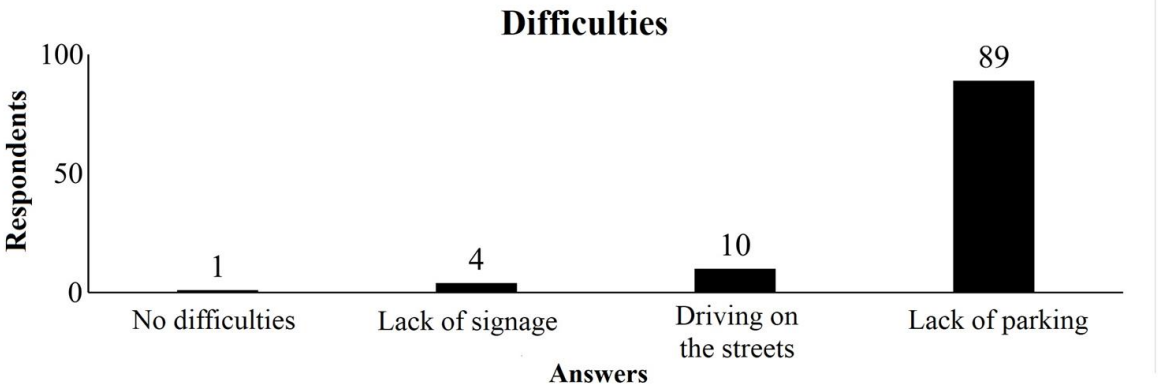
4.2 Traffic difficulties in Alegre

About 85.5% of respondents reported that the lack of parking spaces constitutes the main difficulty they faced, 9.6% stated having difficulty navigating the streets, 4% mentioned the lack of signage, and 1% reported no difficulties (Figure 4). Some reported that they had stopped going with their vehicle downtown and most said they have had to park far from their destination due to the lack of parking. Others reported having stopped shopping in downtown stores due to the lack of parking spaces, which negatively impacts commerce (Amaral, 2019).

The public interview in Piassarolo (2014) showed that 60.7% of drivers have difficulties finding parking spaces, 25.4%, navigating the streets, and 22%, faced problems due to the lack of signage. The difference between these values is related to the larger fleet of vehicles in Cacoal. However, in many municipalities, these difficulties generate problems for the population, such as congestion, narrow roads, insufficient maintenance, inadequate intersections, lack of parking, and thus accidents (Mukai *et al*., 2006; Santos *et al*., 2017).

Figure 4.

Main traffic difficulties in Alegre.



Louback *et al*., (2018) also found that the poor structure of public roads (65.40% of respondents in Manhuaçu) and excess vehicles (59.60%) constitute the main mobility problems, whereas 30% of respondents pointed out poor signage. This value is higher than that in Santos *et al*., (2017) for Campo Grande-MS, in which 8% of respondents reported that poor signage is yet to be solved. Traffic in Alegre works safely, the biggest problem of which is associated with the lack of parking spaces. Also, the problems that can arise due to a lack of parking spaces render alternative transportation viable.

However, as in several Brazilian municipalities, choosing and adhering to alternative transportation faces challenges.

5 OBSTACLES TO CHOOSING ALTERNATIVE TRANSPORTATION

The impossibility of using alternative transportation also depends on the following factors (Magagnin *et al*., 2016):

a) Rugged topography and poor specific infrastructure for bicycles;

b) Narrow sidewalks, which hinder accessibility and traffic;

c) Absence of public policies to encourage walking;

d) Lack of access ramps, tactile signage, and stair treads;

e) Inability of the public transportation system to meet users' needs;

f) Traffic jams;

g) Lack of maintenance in the municipal transportation systems.

The reasons that lead people to leave their homes include work, educational institutions, leisure, shopping, and health and the factors that influence their choice of transportation means, amenities, lack of other choices, absence of efficient alternatives, and cost (Louback *et al*., 2018). These authors found that 15.4% of the interviewees in Manhuaçu reported walking and only 1.3% stated using bicycles, which although sustainable and beneficial for urban mobility, is the least used in the municipality (as in Alegre). Manhuaçu has a mountainous relief resembling that of Alegre. Its population's resistance to bicycles stems from its topography containing steep terrain.

In Londrina, many people favor bicycles as a mode of transportation, have no prejudice against cycling (seen as a leisure and sport activity), and 33% of interviewees owned and used bicycles for leisure and/or sport (Ricieri *et al*., 2017). This population sees bicycles as an alternative means of transportation for short rides on weekends and holidays and as a sport in early mornings, late afternoons, and nighttime as they deem those vehicles to serve these functions. Occasionally, they participate in bicycle rides that seek to encourage the use of bicycles (Silva & Fontenele, 2015), reinforcing the image of this means of transportation and seeking to attribute status to owning one.

Regarding changes in transportation means, 31.1% of interviewees in Manhuaçu expressed the desire to walk more, 28.1% wanted to ride a bicycle and 22.4% to travel by bus. However, the local population and Brazilians in general show prejudice against public transportation (Louback *et al*., 2018). These authors underscore the need for a national cultural change toward transportation means replacement, but also point to a lack of projects that stimulate these changes. They attribute the difficulty of success in encouraging alternative transportation to planning errors in past administrations. Added to this is the lack of roads and public mobility structures compatible with the city's rugged topography that would be adaptable to the national trend of increasing the number of vehicles.

In Jundiaí-SP, which had 400,000 inhabitants in 2015 (13 times as populous as Alegre), the presence of a cycling infrastructure configures an important element to improve urban mobility in the municipality. Improving the infrastructure for walking also demanded attention (Magagnin *et al*., 2016). In Manhuaçu, 73% of interviewees complained about the quality of its sidewalks and mentioned secondary problems, including debris and the absence of traffic lights for pedestrians (Louback *et al*., 2018). Users travelling on foot under compromised urban mobility also face the following problems (Magagnin *et al*., 2016):

a) narrow sidewalks and obstacles that hinder movement;

b) broken floors on the sidewalks;

c) the absence of ramps and tactile flooring, compromising the commuting of older and visually impaired users.

Such problems in the streets and sidewalks, which hinder and inconvenience traffic users and directly influence urban mobility, evince a relative neglect of the public sphere by municipal and national management. Despite its rapid development, Brazil lacks projects observing municipal management, which, if existent, was unable to keep up with the unpredictability of demographic expansion and economic growth. In the last two decades, many people have been able to own vehicles, an event that is gradually increasing but which seems to evince a disparity with the evolution of managers' mentality in adopting measures that meet the precepts of urban legislation.

6 LEGISLATION ON URBAN MOBILITY AND PARKING: ARE THERE PARKING SPOTS FOR EVERYONE?

Law no. 12,587 of January 3, 2012 establishes the guidelines of the National Urban Mobility Policy. Its art. 4, item II defines urban mobility as the movement of cargo and people in urban space (Planalto, 2012). This displacement enables daily activities such as work, supply, education, health, culture, and leisure, at an ideal time and in a comfortable and safe manner (Vargas & Sidotti, 2008). It is a "cause and effect" of urban development related to economic, social, and environmental aspects of a given region. Thus, good mobility planning results in efficient, harmonious, and democratically managed municipalities (Cruz, 2014).

However, mobility is closely related to people and the resources available over time and space, which can give a dimension of the development that occurs in places in which individuals and goods meet (Amaral, 2019). thus, Ferraz and Torres (2004) state that mobility configures the guiding element of urban development and that the process of economic and social development of municipalities should provide adequate mobility for all social classes. Due to the mobility complexity in people's lives, its importance has become public policy. According to the National Secretariat of Transportation and Mobility (SeMob, 2007):

> "Mobility is an attribute associated with people and goods and corresponds to the different responses given by individuals and economic agents to their travel needs, considering the dimensions of the urban space and the complexity of the activities developed in them."

Law no. 9,503, of September 23, 1997, instituted the Brazilian Traffic Code. Its annex I defines "parking" as the stoppage of vehicles for a longer time than would be necessary for boarding or disembarking (Planalto, 1997). However, the term also describes an urban mobility infrastructure (Cruz, 2014). Thus, it can be conceptualized as a set of bays designated for vehicles to be parked in them for a certain period in a place in the urban area (Brasileiro *et al*., 2014). For these authors, parking is a fundamental component of any urban mobility policy as it directly relates to accessibility, the management and exploitation of circulation networks, and use and quality of public space:

> "The lack of transportation planning and the deficiency of public transportation in Brazil mean that certain urban areas do not have parking lots that meet the demand in its entirety. When there are not enough parking spaces in a certain place, drivers keep driving around looking for another parking area, wasting time and fuel, polluting the air, and interfering with the flow of traffic."

The Municipal Master Plan of Alegre (12/28/2008), in Chapter V, describes the Mobility and Accessibility Policy, and its art. 40 provides that (PMA, 2008):

> "Urban road projects will be accompanied by projects for the circulation of pedestrians and cyclists and solutions for parking areas for cars, cargo vehicles, motorcycles, and bicycles in public areas such as parks, squares, and public administrative buildings."

However, Alegre faces the following situation: the scarcity of spaces in public parking leads drivers to eventually stop using their vehicles to go its downtown area, or, if they use them, they park far from their destination (Amaral, 2019) (as it happens in other municipalities in Brazil) in addition to difficulties navigating the streets. Thus, by maintaining an inadequate road structure, Alegre neither provides a good service nor complies with national and municipal laws, indicating the need for traffic improvements. Brasileiro *et al*., (2014) have stated that expanding the supply of parking spaces and encouraging the use of alternative transportation may mitigate gas emissions and global warming.

6.1 How to transform the current situation in Alegre?

Downtown Alegre has a finished road structure ready, which will face difficulties in expansion, requiring interventions to meet the continuous increase in its fleet (Amaral, 2019). Cacoal, the infrastructure of which also ceased to meet the municipality's expansion (which

prevents interventions occurring today) focused on educating its children (Piassarolo, 2014). For this, its educational programs and actions offered teachings and lessons to train more responsible citizens in traffic to improve long-term municipal mobility.

In Campo Grande-MS, with a population of almost 855,000 inhabitants (29 times more populous than Alegre), Santos *et al*. (2017) interviewed 300 people to find their perception of traffic mobility and safety. Users' perception is that awareness, enforcement, and traffic education (17% of respondents) configure priorities to improve trafficability, as well as:

a) awareness would involve greater participation and public and private funding to promote more frequent and impactful multimedia activities and campaigns regarding good manners in traffic;

b) traffic education involves a pedagogical act with an adequate teaching methodology and increased workload including education for children and young people in schools and for adults, in the case of offending drivers and those renewing their license;

c) good enforcement is necessary to minimize bad behavior in traffic, eliminate the culture of impunity, and discourage the commission of infractions.

6.1.1. Implementation of limited waiting in Alegre

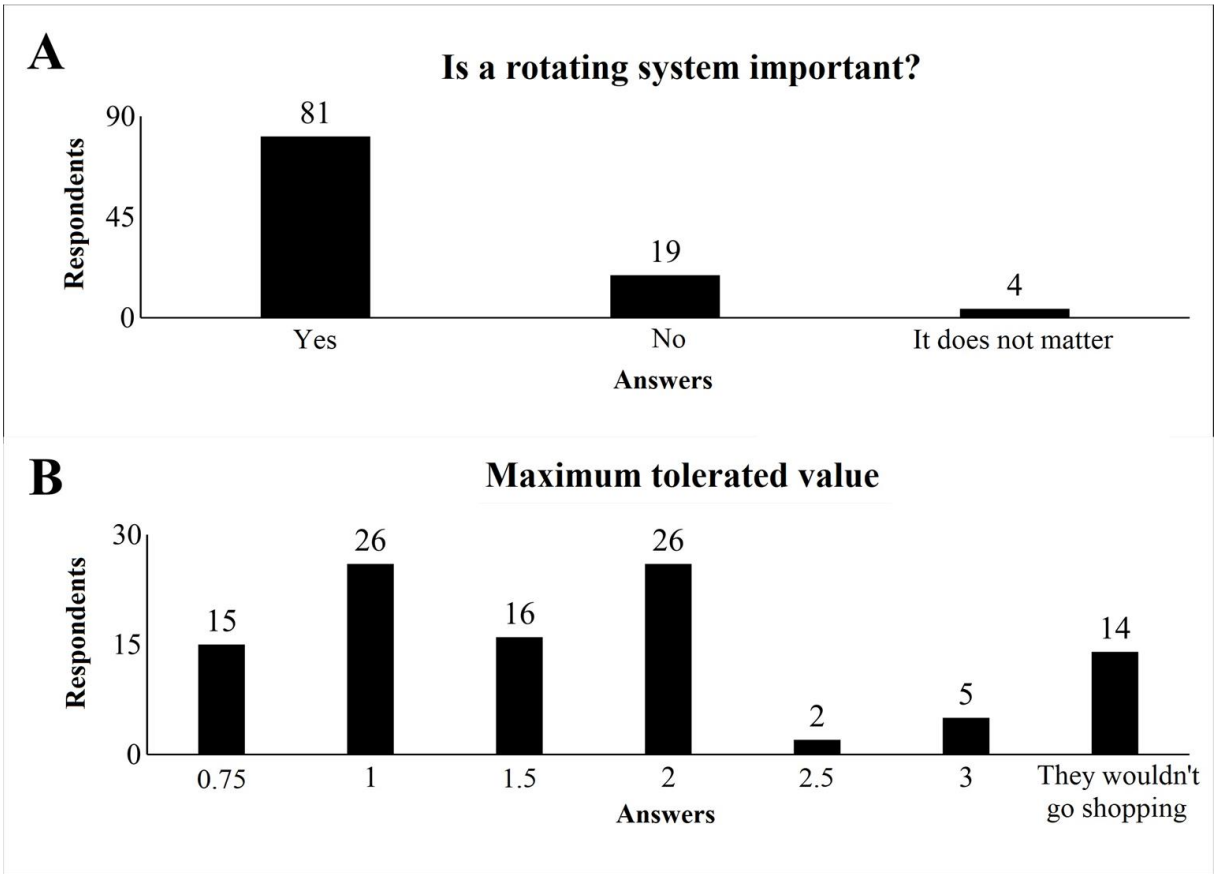
Many respondents in Alegre (81%) believed that implementing limited waiting bays would solve parking difficulties (Figure 5a), whereas 18% thought the opposite and 4% had no concerns for this issue. Some (14%) said that they would stop going shopping with their vehicles if limited waiting existed (Figure 5b). Also, 32% of those who thought limited waiting was important would agree to pay R$ 1.00 per hour; 32%, R$ 2.00 per hour; 20%, R$ 1.50 per hour; 8.5%, R$ 0.75 per hour; and 7.5%, more than R$ 2.50 per hour (Figure 5b). However, limited waiting and value acceptance varied according to the economic and social scenario, time, and location. In Manhuaçu, 73% of respondents doubted the efficiency of limited waiting (Louback *et al*., 2018).

In Pelotas-RS (350,000 inhabitants; 12 times more populous than Alegre), a public interview showed that most users accepted to pay for the service if the values were affordable. At the time, 2001, the maximum acceptance value totaled R$ 0.75 per hour (Elias, 2001). In total, 60% of interviewees accepted this value, much higher than that in Alegre, in which R$ 1.00 and R$ 2.00 comprised the most accepted values. In Pelotas, an average of 35% of interviewees would accept a R$ 1.00 fare. Again, in 2014, the city hall of Além-Paraíba stipulated the acceptable value of R$ 1.60 per hour (Law no. 3194, 2014) and in 2018, the city

hall of Carazinho – RS (6% less populous than Pelotas) stipulated the value of R$ 1.00 per hour (Municipal Law no. 8,366, 2018).

Figure 5

Importance of limited waiting and maximum tolerated value.



7 FINAL CONSIDERATIONS

Alegre is experiencing economic stability, evinced by its higher concentration of vehicles per person. This reflects the increase in purchasing power and the overwhelming need for services geared toward the population in the urban or rural areas of Alegre. Although bike lanes are unlikely to emerge in its downtown, bicycles remain an alternative. However, they fail to serve the population during greater purchases. This also applies to walking since persons, on foot or by bicycle, will eventually need another means of transportation to carry their products. In this situation, local businesses could experiment with new ways of marketing products, such as online sales and home deliveries since Alegre shows a linear expansion of its number of vehicles over the years.

The percentage of people who owned vehicles was higher in Alegre (which has a smaller population) than in Londrina (which houses a larger population and lies in another Brazilian macroregion). This stems from the greater incentive toward bicycles in Londrina, which has increased the percentage of people who use bicycles and decreased that of those who use cars and motorcycles. On the other hand, municipalities such as Alegre and Manhuaçu (in the same region — which includes a mountainous relief), the smaller of the two (Alegre) has the most cars and motorcycles and the least walking despite its greater number of bicycles. This must be related to the floating population in Alegre who responded to the questionnaire in this study and to the habit of choosing to walk and/or cycle. Alegre had a lower percentage of complaints about signage since Manhuaçu is a regional commercial center with more active traffic.

Regarding traffic difficulties, Alegre showed the largest number of complaints about parking, whereas Cacoal, about circulation and signage. The difficulty of parking in Alegre stems from its failure to meet its growing fleet, unlike Cacoal (a larger municipality). However, traffic inadequacies in Cacoal regard circulation and signaling. Despite its relatively good structure, it showed a 3,107-vehicle per year increase, a very high value. Alegre must find solutions before the problems become more costly to solve. Thus, this study suggests limited waiting that enables users to remain in bays for up to two hours to ensure greater turnover and access for people who need the public space for short periods.

Limited waiting as a form of mobility management is acceptable if its fare is low or between R$ 1-2 per hour, motivating a more conscious use of vehicles. However, other aspects require consideration to increase decision-making power. In Pelotas, traffic users who performed activities close to parking spaces tended to refuse to pay high amounts and/or refused to accept limited waiting (Elias, 2001). The sensitivity in accepting the values of the fares is proportional to the absence of vacancies. However, it also requires a certain awareness from users of the increase the search for parking spaces represents in the final cost for the municipality. In Alegre, the suggested charge at the beginning of the system operation would equal $ 1.50 per hour, the average between the two values its population pointed out the most.

The increase in vehicle fleet, although following population growth and greater purchasing power, remains far from meaning a necessary increase in urban mobility problems. Alegre and the other evaluated municipalities would gradually reduce the effects of the expansion of their vehicle fleet if they adopted adequate public policies to educate and change the culture of their population regarding alternative transportation that improve urban infrastructure to enable the flow of bicycles and walking and implement limited waiting system. However, it remains necessary to further the understanding of urban mobility. Future research

to constantly improve urban mobility in Alegre could correlate the length of parking with the number of vehicles per timeslots and analyze the financial feasibility of implementing a limited waiting system in the municipality.

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All authors have a active participation in the discussion of the results and a make a final revision and approaval of this work.

DECLARATION OF CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the research, themselves, and the publication of this article.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE MANUSCRIPT PREPARATION PROCESS.

During the preparation of this work the author(s) used ChatGPT in order to to compare and discuss the comparative data between vehicle fleets and population growth in Alegre and Cacoal. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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DATA AVAILABILITY

Data will be made available on request.

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