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Abstract

Urban grow in Brazilian Metropolitan Regions have not been happening sustainably. Center-periphery dichotomy characterizes these regions by in which amount of inter-municipal commuters increases due to vast conurbation and dependence between their municipalities. Mainly performed by individual motor vehicles, such displacements contribute to the maintenance of urban sprawl and to rise of carbon dioxide (CO_2) emissions in Earth's atmosphere. This paper aims to identify and quantify the CO_2 emissions in displacements caused by urban expansion between Goiânia and Senador Canedo. The methodology includes quantitative analysis in different scenarios, i.e. the current situation can be compared with two more favorable scenarios about CO_2 emissions, in which there is a transfer of displacements between modes of transport and increase of the occupation factor in the vehicles. The results showed a high CO_2 emission in the current situation and a significant reduction of carbon dioxide emissions in the proposed scenarios. The methodology was adequate to record and identify the investigated process. It can contribute to the best understanding and best practices in urban space changes related to the action of different actors who continuously weave the city.

Keywords: Commuters; Dispersed urban form; CO2 emissions.

1 Introduction

The world is going through a period of rapid urbanization. According to the United Nations (2011), population growth projections are 80% rural to 80% urban between 1950 and 2050. Such increase occurs mainly in developing countries, where about 2.2 billion new urban dwellers between 2015 and 2050. Cities ways to accommodate new inhabitants can bring consequences in environmental, economic and social. For this reason, urban development policies could maximize benefits and minimize adverse growth costs (Litman, 2016).

In general, dispersed occupation territorial generates several negative impacts for urban development. According to Litman (2016), the increase of urbanized land reduces agricultural and natural land, which reduces agricultural and ecological production. A dispersed location of activities can: generate high costs for the provision of public infrastructure and services; reduce accessibility and increase travel distances, that promotes the use of automobile and upsurge traffic congestion on roads. Moreover, it needs more land for roads; boost amount of global pollutants emitted.

In Brazil, the intense urbanization has created situations of interdependence between cities, which the municipal boundaries don't correspond to the borders of economic, social and cultural relations (Ministério das Cidades, 2015). According to the Instituto de Pesquisa Econômica Aplicada (IPEA, 2010), a center-periphery relationship of cities marks this process, called metropolization. Downtown concentrates people, investments, activities, and power, but most population lives in remote peripheral areas, in areas devoid of urbanity, opportunities, and possibilities. The dislocation by regular journeys between work/study sites and dwelling places generates commuting (Cunha, 2006). Consequently, all modes of transportation occur and require a provision of infrastructure and services that go beyond the capacity of local pre-locations (Ministério das Cidades, 2015).

These segregated spaces that form Brazilian metropolis were woven by actions of several agents, accordingly to real estate speculation that expresses in various ways: by lands' retention due to the effect of the real estate sector or by State actions that implement the infrastructure and services in central areas. As a consequence, it increases the price of land and values it (Guimarães, 2016). According to Instituto Mauro Borges de Estatísticas e Estudos Socioeconômicos (IMB, 2012), low-income segments occupy as peripheral areas of the city, which lands are more accessible and viable from use and occupation land process point of view, but there are no infrastructure and essential services.

However, it cannot disregard the growing share of the high-income population groups that seeks to reside in peripheral areas and to improve living standard, occupying gated communities (IMB, 2012). The feasibility of new housing developments is a result of the synergy between landowners and real estate companies. It carries out the disclosure of the indications of the Municipal Master Plans. Subsequently, municipality governments redefine the legislative framework to legitimized private sector actions (Souza and Bitoun, 2015).

This situation features as a Metropolitan Region of Goiânia (RMG) that is composed of 20 municipalities. According to Observatório das Metrópoles (2011), this region's populating process occurred mainly through the boundary cities, which population growth rates were higher than the municipal pole (Goiânia). However, the migrations to RMG happen by Goiânia's attractions, i.e. people settle in neighboring municipalities, but seek work, education, and health in the capital.

Distances between the municipalities from RMG and the commuting generated by their interdependence have contributed to the significant increase in the carbon dioxide (CO2) emission in the region due to automobile usages, especially individual vehicles. According to Greenhouse Gas Emissions Estimate System (SEEG, 2015), greenhouse gases emissions increased around 17% in the energy sector of Goias State. From all gases emissions in the region, 68,1% are issued by transportation sector due to displacement in RMG.

Thus, it is necessary to rethink occupation strategies of the territory in the RMG and develop mechanisms to change some needs between municipalities due to commuting, mainly individual vehicles. In this context, the significant occupation of areas in Senador Canedo (Municipality of RMG) by dwellings generates commuting to the capital (Goiânia). This research aims to identify and quantify the CO2 emissions in displacements caused by urban expansion between Goiânia and Senador Canedo. It will be compared current scenario to two more favorable situations concerning carbon dioxide emissions, i.e. part of the individually motorized displacements is transferred to the collective vehicle's mode, and part of the trips by automobiles is eliminated by increasing of passengers per vehicle.

Thus, data from bus lines of Goiania Collective Transport Company (CMTC, 2016), IPEA studies (IPEA, 2011) and Instituto Brasileiro de Geografia e Estatística (IBGE, 2016a) are used, which provide subsidies for the calculation of CO2 emission in the current situation (2016) and favorable scenarios. Results make it possible to identify: CO2 emissions related to the use of motorized transport modes; impacts of the urban expansion of Senador Canedo, in a context of spreading urban and commuting between the capital and the mentioned municipality; and this methodology can be applied to analyses all RMG.

2 Theoretical referential

2.1 Urban dispersion, displacement modes and pollutants emission

The Urban dispersion can be defined as an urban form of low-density occupation in which urban development is geared towards the automobile. This definition is opposite to the idea of smart growth, a term employed to design policies that result in the development of compact, mixed and multimodal communities (Litman, 2016).

The impacts caused by the dispersed occupation are diverse, and it depends on economic, social and environmental dimensions, as shown in Figure 1:

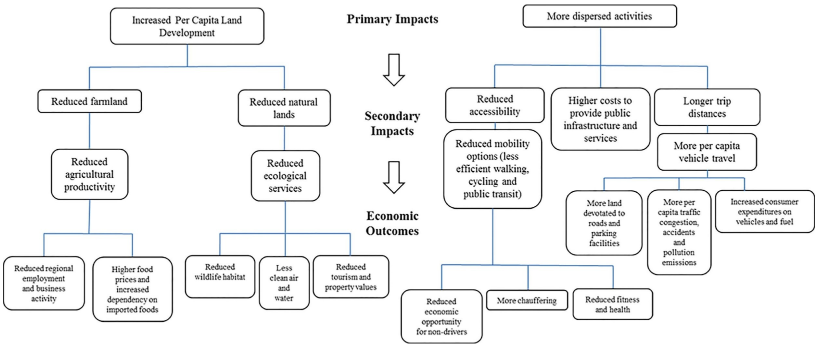

Fig. 1: Impacts of urban form dispersion. Source: Adapted from Litman (2016).

Compact occupation is necessary to the allied territory at appropriate densities, and it is highlighted by the Habitat III Conference, United Nations Conference on Housing and Sustainable Urban Development, held in Quito, Ecuador, in 2016. Due to the promotion of ideas as a compact city, polycentrism, density, connectivity and mixed uses, responsible entities aim to avoid urban sprawl, to reduce mobility challenges and the need for and costs of providing per capita services (United Nations, 2016).

The dispersed occupation of cities, the travel time and the lack of infrastructure, as a priority in the roads, contribute to the lack of quality of collective transport and induce the migration of users to individual motorized transportation (Ministério das Cidades, 2015). To reducing distances between activities, as proposed by the Habitat III Conference, reduces some needs for personal motorized journeys and consequently, CO2 emission by transportation, seen that the increase in greenhouse gas emissions in the transport sector comes from individual's vehicles (Ministério das Cidades, 2008). Cars emissions are 0.1278 kg of CO2 / km per person, while buses emissions are 0.0160 kg of CO2 / km per person (IPEA, 2011).

According to Ministério das Cidades (2008), a complete effort to reduce emissions involves each of the variables shown in Figure 2: behavior, design, and technology. The component of a modal split of behavior variable, which can be expressed by the number of vehicles, is related to all factors that involve user satisfaction (price, comfort, convenience, safety, and protection). The improvement of transit quality attracts users of the car to change transportation mode. Urban land use planning and transport networks can influence the number of trips, and the distance traveled. As well, the technology affects the quality and efficiency of fuels.

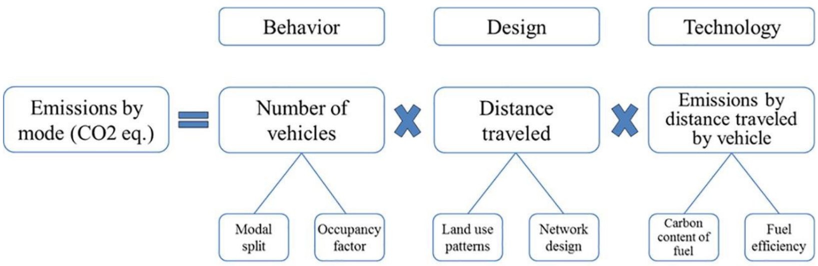

Fig. 2: Generalized emission equation that records the constituent components of emission sources. Source: Adapted from Ministério das Cidades (2008).

2.2 Metropolitan Region of Goiânia and pendulum migration

The Metropolitan Region of Goiania (RMG) was established by the State Complementary Law No. 27 of 1999. In 2004 and 2005, this law was amended and currently presents the constitution established and amended by Complementary Law 78, of 2010, which establishes that RMG consists of 20 municipalities (Secretaria, 2016). Figure 3 shows these municipalities and the evolution of the RMG constitution from 1999 to 2010.

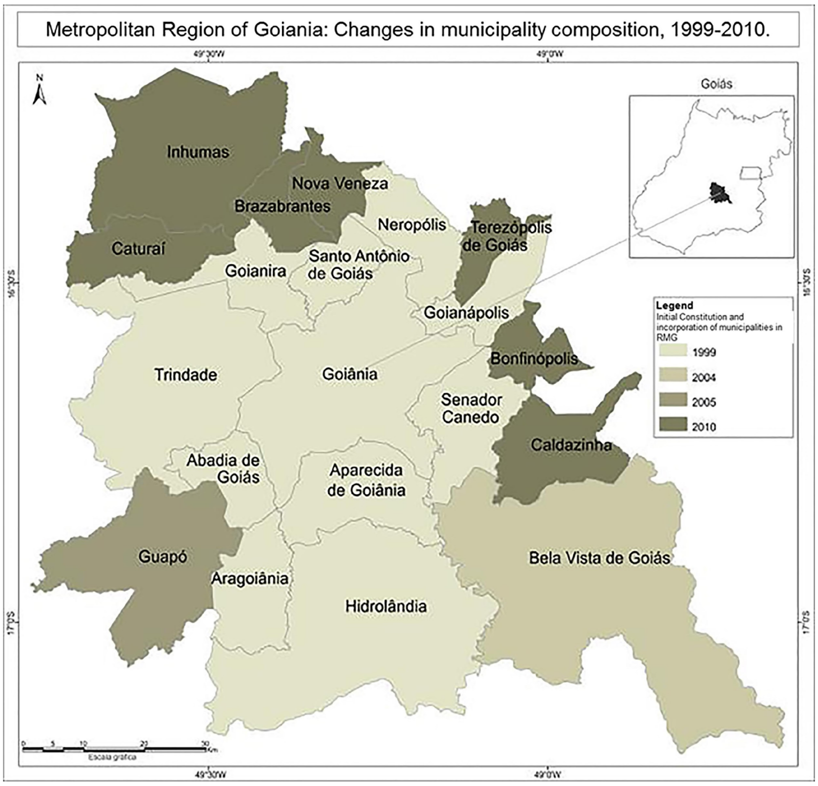

Fig. 3: Metropolitan Region of Goiania: Changes in municipality composition, 1999-2010. Source: Secretaria (2016).

According to Observatório das Metrópoles (2011), the average growth rate of the population in RMG has been maintained at 3% since 1980, and the most of other municipalities have high levels of growth greater than those of Goiania city. While a weight of population in the metropolitan core has declined (from 62.7% to 59.9% of the metropolitan population), a weight of peripheral population has increased (from 37.3% to 40.1% of the metropolis population). The highest population growth rates were observed in Goianira (6.17%); Senador Canedo (4.74%) and Santo Antônio de Goiás (4.21%).

Thus, Goiânia is configured as a metropolitan city attracting immigrant flows. However, social and economic factors determine that the application flow installs in boundaries municipalities. From these municipalities, flows of displacement are due to work, health and education equipment in Goiânia (Observatório das Metrópoles, 2011). People flows towards the capital characterizes the commuting that involves the displacements of the whole region. Table 1 shows the number of commuting in the RMG.

Municipality	Estimate of total population	Studies in different municipality	Works in different municipality	Studies and works in different municipality	Total population commuting	Population commuting (%)
Senador Canedo	84.443	3.118	20.836	1.147	25.101	29,7
Goianira	34.060	1.108	7.527	365	9.000	26,4
Aparecida de Goiânia	455.657	20.163	88.718	6.824	115.705	25,4
Abadia de Goiás	6.876	238	1.284	81	1.603	23,3
Bonfinópolis	7.536	224	1.385	64	1.673	22,2
Santo Antônio de Goiás	4.703	115	768	34	917	19,5
Trindade	104.488	3.057	16.227	780	20.064	19,2
Brazabrantes	3.232	217	361	42	620	19,2
Caldazinha	3.325	116	417	18	551	16,6

Tab. 1: Municipalities of RMG: population estimate and commuting above 15% of total population. Source: Adapted from IPEA (2015), IBGE (2010) and IMB (2012).

The modal split for RMG (Fig. 4) shows that the vast majority uses the individual motorized model (cars and motorcycles - 54.5%) among the people who travel for work reasons (Instituto Verus e Fórum de Mobilidade, 2013).

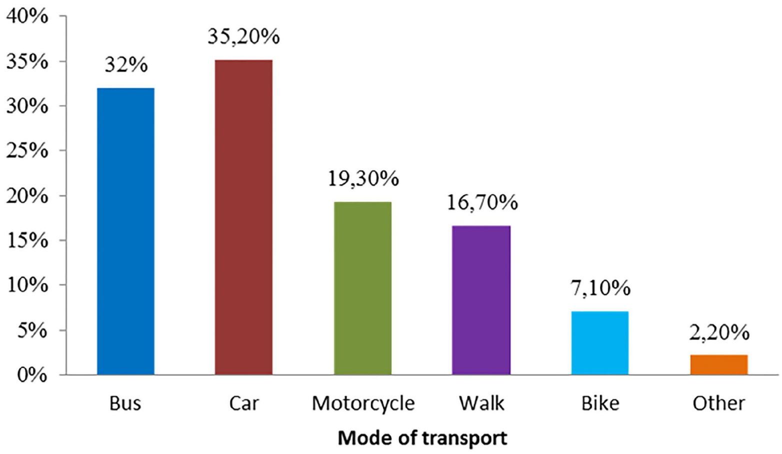

Fig. 4: Modal split motif work for RMG. Source: Adapted from Instituto Verus e Fórum de Mobilidade (2013).

3 Procedure of analysis

The following procedures are needed to achieve the proposed objectives.

Identification of the study area: the study area was chosen based on data from IPEA (2015) and IBGE (2016a). The delimitation of the studied area and the evolution of the urban scene in the region for the period 2000-2016 are shown by map to demonstrate the growth of the resident population in the municipality.

As a quantitative and comparative analysis, the identification of impacts that the urban dispersion and pendulum migration cause in the CO2 emission is realized from the analysis of the amount of daily discharge of this pollutant in the atmosphere. The same analysis is done by relation to the most favorable scenarios. Thus, it is necessary the following steps:

a) to identify the number of daily commuting between Goiânia and Senador Canedo through IBGE data (2016a), which show the number of people traveling between Senador Canedo and Goiânia daily in 2016. These data are used for Identify the Current Situation, as they are the most recent data on the flow of people between Goiânia and Senador Canedo. Only trips for the work motive are counted, since there is only the recent modal split for this reason, as explained in the next item;

b) to characterize the trips according to transport mode used (modal split). As RMG does not present a recent origin and destination survey, we used data from the Verus Institute and the Mobility Forum (2013), as shown in Figure 4;

c) to find the distance between the two municipalities. In this case, the distance was chosen according to the route performed by buses because this is the least flexible traveling mode among others. We used the same distance for the three evaluated modes.

d) to calculate the CO2 emissions for the three motorized modes employed in RMG for the displacement of passengers: automobile, motorcycle, and bus. This calculation refers to IPEA (2011) studies. In this study, a fuel mix of 47% ethanol and 53% C gasoline, obtained from the Agência Nacional do Petróleo (ANP) yearbook, was used to calculate car emissions. For motorcycles, we considered the fuel mix of 22% alcohol x 78% of gasoline used. Total emissions of 0.28 kg of CO2 / km (gasoline) and 0.056 kg of CO2 / km (alcohol) were considered. The CO2 emission factor of each vehicle was calculated applying the following formula:

Fvei = ∑ fri_comb(i)x emissions(i) (1)

In that, Fvei = Final Emissions Factor of vehicle considered

fri_comb(i) = Percental of fuel mix i

emissões(i) = Emissions by fuel kilometers i

For diesel-powered vehicles, the emission rate was around 3.2 kg of CO2 / l of diesel. Table 2 gives a summary of the calculations made to find CO2 emissions per kilometer per mode. The results, in the column "Kilometer emissions kg CO2 / km (B / A)", are used to calculate emissions in this survey.

Modality	Yield Energetic km/l or km/kWh (A)	Emissions by energy source kg CO_2/l or kWh (B)	Kilometer emissions kg CO_2/km (B/A)
Bus	2,5	3,200	1,28
Automobile[1]	8,5	1,747	0,19
Motorcycle[2]	30	2,307	0,07

[1] Average emission weighted by the total consumption of alcohol and gasoline.
[2] Considering mixture of 25% alcohol in gasoline.

Tab. 2: Kilometer yield and CO2 emissions. Source: Adapted from IPEA (2011).

e) to identify the number of CO2 emissions that make up the Favorable Scenario 1. For this, the procedure performed in steps “a” to “d” is repeated, with change only in step b, where the modal split for work in the RMG is changed transferring a part of individually motorized trips to the collective mode.

f) to identify the number of CO2 emissions that make up the Favorable Scenario 2. For this, in addition to the changes made to the Favorable Scenario 1, part of the trips made by car are eliminated by increasing passengers per vehicle.

g) to compare the Current Situation with Favorable Scenarios

4 Procedure application

4.1 Study area

The population of Senador Canedo municipality is 102,947 inhabitants (IBGE, 2016b). Senador Canedo has 248,291km² (IBGE, 2015). It is located in the RMG and home the largest Petrochemical Center in Central-West Brazil and has access to the primary distribution centers for passengers, cargo, and commercialization (Prefeitura, 2016).

Around 21,014 people moved between Senador Canedo and Goiânia only for work purpose in 2016. Of this total, 19,702 people left Senador Canedo for Goiânia, and 1,312 people left Goiânia for Senador Canedo (IBGE, 2016a). These facts combined with the number of approved subdivision of land in the region (46 plots approved between 2008 and 2015 and five after that date) contribute to the increase of the agglomeration between Goiânia and Senador Canedo (IPEA, 2015).

In 2000, the total population of the municipality was 53,105 inhabitants, of whom 50,442 lived in the urban area. The population density for the year 2000 was 216.88 inhabitants / km². In 2010, the population density was 344.27 inhabitants per km². This year, the municipality population was 84,443 inhabitants, of whom 84,111 lived in the urban area. As of 2016, the current population density is 414.62 in hab. / Km² (IMB, 2016). Figure 5 shows the evolution of the urban sprawl in the years 2000, 2010 and 2016.

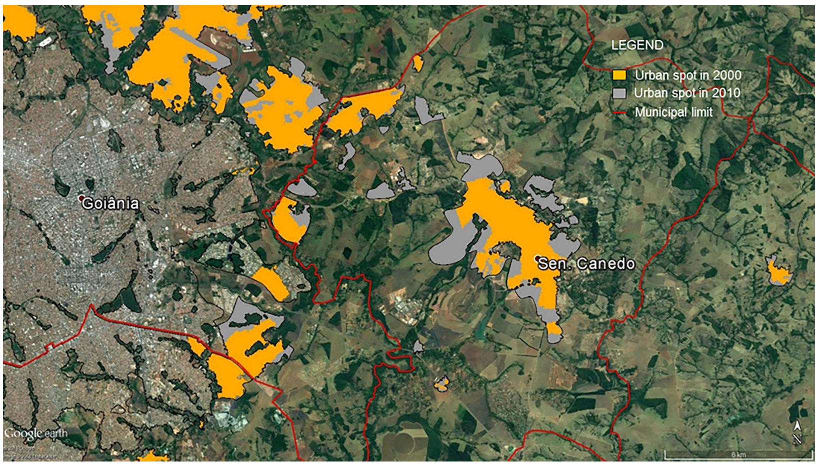

Fig. 5: Evolution of urban sprawl Senator Canedo. Source: Prepared with the State System data Geoinformation (SGEI, 2016th; 2016b) on Google Earth image (2016).

4.2 Quantitative and comparative analysis

To considering the modal split motive work to RMG (Fig. 4) and the amount of people who perform commuting between Goiania and Senator Canedo for work reason (21.014, 2016), Figure 6 shows numbers of people moving and methods related to the Current Situation. In this research, only motorized modes are considered due to the metropolitan scale. Non-motorized modes were not considered in this study because it is complicated to travel in long displacements by this mode. Thus, 2837 displacements are not considered since they are for displacements carried out by other modes in Figure 6.

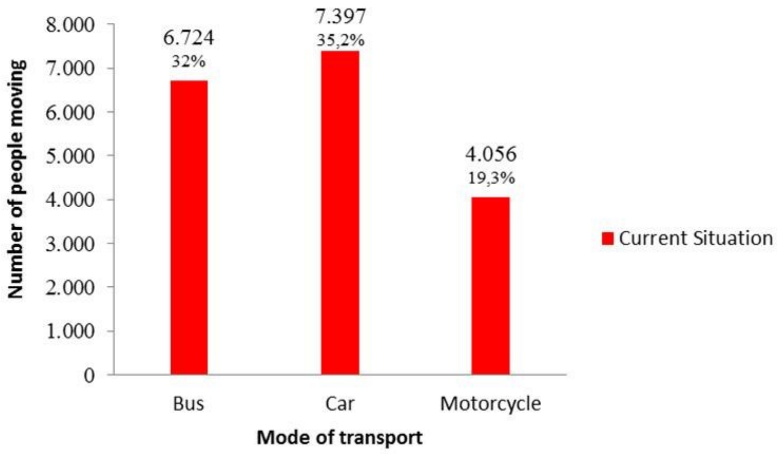

Fig. 6: Number of people moving by a certain mode and their percentage (modal split) in the Current Situation. Source: Authors.

In this study, it was considered that a commute corresponds to two trips (travel generated = travel produced plus trip attracted). Thus, each trip corresponds to the sum of the round trip, assuming that the person uses the same mode of transport for its outward and return travel.

The distance between Senador Canedo and Goiânia is calculated from the route taken by bus line 283, which leaves the Senador Canedo Terminal to the Bible Terminal in Goiânia, and vice versa. The bus travels 53.75 km in all, considering Round trip. This line was chosen because it runs the route through conventional buses, which is the type of bus used to calculate CO2 emissions by IPEA (2011). Therefore, the values referring to CO2 emission per mode of transport in the Current Situation are summarized in Table 3, according to the IPEA study (2011):

Modality	Emissions per kilometer kg of CO_2/km	Occupation Average of Passengers Vehicles	Emissions/ Kg of CO_2/pass./ Km[3]	Total number of pass. per day	Emissions / kg of CO_2 / pass. By Travel[3]	Emissions/ Kg of CO_2/ Travel[3]	Emissions/ Kg of CO_2/day
Bus	1,28	97[1]	0,013	6724,48	0,71	68,8	4.769,53
Automobile	0,19	2[2]	0,095	7396,93	5,11	10,21	37.770,57
Motorcycle	0,07	1	0,07	4055,70	3,76	3,76	15.259,57
						Total	**57.799,67**

[1] Number of passengers per conventional bus according to CMTC (2016).
[2] Average occupation of automobiles according to the author's field research.
[3] Emissions considering the same travel length for all modes (53,75km).

Tab 3: Relative CO2 emissions by mode of transport for travel between Senador Canedo and Goiânia - Current Situation. Source: Elaborated by authors with data from IPEA (2011), IBGE (2016a) and CMTC (2016).

Table 3 shows the high amount of CO2 (57,799.67 kg) emitted by the displacements performed daily for work reasons, between Senador Canedo and Goiânia. Most of the emissions are produced by automobiles (37,770.57 kg), which is almost eight times higher than the total CO2 generated by bus trips (4,769.53 kg). This difference is even more noticeable when the carbon dioxide emissions per passenger are analyzed in a journey.

The most favorable scenario, there is the lower amount of CO2 emissions between Goiânia and Senador Canedo per day, can be achieved through a decrease in trips made by cars and motorcycles (higher CO2 emitters) and an increase in trips made by transit (the lowest emitter of CO2). In practice, according to Associação Nacional de Transportes Coletivos (ANTP, 2016), there is no city in which only one mode of travel is responsible for all travels. Also, there are no cases in which one mode is not used: participation in any mode never less than 5% and never exceeds 50% of total displacements.

To favorable Scenario 1, it is proposed to change the percentage of trips performed by transit (bus), motorcycles and automobiles, as follows:

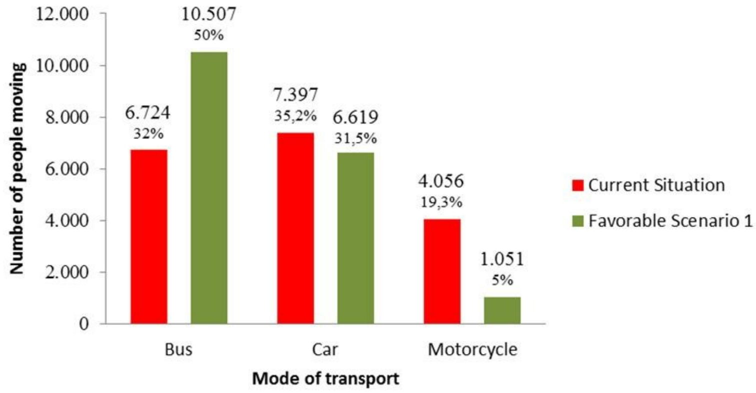

Fig. 7: Number of people moving by a certain mode and their percentage (modal split) in the Current Situation and Favorable Scenario 1. Source: Elaborated by authors with data from IPEA (2011), IBGE (2016a) and CMTC (2016).

In this simulation, the percentage of motorcycles trips was reduced to the minimum. In most cases, motorcyclists stopped using transit either to save travel time or to down the trip cost, even facing high risks and elevated levels of pollutant emissions (Vasconcellos, 2008). In this way, this simulation tries to return transit of its user, which is also a positive factor to reduce accidents, since most of them happen with motorcycles. Table 4 shows the summary of the results obtained for CO2 emission by mode of transport:

Modality	Emissions per kilometer kg of CO_2/km	Occupation Average of Passengers Vehicles	Emissions/ Kg of CO_2/pass./ Km³	Total number of pass. per day	Emissions / kg of CO_2 / pass. By Travel³	Emissions/ Kg of CO_2/ Travel³	Emissions/ Kg of CO_2/day
Bus	1,28	97¹	0,013	10.507	0,71	68,8	7452,39
Automobile	0,19	2²	0,095	6.619,41	5,11	10,21	33.800,36
Motorcycle	0,07	1	0,07	1050,7	3,76	3,76	3953,26
						Total	**45.206,01**

¹ Number of passengers per conventional bus according to CMTC (2016).
² Average occupation of automobiles according to the author's field research.
³ Emissions considering the same travel length for all modes (53,75km).

Tab. 4: Relative emissions of CO2 by mode of transport for travel between Senador Canedo and Goiânia - Favorable Scenario I. Source: Elaborated by authors with data from IPEA (2011), IBGE (2016a) and CMTC (2016).

The reduction in the number of daily trips by motorcycle mode significantly decreases the amount of CO2 emissions for this mode. The decrease in the percentage of motorcycle and motor vehicle displacements is more significant than the corresponding percentage increase in transit, so that total daily CO2 emissions dropped from 57,799.67 kg to 45,206.01 kg.

This mitigation in CO2 emissions can be even more significant with the reduction of the number of travels per car, through the increase of passengers within each vehicle (from 2 to 5), which conforms to Favorable Scenario 2 of this study. Table 5 summarize the results obtained for this scenario.

Modality	Emissions per kilometer kg of CO_2/km	Occupation Average of Passengers Vehicles	Emissions/ Kg of CO2/pass./ Km³	Total number of pass. per day	Emissions / kg of CO_2 / pass. By Travel³	Emissions/ Kg of CO_2/ Travel³	Emissions/ Kg of CO_2/day
Bus	1,28	97¹	0,013	10.507	0,71	68,8	7452,39
Automobile	0,19	5²	0,095	6.619,41	2,04	10,21	13.520,14
Motorcycle	0,07	1	0,07	1050,7	3,76	3,76	3953,26
						Total	**24.925,79**

¹ Number of passengers per conventional bus according to CMTC (2016).
² Average occupation of automobiles according to the author's field research.
³ Emissions considering the same travel length for all modes (53,75km).

Tab. 5: Relative emissions of CO2 by mode of transport for travel between Senador Canedo and Goiânia - Favorable Scenario II. Source: Elaborated by authors with data from IPEA (2011), IBGE (2016a) and CMTC (2016).

Table 5 shows Favorable Scenario II, in which the increase in the number of passengers per car, decreasing the number of travels to that mode and maintaining the amount of travel and passengers to the other modes according to the previous scenario, allows a reduction of 20,280.22 kg in CO2 emissions. A reduction in total emissions is also important, as can be seen in Table 6.

Modality	Number of total pass. per day in current scenario	Number of total pass. per day in favorable scenario 1 and 2	Emissions/ Kg ok CO_2/day in current scenario	Emissions/Kg of CO_2/day in favorable scenario 1	Emissions/Kg of CO_2/day in favorable scenario 2	Difference between scenarios for Emissions /Kg of CO_2/day
Bus	6724,48	10.507	4.769,53	7452,39	7452,39	+2.682,86
Automobile	7396,93	6.619,41	37.770,57	33.800,36	13.520,14	- 24.250,43
Motorcycle	4055,70	1050,7	15.259,57	3953,26	3953,26	-11.306,31
Total			**57.799,67**	**45.206,01**	**24.925,79**	**-32873,88**

Tab. 6: Comparison between the Current Situation and Favorable Scenarios 1 and 2 for related CO2 emissions by mode of transport traveling between Senador Canedo and Goiânia. Source: Elaborated by authors with data from IPEA (2011), IBGE (2016a) and CMTC (2016).

The transfer of 18% of the RMG displacements that were carried out by automobiles and motorcycles for public transport, together with the change in the number of passengers per car per trip. It reduces the CO2 emission per day of 57,799.67 kg to 24,925.79 kg, that is, 32,873.88 kg of CO2 ceased to be emitted daily, which corresponds to a decrease of 56.88% concerning the current scenario (Tab. 6).

By this way, the emission of CO2 can be reduced, if travel from private motorized modes were transferred to less polluting as public modes or increased the number of passengers per car.

Discussion and final considerations

Through the developed and applied procedure, it was possible to explore the impact that the urban sprawl of Senador Canedo and the commute to Goiânia provoke in the CO2 emission of the region. From the analysis of the current situation, it is possible to watch a great distance, and the number of motorized displacements between the two municipalities provokes a high value of emission of CO2 in the atmosphere. Identification of the carbon dioxide emission by the mode of transport has shown that the highest emission values of the above are known by the motor and motorcycle engines. This result is corroborated by IPEA (2011), which affirms a predominance of global pollutant emission by individually motorized modes.

The identification of favorable scenarios has demonstrated the possibility of a reduction in carbon dioxide emissions through changes in travel behavior, changing the way people move and the occupancy factor, as shown in Figure 2 (Ministério das Cidades, 2008). Thus, the Ministério das Cidades (2015) proposes policies restricting individual motorized movements and, at the same time, policies of attraction to collective modes. Policies of automobiles and motorcycles restriction are based on strategies as parking lots reduction or the increase of parking rates, increase of tariffs and taxes on vehicles, limitation of areas for traffic, tolls, etc. Policies for transit attraction involve incentives from the government, transfers of financial resources from individual motor vehicles such as taxes and fees, fleet increase, and quality of service.

Another possibility is to decrease the distance to be overcome by the displacements. In this case, it is important that public policies or center-periphery models of cities' expansion can be revised to not approve subdivisions in remote areas away from work/study sites and to convert central areas more accessible to the low-income population. For this to happen efficiently, urban planning must occur on a metropolitan scale and in conjunction with the mobility plans of the region, as provided for in the Estatuto da Metrópole (Brasil, 2015). In this way, it is possible to limit urban expansion and to delimit the places where urban growth does not cause environmental, economic and social impacts. At the same time, strengthening the local economy of municipalities generating displacements can reduce the amount of inter-municipal travel required and use the financial gain to enhance transit and the use of non-motorized modes in the municipalities themselves.

Analyzes presented by this work were limited to the existing information on urban mobility in the RMG. The last origin and destination survey for the RMG refers to the year 2000 and does not correspond to the current reality. Therefore, the research was limited to the displacements for work reasons, since there is only the modal split for the year 2013 specifically for the trip made for this reason. However, considering the predominance of the commuting displacements for the motif work in the RMG, as could be observed in Table 1, the validity of this study can be considered relevant.

In conclusion, the quantitative and comparative analysis adopted in this work for the calculation of CO2 emissions in regions of dispersed urban occupation can be extended and applied to the entire RMG as well as to other metropolitan areas of the country, despite limitations and difficulties of methodology. Thus, it is possible to elaborate other Scenarios and contribute with diagnoses, prognoses, and proposals for the Master Plans, Metropolitan Mobility Plans, Energy Plans and Reduction of Emissions of Pollutants.

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