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Comparing scenarios to improve accessibility to local opportunities in Montreal, Canada.

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Abstract

Density and diversity of land use are recognized as key features of neighbourhoods that can reduce car dependency and improve accessibility to local opportunities. This paper proposes to evaluate scenarios optimizing the spatial distribution of local opportunities to better align the distribution of both day population (where people conduct their activities) and night population (where people live). Hence, COVID-19 has changed the typical distribution of people across space, because of full or partial virtualization of activities, raising questions about the optimal distribution of opportunities. We thus evaluate the opportunity density per square kilometer for night and day population, with the current distribution of opportunities as well as two scenarios that distribute opportunities proportionally to the night and day populations. Furthermore, we evaluate two scenarios of restaurant redistribution that may result from the teleworking. The results indicate that the current distribution of opportunities is better aligned with the day population distribution. However, the population distribution could, in the upcoming years, shift towards the night population distribution with the increase in activity virtualization. Our findings show that strategic planning oriented towards a distribution in proportion to the night population would increase proximity for large proportion of the population in Montreal.

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Keywords: Optimization scenarios; proximity services; virtualization of activities; imbalance indicator; accessibility; Covid-19.

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1. Introduction

The spatial location of opportunities, activities and dwellings is a key determinant of transportation demand. However, it is essential to determine whether these opportunities are effectively distributed to meet the needs of the population while minimizing travel distances. Accessibility to local opportunities from both residential and workplace locations is a critical consideration in this regard. Hassani, Saunier and Morency (2017) have examined the question of optimal location by estimating, scenarios minimizing the total home-work distances by reallocating households, while Pepin and Morency (2012) have evaluated scenarios minimizing home-school distances by changing the allocation of children to school . Other researchers have optimized household locations while taking into account both work and study distances from the dwelling (Morency and Verreault 2020). In the same order of ideas, this paper examines scenarios that optimize the distribution of local amenities such as grocery stores, drugstores, child daycare services and restaurants, both from the point of view of night population (based on residential location) and day population (based on where people are during their daily activities).

The COVID-19 pandemic has significantly impacted the way people live by forcing an almost complete virtualization of activities. While many researchers have addressed the various impacts of teleworking (Curtis 2020; Pérez et al.2004; Kitou and Horvath 2006; Helminem and Ristimaki 2007), few have examined the structural impacts of virtualization of activities at a larger scale. An example of such investigations was carried out in Barcelona to measure the impact of COVID-19 on commercial activities. The results show that the pandemic has had an impact on global tourism and led to significant commercial desertification (Frago 2021). It is therefore important to assess the possible impacts of such changes in people's daily movements in terms of accessibility to important opportunities. Despite the virtualization of activities, the population still requires access to services such as grocery stores, drugstores, child daycare services, and restaurants, and the current location of these opportunities may not be optimal given the significant changes in activity systems. In this context, this paper proposes redistribution scenarios that aim to improve accessibility to local opportunities, while considering the virtualization of activities and the potential closures of services resulting from the pandemic.

First, this paper proposes some background elements with respect to optimization scenarios, accessibility to local opportunities and virtualization of activities. The methodology presents the data used to develop the scenarios as well as the key steps for their estimation. Then, two scenarios are presented. They consist in redistributing the existing opportunities per census tract in proportion to the population based on their home location (what we call the night population) and based on their location at noon, following their various daily activities (what we call the day population). Results are presented and discussed for various types of local opportunities. A section is then dedicated to restaurant closures as a possible result of the pandemic impact on working conditions. The paper concludes with a summary of contributions, limitations, and further steps for future research.

2. Background

The main drivers of motorized vehicle-kilometers travelled in a metropolitan area are the spatial locations of dwellings and activities. With the spreading and burst of these two sets of locations, distance to travel between them increases so trips must rely mainly on motorized modes (Brunner 2012; Dieleman and Wegener 2004). Strategies to reduce distances go from improving density (Brunner 2012; Dieleman and Wegener 2004), land-use diversity (Dieleman and Wegener 2004; Van Eck and Koomen 2008; Maoh and Tang 2012), controlling urban sprawl (Dieleman and Wegener 2004; Halleux and al.2012; Maya 2008; Blair and Wellman 2011; Fox 2010), dwelling costs (Blais 2010) or transportation costs using tolls (Brueckner 2000; Zhang and Kockelman 2014) for instance. In the context of increasing land-use diversity, the idea is to provide the necessary services close to housing, rather than specializing areas with either dwellings or services (Maoh 2012).

2.1. Optimization Scenarios of Localizations

Actually, services should probably be where people need them to be so they can easily access to them when required. This raises the question of optimal location of services or optimal distribution of available opportunities.

In the Greater Montreal Area (GMA), researchers have evaluated various types of scenarios to assess whether final destinations were distributed optimally. First, three scenarios optimizing home-work place distances while considering household size, dwelling type preferences and tenure type in the GMA were first estimated (Hassani, Saunier and Morency 2017). Authors find out that the total sum of home-work distances reduces significantly for each scenario, with a diminution of 51% with the most restricted scenario. A recent update of this scenario, using data from the 2013 Origin-Destination survey, proposed to swap households between dwellings so as to minimise total distance travelled for work and school. This theoretical swapping, between households of similar types, could reduce home to work/school distances by 37.9% while generously increasing probability to use an active mode due to shorter distances to travel (Morency and Verreault 2020). Others have proposed scenarios of school allocation minimising the total sum of home to school distances and taking into account proximity, type of school (private or public) and capacity (Pepin and Morency 2012). Their results show that optimizing school allocation can reduce travelled distances by 40% even with the most restrictive scenario.

Optimization scenarios have also been suggested by researchers to evaluate scenarios improving accessibility to blood donor clinics while mentioning the amount of resources to be redistributed amongst the clinics for the optimization to take place (Páez and al.2013).

2.2. Impacts of the Virtualization of Activities on Transport

COVID-19 has put a drastic acceleration to virtual activity adoption. In this context, it becomes important to address the impacts of this stay-at-home situation on the transportation sector. While some researchers have found that teleworking can reduce air pollution emissions (Curtis 2020; Pérez and al.200; Kitou and Horvath 2006) and total travelled distances (Curtis 2020; Pérez and al.2004; Helminem and Ristimäki 2007), the virtualization of activities on a large scale is still to be investigated. As some services are still used by the population during confinement, we will address accessibility to grocery stores, drugstores, child daycare services and restaurants in th e Greater Montreal area using density indicators. However, behaviors could tend towards e-shopping due to the COVID-19 situation (Hashem 2020). As the delivery would still induce commuting from the store to the dwelling, we will not insist on this aspect.

This study proposes an aggregated method to evaluate scenarios improving the distribution of opportunities based on population distribution. The case study is first presented, along with the data required for the analysis, followed by the main methodological steps.

3. Data

3.1. Case Study

Our study is based on the GMA (Greater Montreal Area). We focus on some local opportunities: grocery stores, drugstores, child daycare services and restaurants but the method could easily be used to examine other types of opportunities. These are selected since they first are frequently visited services and second, they still are frequented by the population during the confinement period, confirming their importance in the activity systems. To compare the impacts of the full or partial virtualization of activities on accessibility to local opportunities, we analyse the distribution of these opportunities against night and day population of each census tract. Since census data only report on the night populations (where people live), we use data from the 2013 Montreal Origin-Destination (OD) travel survey to estimate day population from the daily movements of travelers. We hence value land-use data of enhanced points of interest for grocery stores, drugstores, child daycare services and restaurants from the 2019 CanMap® Content Suite of DMTI Spatial.

3.2. Census Tracts of the Greater Montreal Area (GMA)

In this study, we aggregate data at the census tract (CT) level (921 CT in Montreal in 2011). The mean area of the census tracts is 4.66 km2, with a standard deviation of 14.87 km2, which is equivalent to a coefficient of variation of 319%. The figure below shows the distribution of census tracts according to size and confirms that they are quite heterogenous across the region.

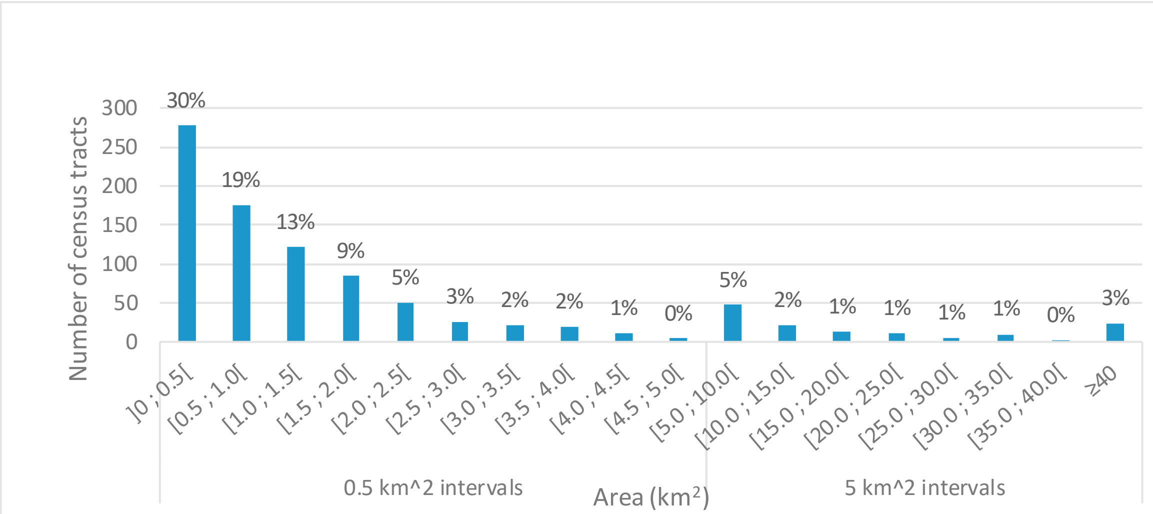

Fig. 1. Distribution of census tracts per size (km²).

This figure indicates that 49% of the census tracts in the GMA have an area of less than 1.0 km2, while 3% of them have an area greater than 40 km2. To allow for comparison despite the size heterogeneity, ratios of opportunities per squared kilometer and per 1000 people at night and at noon are used. This allows to assess both the average area covered by each opportunity within a CT and the average population count that each opportunity would have to service depending on the time of the day.

3.3. Night vs Day Population

Using the data from the 2013 Origin-Destination Survey, the total population in the area is 3 834 652 people at night and 269 people more at noon, or 3 834 921 people. Both at night and at noon, the mean population per CT is 4200. At night, the coefficient of variation is 100%, while it is 166% at noon, or two thirds more than at night. We calculated the ratios of population at night and at noon per squared kilometer for each CT. Then, we calculated the ratios of population density at noon over the population density at night. The figure below presents a choropleth map of these ratios, showing, in red, CT where the population density at noon is smaller than the one at night, and, in green, CT where the population density at noon is larger than at night. There is eight CT that do not appear on this map because their population is zero but, as they have opportunities, they will figure in the opportunity analysis.

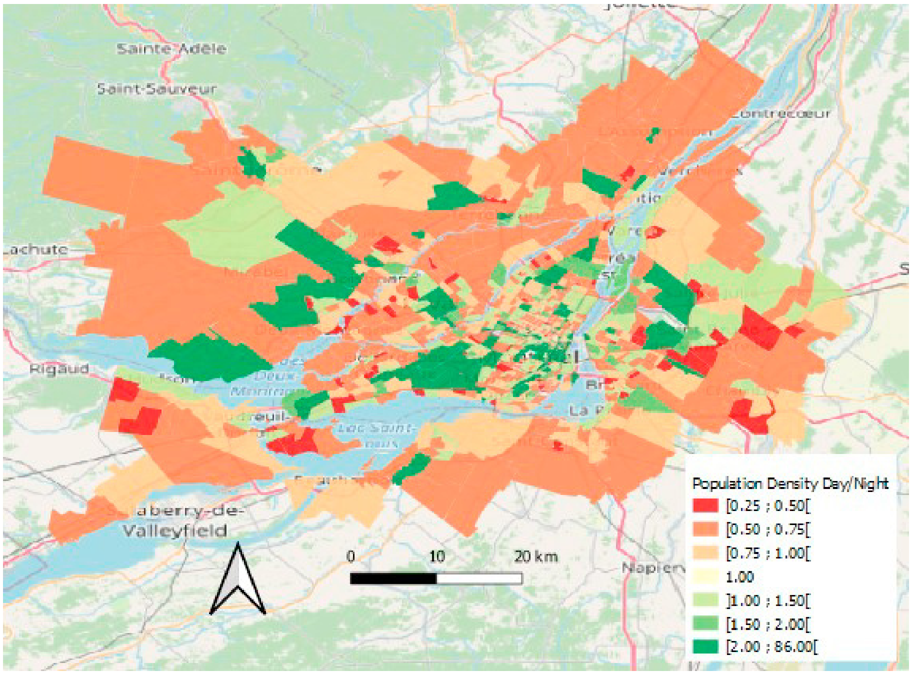

Fig. 2. Choropleth map of ratios of day population density over night population density per census tract.

This figure highlights that in the Montréal Island and some commercial sectors on the shores, there is more people at noon than at night, and this ratio can go up to 86 times more. However, in Laval and most parts of the shores, population is greater at night than at noon, and the difference is up to 4 times more.

3.4. Land Use Data

In this study, we analyse four types of proximity services: grocery stores, drugstores, child daycare services and restaurants. From the enhanced points of interest of the CanMap® Content Suite of DMTI Spatial, there are 3400 grocery stores, 1072 drugstores, 1414 child daycare services and 10 722 restaurants in the census tracts of the GMA. Concerning the number of restaurants, we filtered the data for "eating places" from the CanMap® Content Suite of DMTI Spatial, but the term "restaurants" will be used in this paper for simplicity reasons. We will present distributions of the population at night and at noon per ratios of opportunities per squared kilometer and per 1000 people in the CT. These distributions will serve as opportunity-based accessibility indicators at the aggregated level of the CT for different scenarios of opportunity and population distribution.

4. Methodology

4.1. Scenarios Optimizing the Spatial Distributions of Opportunities

In this study, we will analyze two scenarios where the opportunities are distributed according to the night and day population in the CT. As these scenarios could reduce inequalities of opportunities by ensuring a uniform opportunity density per population, they can relate to principles of distributive justice and Rawl's egalitarianism (Michaud 2019; Pereira 2016). For clearness purposes, the two scenarios will be further called "Scenario Night Pop" and "Scenario Day Pop", respectively.

4.2. Imbalance indicators

Furthermore, imbalance indicators will help assess how much the current distribution of opportunities is different from the tested scenarios. These indicators consist in the percentage of opportunities that would be relocated if the scenarios were to be implemented.

$$\varphi = \frac{\sum_{i=1}^{n} |O_i - A_i|}{2 \sum_{i=1}^{n} A_i} \quad (1)$$

where φ is the total percentage of opportunities to be relocated by the optimized scenario, and n is the total number of CT. O_i is the number of opportunities in the CT i with the distribution of the optimized scenario and A_i is the number of opportunities in the CT i as they are currently distributed per the 2019 CanMap® Content Suite. Also, the distributions of the number of opportunities that would be relocated per CT if the scenario was implemented will be shown. This will help to assess which areas have excessive or deficient numbers of opportunities per population and will allow planning authorities to target efforts where they are most needed. The results are obtained by taking the difference between the number of opportunities between the tested scenario and the current distribution for each CT.

4.3. Impacts of restaurants bankruptcies

Considering that 60% of restaurants could close definitively if the confinement was to last until 2021 (ARQ,2020), we will compare the current distribution of restaurants with two scenarios of 30% and 60% of restaurant closures, respectively. Supposing that the closures happen uniformly across the GMA, the number of restaurants per CT for each scenario is calculated by subtracting the number of supposed closures from the current number of restaurants. We will present the impacts that these bankruptcies could have on the proportion of the population having access to different densities of restaurants per squared kilometer and per 1000 habitants. Furthermore, we calculated a risk indicator by multiplying the ratio of the day population over night population by the number of restaurants in the CT. This indicator considers that the higher the day population is compared with the night population, the more the potential clientele of this CT would be reduced by increased activity virtualization. This reduction would be even more exacerbated in a context where there are many restaurants in the CT.

5. Results

5.1. Diagnostic for the Greater Montreal Area

Regarding the opportunity density per 1000 people, the mean number of opportunity density is inferior at noon than at night for each type of opportunity. For grocery stores, the number goes from 1.17 grocery store per 1000 people at night to 1.15 for each 1000 people at noon. There is an average of 0.35 drugstore per 1000 people at night, while there is 0.32 drugstore per 1000 people at noon. The mean number of child daycare services per 1000 people goes from 0.45 at night to 0.44 at noon. Finally, the average number of restaurants per 1000 people goes from 4.53 at night to 3.00 at noon. The next figure shows the distribution of the population at noon and at night following the number of opportunities per 1000 people in the CT.

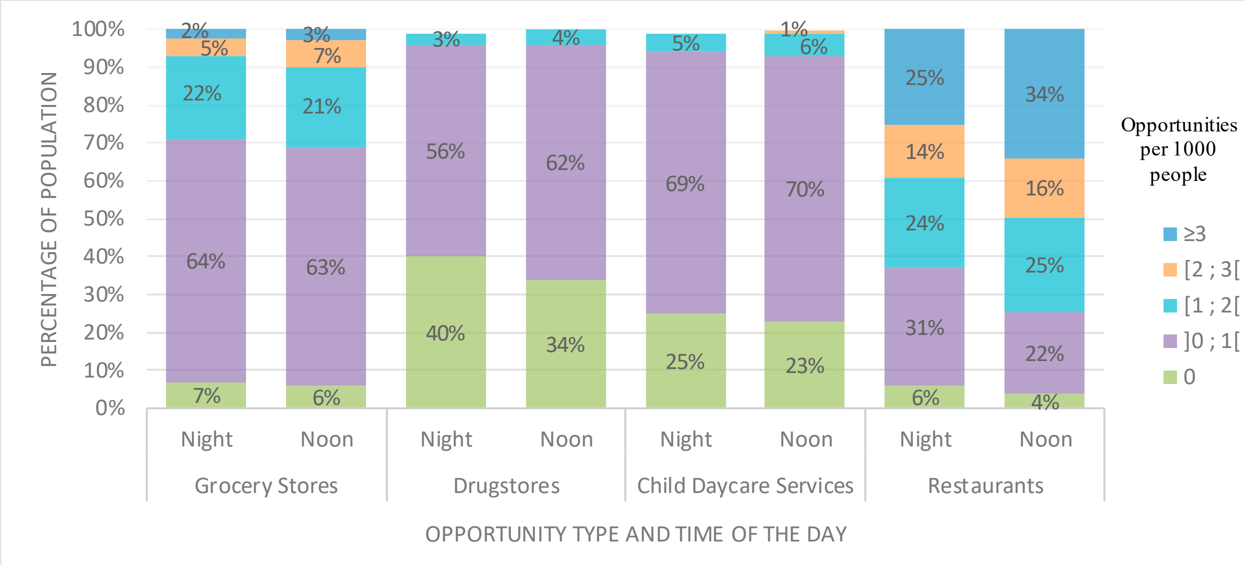

Fig. 3. Distribution of the population at night and at noon per number of opportunities per 1000 people (CT level).

At night, a larger proportion of the population is in a census tract where there are zero opportunities per 1000 people compared with the proportion at noon, for every type of opportunities. Also, at night, smaller proportions of the population are in CT where there are two or more opportunities for 1000 people, for every type of opportunities. The proportion of the population at night and at noon having access to different classes of opportunity density per squared kilometer is presented in the figure below.

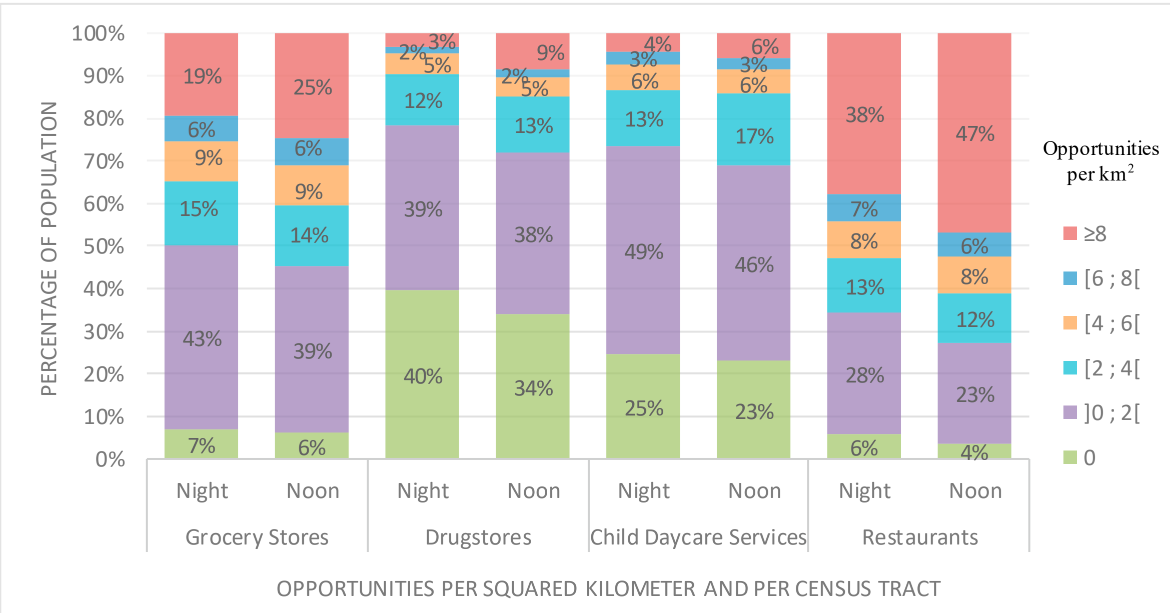

Fig. 4. Distribution of the population at night and at noon per number of opportunities per squared kilometer (CT level).

This figure shows that, for each type of opportunity, the proportion of the population having zero opportunity in their CT is greater at night than at noon. This indicates that opportunities are more closely located to the daytime activities than nighttime activities of the population and that some residential areas have few opportunities. Furthermore, if the opportunities were distributed uniformly across the area, there would be 0.79 grocery store per km2, 0.25 drugstore per km2, 0.33 child daycare service per km2 and 2.50 restaurants per km2.

5.2. Optimization Scenarios

When distributed in proportion to the population in the GMA, there are in average 0.89 grocery store per 1000 people, 0.28 drugstore per 1000 people, 0.37 child daycare service per 1000 people and 2.80 restaurants per 1000 people. As the opportunity density varies across the territory, the distributions of the population having different opportunity density in their CT will be presented following the imbalance indicators for the two tested scenarios.

As an indicator of the difference between the scenarios and the current distribution of opportunities, we calculated the percentage of opportunities that would be relocated if the scenario were to be implemented using equation (1). The table below shows the imbalance indicators obtained for the scenarios of opportunity distribution in proportion to the population at noon (scenario day pop) and at night (scenario night pop).

Table 1. Percentage of opportunities relocated in case of scenarios of distribution proportionally to the population.

Scenario	Grocery Stores	Drugstores	Child Daycare Services	Restaurants
Scenario Night Pop	34%	47%	39%	45%
Scenario Day Pop	35%	46%	42%	35%

This table indicates that, globally, drugstores are the opportunities currently distributed the least proportionally to the population at noon and at night, while the grocery stores are distributed the most in proportion to the population at noon and at night. Also, the current distribution of restaurants is better fitted to day population. For more details on the changes in the number of opportunities per CT, the distribution of differences in the number of opportunities between the scenarios and the current distribution are presented below for each type of opportunity.

Grocery Stores

The distribution of differences in the number of grocery stores per CT between the scenarios and the actual distribution is presented below. The next figure indicates that only six census tracts already have the number of grocery stores that corresponds to a distribution in proportion to the night or noon population. Also, for the distribution in proportion to the day population, there are more CT where one or two grocery stores need to be removed than for the night population scenario.

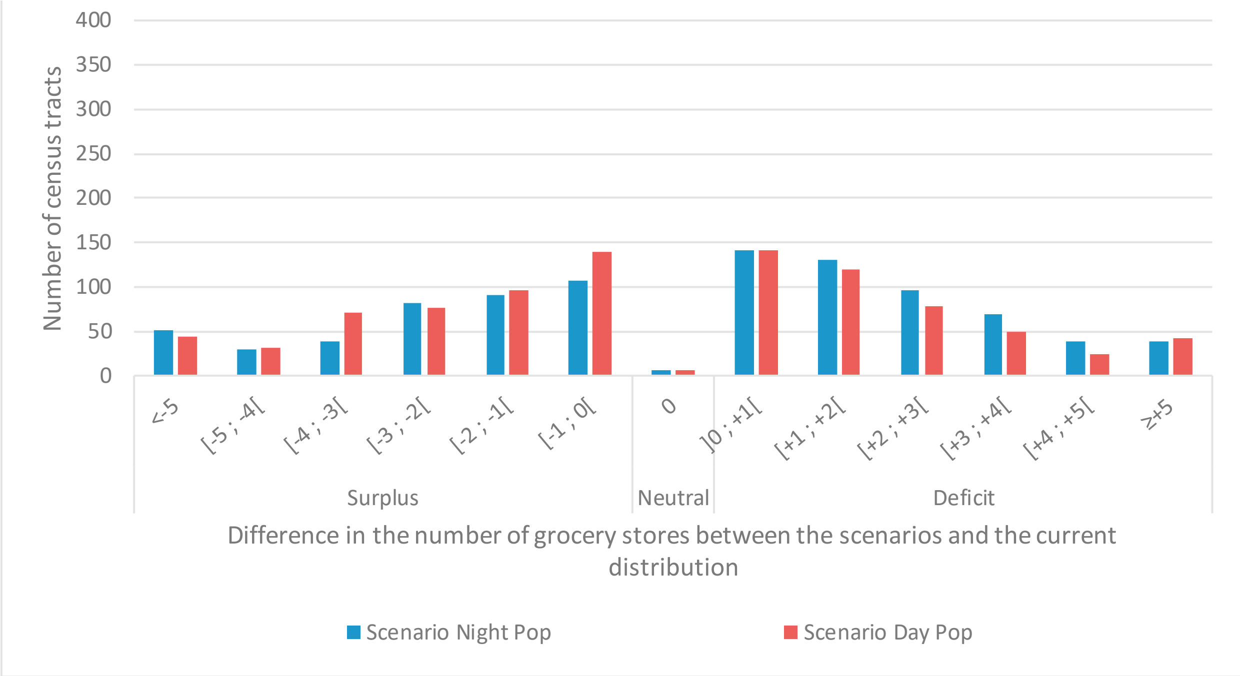

Fig. 5. Distribution of the differences in the number of grocery stores per CT between the tested scenarios and the current distribution.

Drugstores

The distribution of the differences in the number of drugstores per CT for the two tested scenarios is shown below.

As there are fewer drugstores than other types of opportunities, most census tracts need only a difference of one or two drugstores for the scenarios to be implemented. Also, for the day population scenario, there are more CT in a situation of large deficit than for the night population scenario.

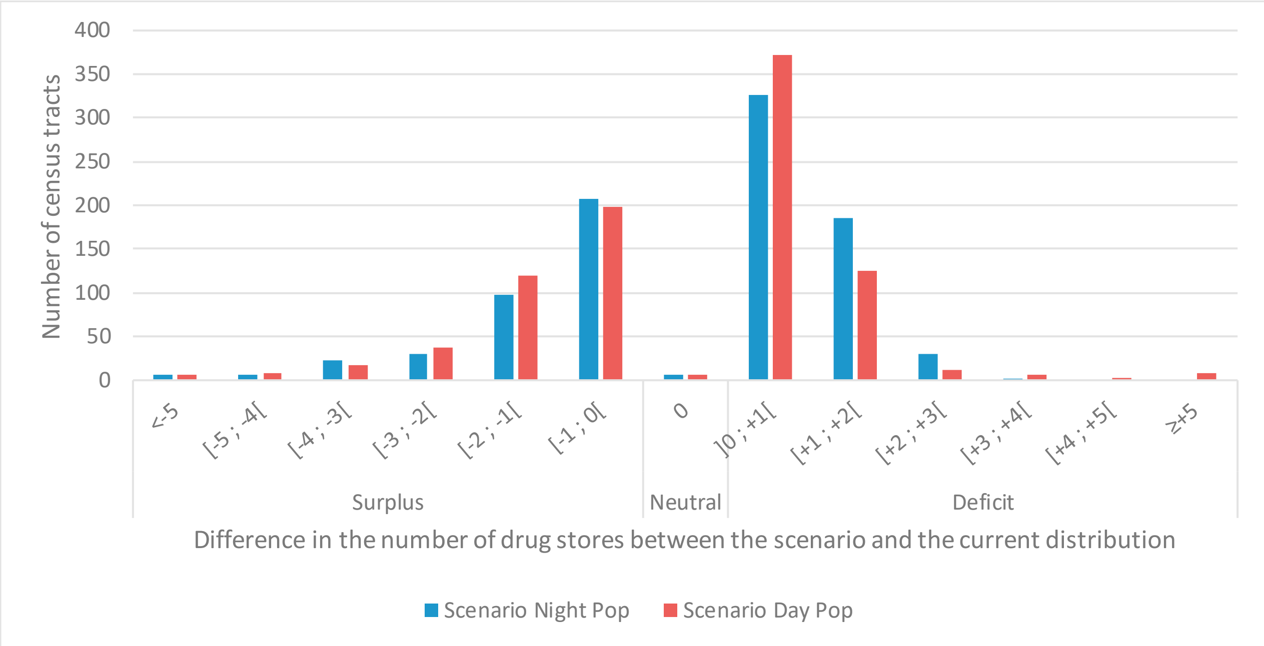

Fig. 6. Distribution of the differences in the number of drugstores per CT between the tested scenarios and the current distribution.

Child Daycare Services

The distribution of the differences in the number of child daycare services per CT is shown below.

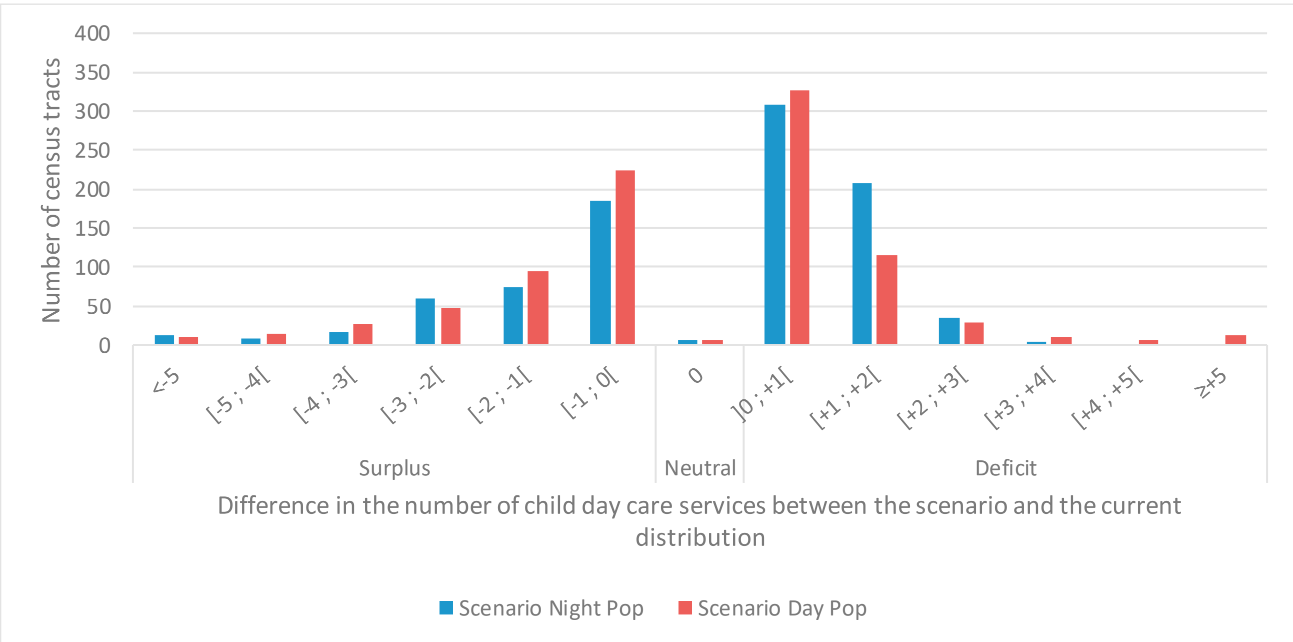

Fig. 7. Distribution of the differences in the number of child day care services per CT between the tested scenarios and the current distribution.

The distribution of differences needed for the scenarios to happen for child daycare services resembles the distribution of drugstores. For the day population scenario, some CT are in a position of larger deficit than for the night population scenario.

Restaurants

The distribution below shows the differences in the number of restaurants per CT between the scenarios of redistribution and the current distribution of restaurants in the GMA.

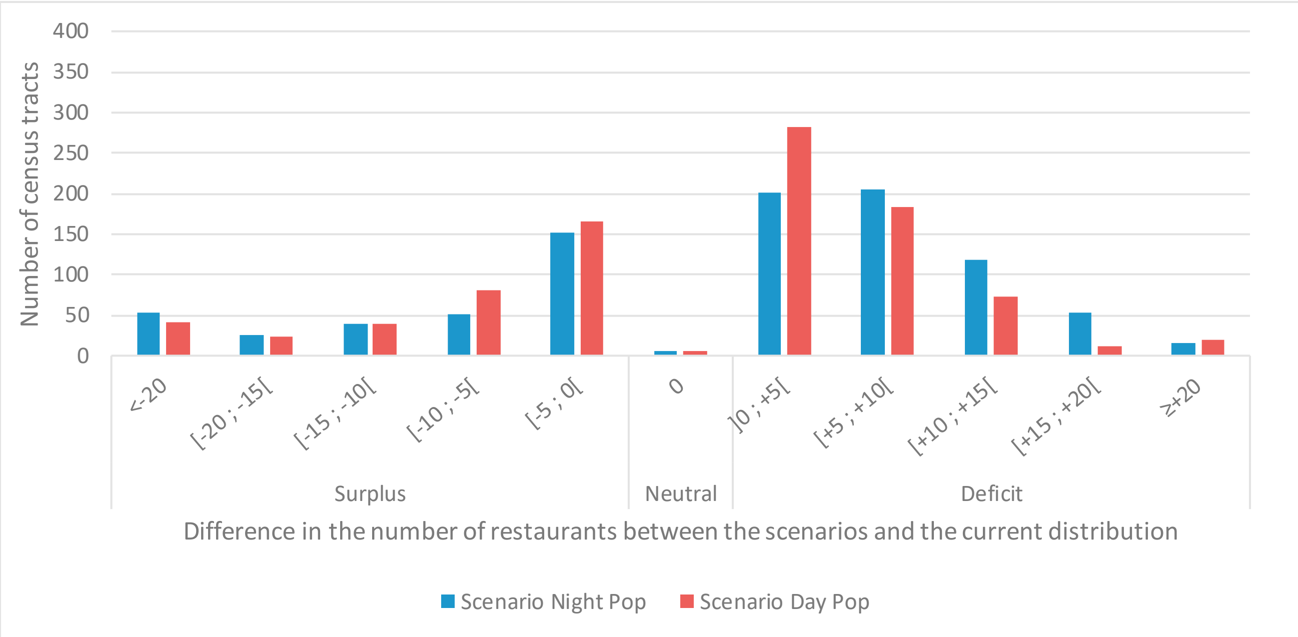

Fig. 8. Distribution of the differences in the number of restaurants per CT between the tested scenarios and the current distribution.

As there are more restaurants than any other tested types of opportunities, there is a higher number of opportunities to be relocated for the scenarios to happen. For the night population scenario, more CT have currently more than 20 restaurants in surplus and those need to be relocated to CT that have 5 to 20 restaurants in deficit, compared with the day population scenario. For the day population scenario, more CT are in a situation of 0 to 5 restaurants in deficit.

Scenario 1: Distribution of opportunities in proportion to the population at night

In this section, we will present the results obtained when applying the night population scenario, which consists in redistributing the opportunities in proportion to the population at night per CT. We will thus show the percentage of the population per opportunity density with this theoretical opportunity distribution across the GMA.

The figure below shows the distribution of the population at noon and at night per opportunity density per 1000 people in the CT, for the current distribution of opportunity and for the night population scenario. This figure indicates that, when applying the night population scenario, nobody is in a CT where there are zero opportunity, and this applies for all types of opportunity. Also, for drugstores and child daycare services, the night population scenario ensures the same opportunity density for everybody, even with the day population.

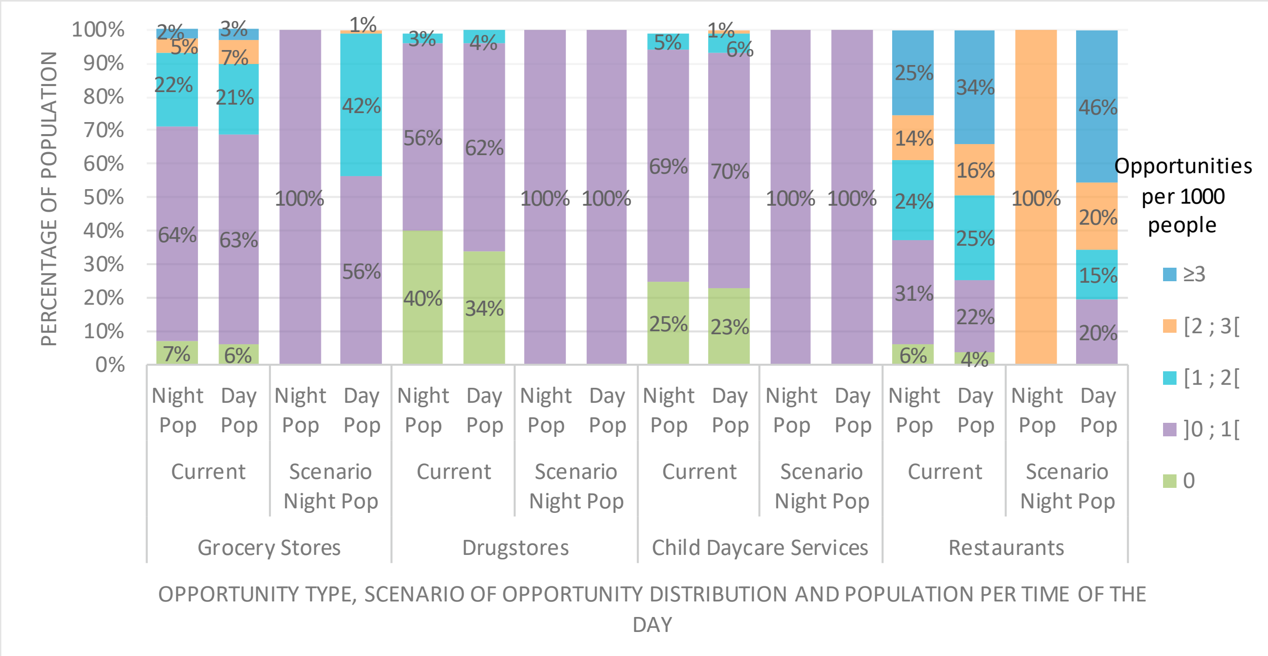

Fig. 9. Distribution of the population at night and at noon per opportunity density per 1000 people with the current distribution and the night population scenario.

Then, the figure below shows the distribution of night and day population per opportunity density per squared kilometer in the CT, for the current distribution of opportunities and the night population scenario.

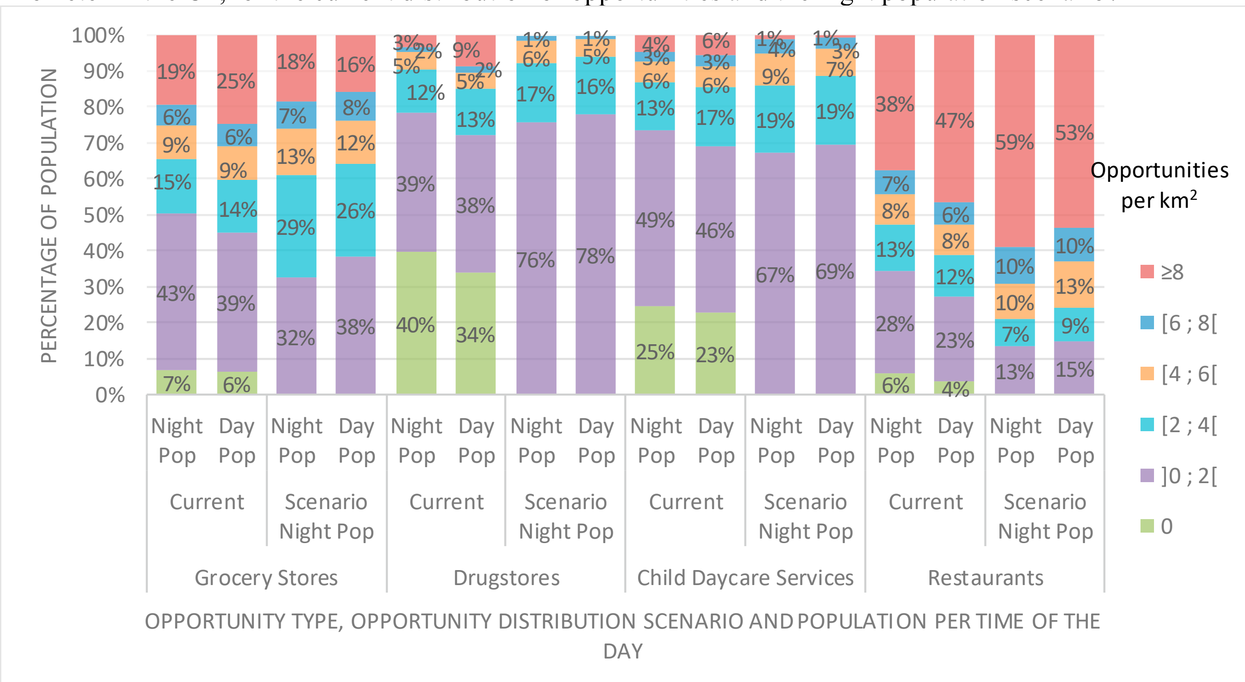

Fig. 10. Distribution of the population at night and at noon per opportunity density per squared kilometer with the current distribution and the night population scenario.

The figure above shows that, when applying the night population scenario, the proportion of the population having 2 to 8 grocery stores per squared kilometer is increased by 19% for the night population and 17% for the day population. Furthermore, while the current distribution of opportunities lets 40% of the night population and 34% of the day population without drugstore, and 25% of the night population and 23% of the day population without child daycare services in their CT, no one would be left without opportunity if the night population scenario were applied. However, there are no more people with more than 8 drugstores in their CT, as they have been more equally distributed across the territory. The proportion of the population having more than 4 restaurants per squared kilometer would increase by 26% at night and by 14% at noon if the night population scenario were applied.

Scenario 2: Distribution of opportunities in proportion of the population at noon

In this section, the same analysis of opportunity density is conducted using the population at noon (scenario day pop). The next figure presents the distribution of the population at noon and at night per number of opportunities per 1000 people in CT, with the current distribution of opportunities and the day population scenario.

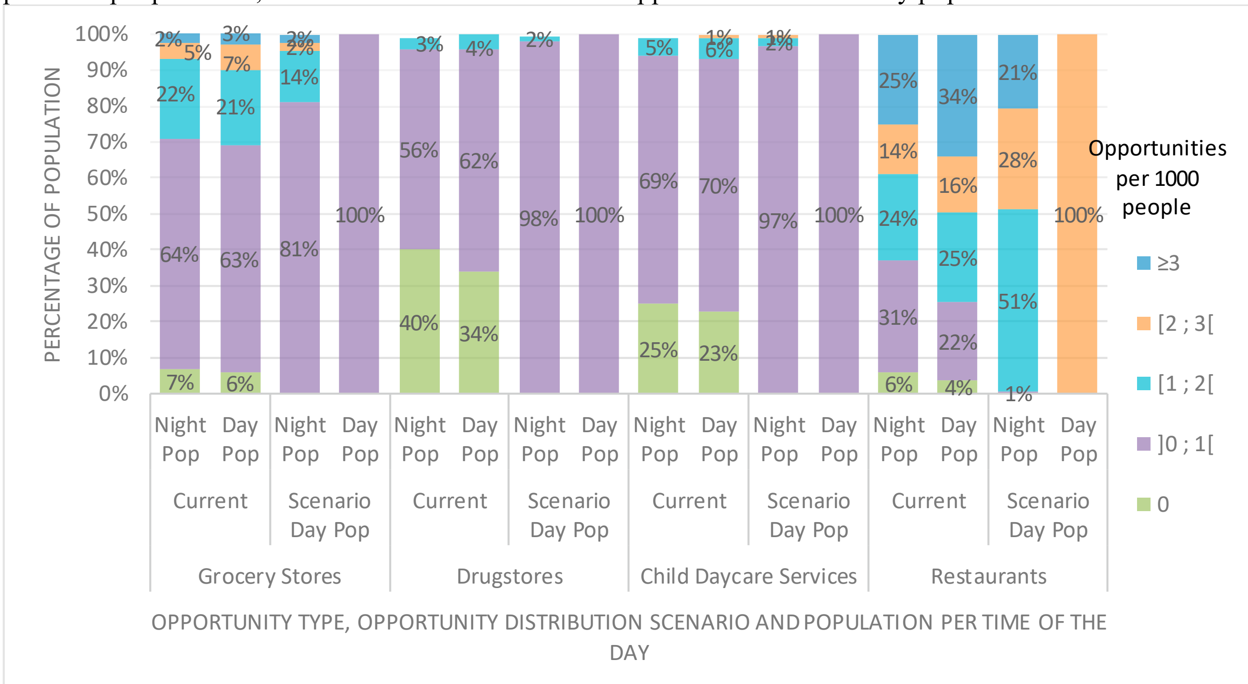

Fig. 11. Distribution of the population at night and at noon per opportunity density per 1000 people with the current opportunity distribution and the day population scenario.

This figure indicates that, when applying the day population scenario, there is opportunity density equity for the day population. Nevertheless, while the night population scenario offered opportunity density equity for drugstores and child daycare services, even with the day population repartition, it is not totally the case for the day population scenario. As such, with the day population scenario, the proportion of the night population having more than one drugstore or child daycare services per 1000 people is 2% and 3%, respectively. This indicates that the night population of the CT where there is a larger day population would enjoy higher opportunity density per 1000 people at night than the rest of the population if the day population scenario were to be applied. Concerning the restaurants, the day population scenario offers two to three restaurants per 1000 people at noon, while there is 52% of the night population having less than two restaurants per 1000 people. The figure below presents the proportion of the population at night and at noon per opportunity density per squared kilometer in the CT with the current opportunity distribution and the day population scenario.

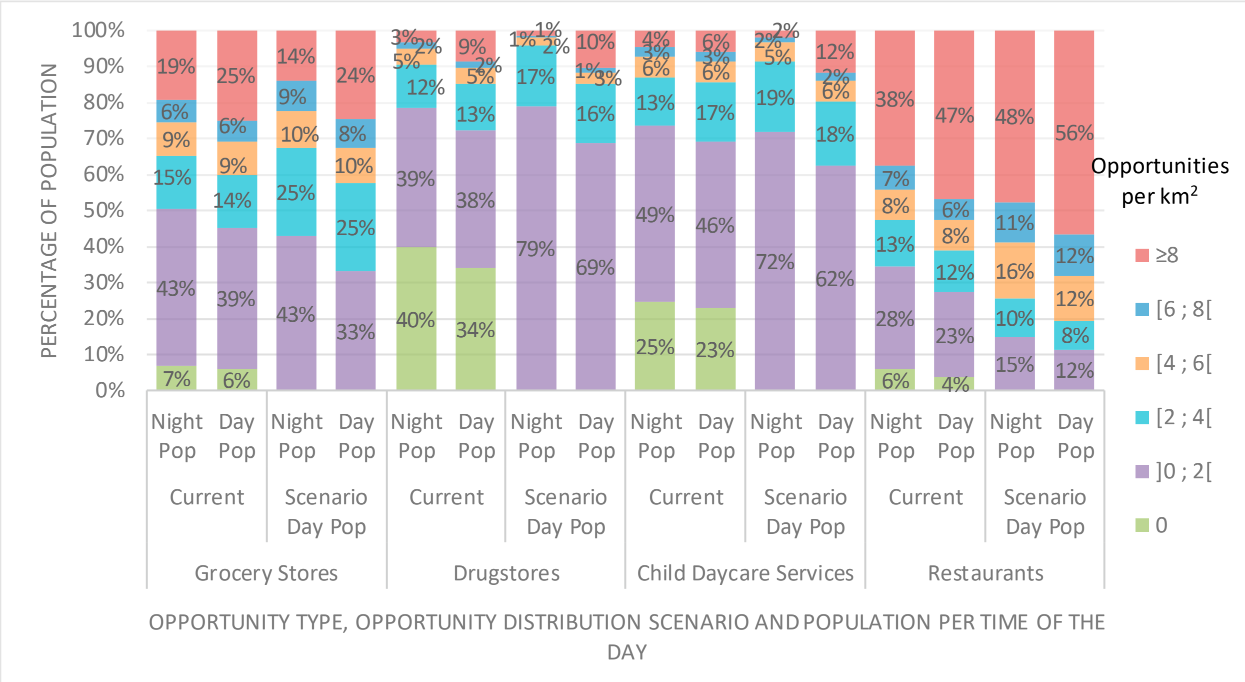

Fig. 12. Distribution of the population at night and at noon per opportunity density per squared kilometer with the current distribution and the day population scenario.

This figure indicates that, with the day population scenario, the percentage of the population having more than two grocery stores per 1000 people in their CT goes from 49% to 57% for the night population and from 54% to 67% for the day population. However, the percentage of the population having more than two drugstores per 1000 people goes from 22% to 21% for the night population, and from 29% to 30% for the day population. Concerning the proportion having more than two child daycare services, the proportion increases from 26% to 28% for the night population and from 32% to 38% for the day population. Regarding restaurants, the proportion of the population having more than four restaurants per 1000 people goes from 53% to 75% for the night population and from 61% to 80% for the day population. These numbers also indicate that the current distribution of opportunities resembles more to the distribution of the day population than the night population.

Calculated Variables

This section presents a summary of the variables calculated for this study. To ensure that the minimums obtained are not zero, but the minimal positive value, the results for the 913 CT where there is a population are shown in the table below.

Table 2. Description of the studied characteristics of CT in the GMA.

Variables			Min	Max	Mean	CV
Area of CT (km2)			0.04	275.03	4.68	319%
Population at night per squared kilometer			0.00	38.30	5.70	99%
Population at noon per squared kilometer			0.01	139.32	5.93	165%
Number of opportunities per km2	Grocery Stores	Current	0.00	150.72	7.10	166%
		Scenario Night Pop	0.00	33.88	5.05	99%
		Scenario Day Pop	0.01	123.23	5.25	165%
	Drugstores	Current	0.00	36.62	1.76	195%
		Scenario Night Pop	0.00	10.67	1.59	99%
		Scenario Day Pop	0.00	38.80	1.65	165%
	Child Daycare Services	Current	0.00	56.34	2.05	194%
		Scenario Night Pop	0.00	14.10	2.10	99%
		Scenario Day Pop	0.00	51.30	2.18	165%
	Restaurants	Current	0.00	754.99	23.23	256%
		Scenario Night Pop	0.01	106.36	15.84	99%
		Scenario Day Pop	0.02	386.85	16.47	165%
Number of opportunities per 1000 people at night	Grocery Stores	Current	0.00	40.94	1.17	180%
		Scenario Night Pop	0.88	0.88	0.88	0%
		Scenario Day Pop	0.22	75.87	1.31	319%
	Drugstores	Current	0.00	9.95	0.35	204%
		Scenario Night Pop	0.28	0.28	0.28	0%
		Scenario Day Pop	0.07	23.89	0.41	319%
	Child Daycare Services	Current	0.00	15.67	0.45	216%
		Scenario Night Pop	0.37	0.37	0.37	0%
		Scenario Day Pop	0.09	31.58	0.54	319%
	Restaurants	Current	0.00	304.85	4.53	390%
		Scenario Night Pop	2.78	2.78	2.78	0%
		Scenario Day Pop	0.69	238.17	4.11	319%
Number of opportunities per 1000 people at noon	Grocery Stores	Current	0.00	8.09	1.15	89%
		Scenario Night Pop	0.01	3.56	1.13	44%
		Scenario Day Pop	0.88	0.88	0.88	0%
	Drugstores	Current	0.00	3.36	0.32	130%
		Scenario Night Pop	0.00	1.12	0.36	44%
		Scenario Day Pop	0.28	0.28	0.28	0%
	Child Daycare Services	Current	0.00	4.93	0.44	124%
		Scenario Night Pop	0.00	1.48	0.47	44%
		Scenario Day Pop	0.37	0.37	0.37	0%
	Restaurants	Current	0.00	38.28	3.01	119%
		Scenario Night Pop	0.03	11.19	3.55	44%
		Scenario Day Pop	2.78	2.78	2.78	0%

As previously mentioned, this table underlines the fact that there is size heterogeneity in between the CT of the GMA, because the coefficient of variation for the area is high. Considering the number of opportunities per squared kilometer, the night population scenario offers the least variation for each type of opportunity. However, this scenario results in a reduction in the mean number of opportunities, because it implies that opportunities are more equally distributed across the GMA, as the night population is. Obviously, the variation is zero for the number of opportunities per 1000 people at a time of the day if the opportunities are distributed in proportion to that population. This table also highlights the fact that when applying the day population scenario, the coefficient of variation for the opportunity density per night population gets very high (319%). However, when applying the night population scenario, the coefficient of variation for the opportunity density gets relatively low (44%).

5.3. *Scenarios of restaurant closures*

This section presents the analysis of density of restaurants for the actual distribution and for two scenarios of 30% and 60% of restaurant closures, respectively. While the mean number of restaurants per CT is 11.6 with the actual distribution, it falls to 8.1 restaurants if 30% of them close and to 4.7 restaurants if 60% of them close. The figure below shows the distribution of restaurants per 1000 people with these three scenarios of restaurants per CT.

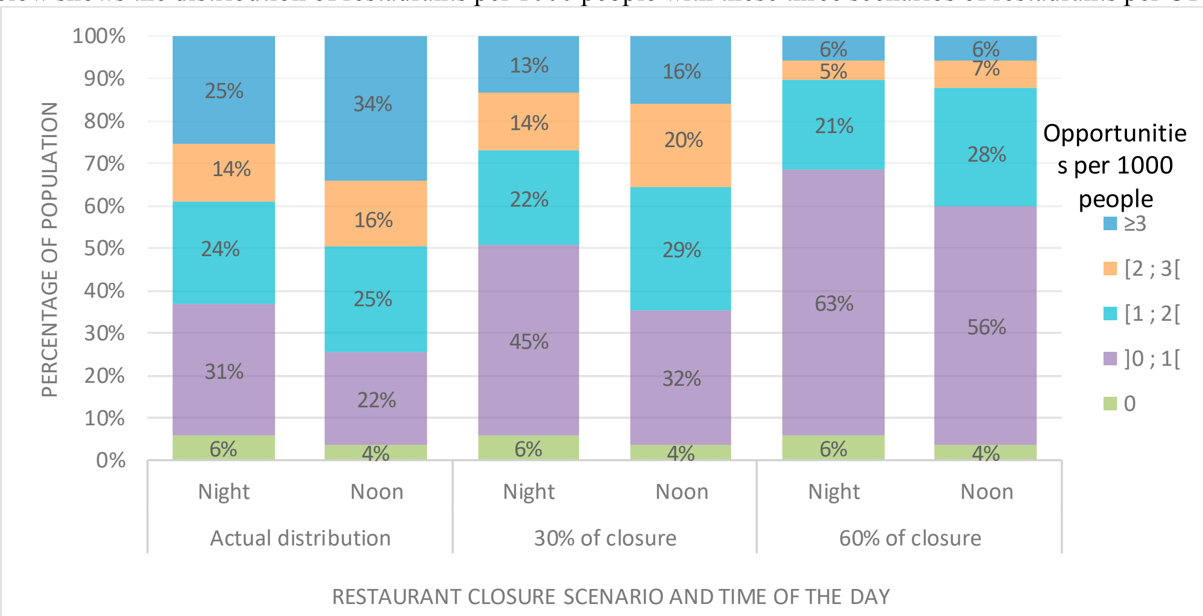

Fig. 13. Distribution of the population at night and at noon per restaurant density per 1000 people for the current distribution and two restaurant closure scenarios.

This figure indicates that the proportion of population having access to less than one restaurant per 1000 people increases when the proportion of closures increases, while the proportion of the population having access to zero restaurant in their CT stays constant. Indeed, the proportion of the population having less than one restaurant per 1000 people at night goes from 31% to 45% with 30% of closures, and to 63% with 60% of closures. For the day population, the percentage of the population having less than one restaurant per 1000 people at noon goes from 22% to 32% with 30% of closure and to 56% with 60% of closures.

The next figure presents the distribution of the population at night and at noon per restaurant density per squared kilometer for the three scenarios of restaurants distribution.

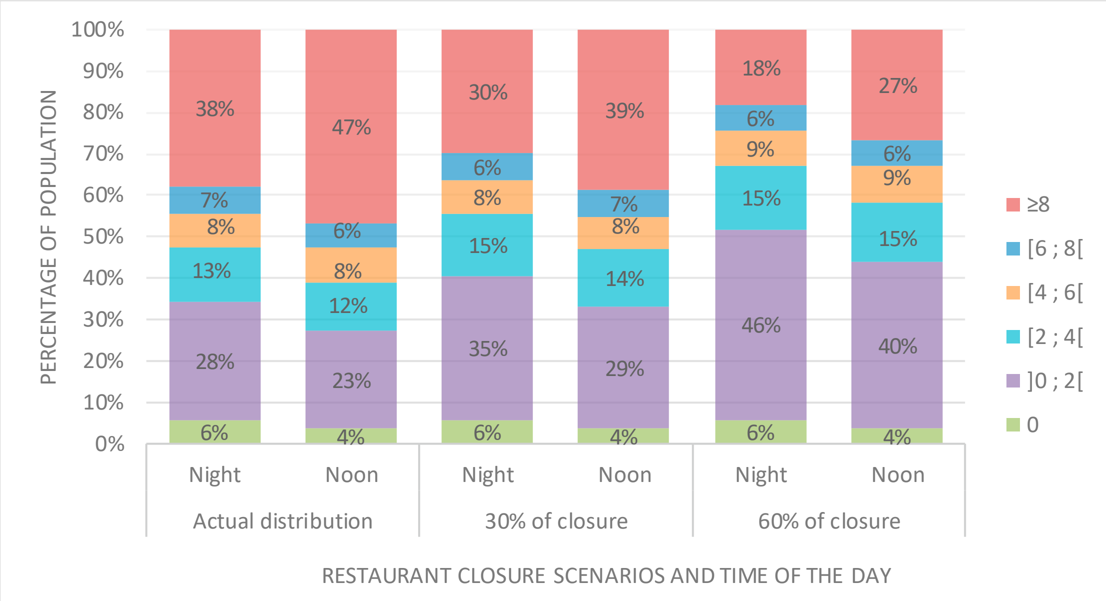

Fig.14. Distribution of the population at night and at noon per restaurant density per squared kilometer with the current distribution and two restaurant closure scenarios.

This figure shows that the proportion of the population in a CT where there are less than two restaurants per squared kilometer would increase by 7% at night and 6% at noon if there were 30% of restaurant closures and by 18% at night and 17% at noon if there were 60% of restaurants closures.

As factors can increase the risk of some sectors to be subject to closures, the next figure presents a choropleth map of a risk indicator multiplying the ratio of the day population over the night population and the number of restaurants per CT. The higher the value is, the larger is the risk of receiving less customers in a situation of increased virtualization of activities. The figure below underlines the places in the GMA where there are either many restaurants, much more people at noon than at night, or both. The higher risk regions correspond with the areas where the ratio of the day population over night population is higher, as shown in figure2.

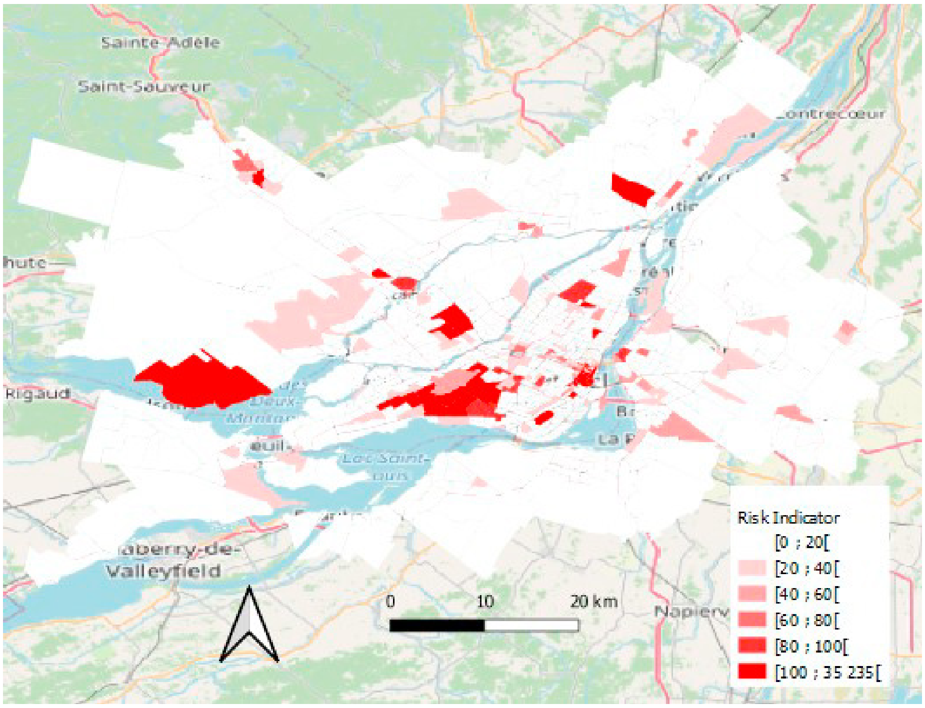

Fig. 15. Choropleth map of the restaurant closure risk indicator per CT.

6. Discussion

As previously mentioned, there is an important size heterogeneity among the CT of the GMA. This is due to the delimitations of the CT, which depends on the population density, and to the higher population density in downtown Montreal. This leads to smaller areas downtown and higher areas in periphery.

The results indicate that the current distribution of opportunities favor the day population distribution, particularly for restaurants, but also for the three other types of opportunities. The reason for this could be that the population usually shops or eats during lunch hour near their workplace or that shops are attracted by the large concentration of potential clients during the day. However, concerning the scenarios in proportion to the population, the results show that the opportunity density equity is greater with the night population scenario than with the day population scenario. Considering that the virtualization of activities would make the day population resemble more and more the night population, the results suggest that encouraging strategic planning oriented towards the population localization at night could be beneficial for the opportunity density equity. Furthermore, even if the population is more like the pre-confinement day population, the night population scenario increases opportunity density equity compared with the current distribution of opportunities, more than the day population scenario does for the night population distribution.

The results also show that, if scenarios of restaurant closures were to happen, the restaurant density per squared kilometer and per 1000 people could both decrease significantly. However, if such a situation were to happen, it could be beneficial on the long term for restaurant density equity to encourage the reopening of restaurants more proportionally to the night population.

6.1. Limitations

There are some limitations to this research. As we performed an aggregated method, there are border effects due to the delimitations of the CT we used. Also, the scenarios we tested are theoretical and aiming to help planning authorities understand the possible impacts of a planning strategy accounting for the population distribution, both at night and during the day. As such, we presented the density of opportunities, which does not consider the time or distance for the population to access these opportunities but gives an aggregated portrait of the area depending on the opportunity density per area and per population to service. Furthermore, we suppose that all opportunities of the same type are equivalent in the fulfilment of the needs of the population, but this is not necessarily the case as a person can have more restrictive preferences and needs. We also suppose that the restaurant closures would happen uniformly across the GMA for simplification, but this is not true as factors can increase the risk of closure. Also, we did not consider the increase in e-shopping and delivery than can result from the COVID-19 situation.

6.2. Perspectives

To refine the temporal component of this study, it would be interesting to calculate the total sum of person-hours per census tracts. Subsequently, it would be possible to randomly choose a percentage of the activities to be virtualized, which would correspond to a certain proportion of person-hours per CT. This method permits to consider that activities of different length are not equivalent. Furthermore, to refine the spatial component of this paper, it would be interesting to repeat the methodology at a finer level of aggregation. It would also be possible to reduce border effects by evaluating the difference in the results with sensitivity analysis by shifting zones, as recent researchers have done (Mageau-Béland,2019).

7. Conclusion

This paper evaluated the current distribution of some local opportunities throughout the GMA, using an aggregate approach at the CT level. The results indicate size heterogeneity amongst the CT, and higher concentrations of population in downtown and some periphery areas during the day. Also, the variation in the population per CT is greater at noon than at night, because of large concentrations of people in some CT due to their daily activities. The main contributions of this study are the investigation of the differences between the day and night population in an area as well as the adequacy between these populations and spatial distribution of opportunities. Furthermore, we presented the results of opportunity density for two theoretical scenarios of opportunity reallocation, which are the distributions in proportion to the night and day populations. While these scenarios do not correspond to real accessibility by the population, they present the possible impacts in opportunity density equity that can be attained if strategic planning was implemented. The results show that the night population scenario increases opportunity density for every type of opportunity and even for the day population distribution, which is not necessarily the case for the day population scenario.

We also evaluated the potential impacts of restaurants closure if the closures happen uniformly across the CT. Currently, the mean number of restaurants per CT is 11.6, but it could fall to 4.7 if 60% of restaurants closed, as was predicted by a survey under the assumption that confinement lasts until 2021 (ARQ,2020).

Further research could repeat the process at a finer level of aggregation, for example at the level of the dissemination area of the Canadian Census. It would also be possible to test more scenarios improving accessibility for the population, e.g. following sufficientarism principles, by adding opportunities where they are most needed until a sufficient threshold is attained everywhere. It could also be interesting to evaluate more scenarios that are plausible for the future, e.g. different scenarios of virtualization of activities using the total sum of person-hours in an area.

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