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Access to urban activities during the Covid-19 pandemic and impacts on urban mobility: The Brazilian context

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ABSTRACT

Social distancing has been adopted as a strategy to contain the advance of the pandemic until specific solutions to combat the virus are available. Many economic sectors and social activities need to continue despite the viruses, and most social distancing policies disregard individual choices, resulting in greater or lesser adherence to isolation. In this paper, we characterize the differentiation of access to essential activities within Brazilian cities during social distancing and the intention to maintain behavior changes concerning these activities in the post-pandemic period. The results showed that the behavior regarding essential activities during the pandemic is not independent of variables associated with pre-pandemic travel patterns, isolation conditions, and socioeconomic factors. Post-pandemic intention proved to be statistically dependent on factors associated with the activities' characteristics and experiences during the pandemic. Accessibility-oriented planning can guide urban and transportation policies more equitably through the identification of the most affected groups by activity disruption. At the same time, the incorporation of new routines less dependent on displacement offers opportunities to review public space.

1. Introduction

Since January 2020, a significant challenge has emerged globally: the need to overcome the Covid-19 pandemic caused by the SARS-CoV-2 coronavirus. Transmission is deeply affected by environmental, social and economic issues (Batty, 2020) and several studies have shown that reduced contact among people contributes to reducing the rate of infection transmission and can slow down epidemics if started quickly and maintained for a relatively long period (Kelso et al., 2009). Therefore, non-pharmaceutical interventions (NPIs) have been adopted as the primary strategy to contain the advance of the epidemics until specific solutions to fight the virus are available. In several cities around the world, public authorities have adopted restrictive measures to reduce this rate, preventing health systems from collapsing. These measures, which can be adopted at different levels of flexibility culminating in lockdown, include the cancellation of events that promote agglomeration of people, the closure of schools and commercial activities, the limitation of people’s freedom to leave their homes and, as a consequence, the need to institute teleworking in different production sectors.

This phenomenon, on a large scale, had never been experienced before by this generation. Many economic sectors and social activities need to be sustained despite the pandemics and, frequently, policies that promote social distancing disregard individual choices and behaviors, resulting in greater or lesser adherence to distancing, and consequently affecting the evolution of the epidemic (Batty, 2020). In the long term, economic impacts might affect job opportunities and enhance inequalities regarding access to urban functions. Additionally, during the pandemic, government policy needs to be changed within days or even hours, and, therefore, demands frequent information on the behavior of the population (Montaceu, 2020).

All over the world, mainly in urbanized areas, significant differences in the levels of social distancing, transmission rates, and severity of COVID-19 infections are perceived among different population groups. The urban structure, socioeconomic, and demographic attributes contribute to this differentiation (Atchison et al., 2020; Bezerra et al., 2020; Canning et al., 2020) and are essential components of the access to fundamental urban activities such as housing, work, education, and food consumption. In cities of countries with significant inequalities, such as the ones in Brazil, these different accessibility levels and response to the pandemic are even more evident among social strata.

Most of the research on the investigation of NPIs concerning the urban issues for containing the spread of COVID-19 focuses on the
changes in the mobility of people on urban and regional scales (Candido et al., 2020; Enrique and Aragon, 2020; Ghader et al., 2020; Warren and Skillman, 2020). The data sources considered in these studies are mostly secondary data, such as high-frequency information - mobility data from mobile operators, social networks, energy consumption, for instance (Huang et al., 2020; Oliver et al., 2020; Warren and Skillman, 2020). The reduction of movements to reach essential and non-essential functions, reflecting social distancing and changes on mobility levels, are considered as a proxy of the economic contraction during the pandemic (Bonaccursi et al., 2020). Nonetheless, some social groups can maintain access to these functions at some level even after isolation, depending mostly on the economic capability of the household, and the relative location and connectivity among residential units and functional destinations. The characterization of perception and individual attributes that contribute to social distancing needs to be investigated to support immediate changes on policy to contain the virus (Bezerra et al., 2020; Canning et al., 2020; Dietrich et al., 2020). In countries with structural inequalities, such as Brazil, primary data on individual characteristics and behavior becomes even more relevant to reduce social and economic exclusion in policy-making.

In this paper, we characterize the perceived access to essential activities (work, study, consumption of essential and general goods, and service demand) within Brazilian cities before and during social distancing. Also, we have developed a descriptive analysis of the intentions to maintain, in the post-pandemic, the measures adopted to perform these activities during the social distancing. For that, we have investigated: (i) changes on habits during the social distancing concerning work, study, consumption, and use of service; (ii) changes on travel patterns to perform these activities; and (iii) different intentions concerning the maintenance of habits in the post-pandemic period. For that, we have considered different social strata and confronted a baseline scenario with the social distancing context caused by the pandemics, through the collection and analyses of primary data.

This study brings a phenomenological contribution since it characterizes behavioral changes during the pandemic and the intentions in the post-pandemic period concerning access to essential urban functions in Brazilian cities. The analyses were carried out considering the need to discuss the access to opportunities as one main urban planning goal, in opposition to the isolated provision of mobility. The results can subsidize the assessment of the social distancing impacts on cities. Identifying which groups may be more likely to change their post-pandemic displacement patterns will help drive demand management policies. Also, identifying which variables interfere in this process may support the targeting of resources and efforts to provide the necessary support for access to urban activities from a less traveling-dependent perspective.

2. COVID-19 impacts on urban life

Despite the methodological and empirical limitations, the available studies on Non-pharmaceutical interventions (NPIs) indicate that such interventions are still the best alternative for reducing transmission of COVID-19, at least until vaccines and pharmaceutical solutions are broadly available (Askitas et al., 2020; Atchison et al., 2020; Batty, 2020; By and Parkins, 2020; Candido et al., 2020; Enrique and Aragon, 2020).

NPIs have been, therefore, considered in different countries to contain the transmission of the new coronavirus (SARS-CoV-2). As a result of these interventions, economic and social activities, which are part of the routine in urban areas, have been modified, culminating in the ceasing of retail, leisure and school activities and barriers in local and regional scale. The result is an unprecedented economic disruption in scale and speed never experienced before (Chen et al., 2020), compromising the performance of global supply chains, affecting companies across the globe, and provoking massive unemployment. Consumers’ habits have also been altered through the adoption of different consumption patterns (Fernandes, 2020).

Some recent studies have presented analyses of the effects of NPIs, especially in those countries that have already reached the peak of the diffusion curve (Chen et al., 2020; Flaxman et al., 2020; Ugur, 2020). Other present aggregated analysis concerning the economic impacts of the pandemic in the country level (Askitas et al., 2020; Bonaccursi et al., 2020; Chen et al., 2020; Fernandes, 2020; Mckibbin and Fernando, 2020). Scientific research on the effects of NPIs concerning SARS-CoV-2 includes epidemiological studies such as backward analyses of deaths and transmission rates (Flaxman et al., 2020) and the comparison between administrative measures and voluntary isolation (Chen et al., 2020; Correia et al., 2020; Morales, 2020; Warren and Skillman, 2020; Yan, 2020).

Studies that aimed at understanding changes in travel behavior are being developed in several countries in order to guide future mobility policies. Reduction in the use of public transport and preference for the use of individual private transport has been noticed (Abdullah et al., 2020; Muley et al., 2020) and walking and cycling should be encouraged as important ways to maintain satisfactory levels of health and well-being (De Vos, 2020; Shamshiripour et al., 2020). Also, change in primary purpose of traveling was observed due to the pandemic (Abdullah et al., 2020). The air transport and tourism sector were noted to be the hardest hit and may recover slowly (Muley et al., 2020). Studies on past epidemics corroborate these results (Muley et al., 2020), further indicating that factors such as risk perception (Rubin et al., 2009; Cahyanto et al., 2016), fear, socioeconomic aspects, routine flexibility, and regional characteristics can influence travel behavior (Kim et al., 2017).

Some researchers have tried to explore whether these changes will persist afterward or will bounce back to the pre-pandemic situation (Shamshiripour et al., 2020; Haas et al., 2020). The economic and social shock caused by distancing can reshape the perception of individuals and companies about the value and status of work, resulting in changes in supply and demand for labor activities (Wyplosz, 2020). Moreover, the experience of telework can change the engagement in this type of solution in a permanent way (Haas et al., 2020), also impacting mobility in urban areas. However, a potential for increasing inequalities in occupational segmentation that allows access to telework is identified, considering income, gender, race, and ethnicity differences (Kramer and Kramer, 2020). The impacts of social distancing have also been investigated in recent research to understand educational access and inequality (Cullinane and Montacute, 2020; Montacute, 2020).

Even though effective, measures related to social distancing practices might reach a plateau, suggesting that those who could not or did not want to stay home will not respect normative government actions, making NPIs less effective (Ghader et al., 2020). Several characteristics can influence this behavior. High-income tracts in the United States, in comparison to lower-income populations, presented higher social distancing index, higher percentage staying home, fewer miles traveled, less trip rate, less work trip rate, and less non-work trip rate (Sun et al., 2020). These results point out that research that focuses on attributes related to economic inequalities are necessary to understand the effectiveness of NPIs measures and guide public agents.

The investigation of the socioeconomic impacts of COVID-19 in developing countries is still scarce, both because of low investment in scientific research and due to the need for more information in order to develop conclusive observations appropriately. When available, the geographical scope of the data is limited and the information aggregated (Lai et al., 2020; Sumner et al., 2020). For developed countries, disaggregated data is more accessible and allows both investigations regarding economic impacts on city-scale (Aitkson, 2019) and research on pharmaceutical and medical impacts of the pandemic (Flaxman et al., 2020; Toda, 2020).

In general, high-frequency indicators are essential for policy-makers to evaluate the effectiveness of containment measures of COVID-19 in shorter time frames. Aggregate measures of economic activity may not
be sensitive to changes in the guidelines for inducing behavioral changes over the course of a pandemic. Thus, high-frequency data and indicators such as Google Community Mobility index (Google, 2021), Mobility Trends Reports (Apple, 2021) and Data for Good (Facebook, 2021), along with energy consumption and emergency economic assistance, are considered adequate proxies of economic activity (Bonaccorsi et al., 2020; Chen et al., 2020).

Movement data from mobile operators and social networks, even though allowing the assessment of NPIs by public agents and economic declines associated with distancing, have not been broadly used. Individual privacy issues coerce the publishing of aggregated data, diminishing analytical capability (Oliver et al., 2020). Another caveat of using mobile and smartphone app data for short or long-term planning is the bias concerning mobility information. This bias is mostly related to economic inequalities among population strata, concerning both differences on access to mobile and internet services and different levels of access to essential urban functions, not represented by mobility and connectivity information. In other words, public policies, investment, and immediate actions based on the measurement of movement do not necessarily reflect access to essential activities and services in order to sustain the urban way of life. Mobility measures are related to speed and coverage, and usually disregard or reduce the importance of non-motorized modes, focusing on increases of vehicle traffic, which can result in reductions in walkability, livability, and access to essential urban functions (Cui et al., 2019; 2018; Deboosere et al., 2018; Farber et al., 2015; Garcia, 2016; Garcia et al., 2018; Geurs and van Wee, 2004; Lopes et al., 2020; Pritchard et al., 2019; Tomasiello et al., 2020).

Generally, different population groups face different challenges and opportunities concerning the adherence to social distancing and contamination risk, which are disregarded when the data and analyses supporting decision is oriented to mobility.

On the long-term planning, the focus on mobility stimulates distance increase between activities, advocating speed at the expense of access and, even though it may result in increases in the quality of travel, it also may collaborate to the reduction of accessibility, generating inequalities in access to essential urban functions among different socioeconomic groups (Banister, 2011; Pereira et al., 2017, 2019).

To reduce the bias in the analysis founded on mobility data, information regarding the spatial structure of functions and the connectivity among these functions can help the characterization of the interaction potential (accessibility), which differs in space and among population strata (Levine et al., 2019). Accessibility should be the goal in urban planning in the long term and on urgent measures to contain the COVID-19 transmission to reduce inequalities concerning risk exposure and transmission rates.

3. Material and methods

In order to identify the differences in access to essential urban functions, we followed three steps for the methodological analysis:

3.1. Data collection and characterization of the sample

We have collected data through a web-based survey in April and May. We have gathered 211 responses in 10 days in April and 314 responses in 4 days in May, considering that most of the web-based surveys are completed within the first days (Granato and Wheaton, 2004). Responses about the location and movement patterns before and during the pandemic and different socioeconomic characteristics were computed from seventy-four Brazilian cities.

In this analysis, two variables were explored to understand the behavior of the population and the respective intention to maintain the new experiences provided by the social distancing: (i) the possibility to perform essential activities without travel, with changes in the usual routine; (ii) the intention to maintain the changes, aiming some or full reduction of displacements after the pandemic. We then related these variables to activity characteristics and mobility patterns for work, education activities, consumption, and service activities. We have grouped the variables in four factors: (i) reason (work, study, shopping, service); (ii) displacement pattern (travel frequency and mode of transportation); (iii) isolation condition (belonging to a risk group, permanence in social distancing, time from the start of social distancing); (iv) size of the city, represented by the number of inhabitants. For the questionnaire applied in May, we also included socioeconomic characteristics: gender, schooling, revenue, revenue changes during pandemics, and age.

3.2. Statistical analysis of the relationships among categorical variables and changes or intentions from the pandemic

As the methodological approach for the exploratory analysis, the statistical test chi-square of independence was performed among variables to analyze the factors associated with the behavior of the Brazilian population during social distancing demanded to control the Covid-19 diffusion. This test is consolidated and thoroughly applied in the literature to analyze relationships between categorical variables (Bezerra et al., 2020; Cools and Creemers, 2013).

The Pearson statistic \( \chi^2 \) is defined by Equation (1):

$$
\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{l} \frac{(n_{ij} - \mu_{ij})^2}{\mu_{ij}}
$$

where \( n_{ij} \) concerns the observed frequency in the cell (i, j), which is calculated by multiplying the observed chance by the sample size, and \( \mu_{ij} \) is the expected frequency for each cell (i, j). When the variables are independent, \( \chi^2 \) has an asymptotic distribution with \((k - 1)(l - 1)\) degrees of freedom. The test assumes that at least 80% of the cells have expected frequencies of 5 or more. When this assumption was not met, modifications of the answer categories are performed to ensure that this criterion is satisfied (Cools and Creemers, 2013).

When the sample is not large enough to perform the Chi-square test (the expected values for at least of the cells in the contingency table is lower than 5), the Fisher’s exact test was the choice (Bower, 2003). The Hypotheses for Fisher’s exact test are the same as the Chi-square test. Both tests were implemented through R 4.0.

3.3. Characterization of behavior changes during the pandemic and intentions post-pandemic

For the variables whose hypothesis of independence was rejected by the Chi-square Test, a descriptive analysis was made in order to observe the differences between categories. This analysis allowed identifying how different stratus were affected in relation to i) changes in behavior concerning work, study, purchases and services activities, and ii) intention to maintain post-pandemic changes for work, study, and essential goods purchases.

For behavior changes during the pandemic, three categories were considered: i) no changes, which means that the activity was performed in the usual way, maintaining ordinary trips; ii) not performed, refers to cases where the activity was interrupted, voluntarily or not; and iii) performed with changes, for cases where the activity was performed without travel, by any remote means. For general consumption and service, the responses concerned the trip frequency changes during pandemic compared to the routine before social distancing. There were three categories: i) higher frequency, ii) lower frequency, and iii) no changes.

For intentions concerning behavior after the pandemic, the respondents manifested the willingness to maintain the changes adopted during the pandemic. For work and study activities, the answer could be i) contrary, ii) favorable, or iii) no autonomy to take this decision. For essential consumption, the respondents could state i) contrary, ii) favorable or iii) no trips necessary, to identify when they had not could perform the activity without displacement.
4. Results

These are exploratory results for an initial understanding of the accessibility phenomenon before and during the social distancing.

4.1. Characterization of the sample

The sample gathered does not represent the whole Brazilian context, nor the strata and categories analyzed. We have obtained a significant number of responses for each category of the variables studied, which allows us to perform comparative analyses between them. Table 1 shows the profile of the sample (65% of the respondents live in cities with more than 1 million inhabitants, 45% belong to the risk group or live with a person in this group, 100% are experiencing some degree of social isolation). Concerning the work status, the categories with the highest number of respondents were private-sector workers (28%), public employees (22%), and self-employed professionals (20%). Regarding students, 37% were in undergraduate courses, 27% in graduate programs, and 16% declared other education activities.

Concerning the trip patterns (Fig. 1), even though trips for all motives have considerably reduced, trips for work and educational purposes have suffered the most considerable reduction in frequency. It is possible to see a reduction in the use of public transport in all types of travel and an increase in travel on individual motorized modes.

Despite the reduction considering respondents’ movements, 68% could carry on work activities alternatively, which means without travel, and 45%, education activities. From all respondents, 45% are contrary to maintaining the alternatives to perform work activities adopted during social distancing after this period, and more than 58% are not willing to keep education alternatives after the pandemic is over (Table 2). Among those who declared not having the autonomy to decide, most are in favor of maintaining, at least partially, work (88%) and study (53%) activities changes experienced during isolation. Regarding trips for purchase and service, the majority of respondents revealed to have carried out the activity with some routine change, either by changing the frequency of trips or by carrying out the activity without traveling. Also, there is a position contrary to the maintenance of activities carried out at a distance for purchases of essential products (51%), revealing greater difficulty in adapting to remote environments of this type of activity.

4.2. Statistical analysis of the relationships among categorical variables and changes or intentions from the pandemic

In Table 3, from the Chi-square tests, there cannot be assumed that work behavior is independent of the activity status, the frequency of trips, and schooling. Similarly, educational activities are not independent of these same variables and also of the social distancing status, time of data collection, transport mode, income, and age. For the activities of consumption of essential goods, the behavior during social distancing revealed not to be independent of risk and social distancing levels. The relationship between general consumption habits and the categorical variables travel frequency, transportation mode, education status, schooling, income, and age were statistically significant. The behavior concerning access to service was not independent of the level of social distancing, education status, trip frequency, and gender.

The intention to maintain alternative solutions for work and study after the pandemic are both statistically related to the activity status, time of data collection, and behavior changes, meaning that both perspectives depend on the experiences of the respondents during the social distancing. For work activities, the respondents’ intentions are also related to trip frequency. The level of social distancing was the only

Table 1
Survey respondent characteristics.

| Factor          | Variable      | Categories               |
|-----------------|---------------|--------------------------|
| Size of city    | Size of city  | up to 1 million          |
|                 |               | more than 1 million      |
| Isolation       | Level of risk | no                       |
|                 |               | yes                      |
| Isolation       | partial       | Yes                      |
| Activity        | Work status   | internship               |
|                 |               | no job                   |
|                 |               | other                    |
|                 |               | private employee         |
|                 |               | public employee          |
|                 |               | self-employee            |
| Trip patterns   | Trip frequency| less than three times per|
|                 |               | daily                    |
|                 |               | 3-6 times per week       |
|                 | work          | 14%                      |
|                 | education     | 50%                      |
|                 | consumption*  | 77%                      |
|                 | service*      | 84%                      |
|                 | other         | active                  |
|                 | mode          | transit                  |
|                 | work          | 2%                       |
|                 | education     | 1%                       |
|                 | consumption*  | 0%                       |
|                 | service*      | 0%                       |
|                 | other         | 6%                       |
|                 | mode          | 11%                      |
|                 | work          | 14%                      |
|                 | education     | 8%                       |
| Socioeconomics*| Gender        | other                    |
|                 |               | man                      |
|                 | Age           | < 30                     |
|                 |               | 30-39                    |
|                 |               | 40-49                    |
|                 |               | 50-59                    |
|                 |               | > 60                     |
|                 | Schooling     | Bachelor's degree        |
|                 |               | high school              |
|                 |               | master or doctorate      |
|                 | Individual income| < 1,500               |
|                 |               | > 10,000                 |
|                 | Revenue situation| income loss             |
|                 |               | no change                |
|                 |               | other                    |
| Socioeconomics*| Individual income| < 1,500               |
|                 |               | > 10,000                 |
|                 | Revenue situation| income loss             |
|                 |               | no change                |
|                 |               | other                    |

* Responses collected only on May.
related variable to the consumption of essential goods, among those investigated.

In Fig. 2, we present a summary of the p-values for Chi-square tests regarding the statistically significant relationships among (a) categorical variables and behavior changes; (b) categorical variables and intention after the pandemic. The analyses, as presented in the methodological section of this paper, were performed considering a confidence level higher than 95%. We highlight that information about intention concerning general consumption and service were not gathered and, therefore, are not presented in Fig. 2.

4.3. Characterization of behavior changes during the pandemic and intentions post-pandemic

A descriptive analysis of the variables whose hypothesis of independence was rejected by the Chi-square Test is presented, in order to observe the differences between categories.

4.3.1. Behavior changes during the pandemic

Regarding the professional status, among the self-employed, a lower portion of workers have managed to maintain work activities during social distancing (Fig. 3a). Among employees in the private sector, most have managed to maintain activities, but 75% of these workers performed the activities in an alternative manner. Among those who went to work less than three times a week (Fig. 3b), the percentage of people who did not change their work routine during the pandemic (42%) was higher than among those who went more frequently (3–6 times per week 13% and daily 7%). Still, most of the trips with frequency varying from three to six times per week and daily were performed with changes for 73% of the respondents in these groups.

Workers with a bachelor’s degree (Fig. 3c) were the ones with the highest proportion of interrupted work activities (28%). Respondents who presented the highest proportion of work activities performed with no changes were those with less schooling (high-school 22%).

Education activities were mostly performed with changes (45%) or not performed (43%) during social distancing. Only 12% of these activities were held with no changes during social distancing and the proportion of respondents who declared that performed educational activities with some changes were higher for those in total social distancing (51%) and lower for the people in partial distancing (38%) (Fig. 4a). The balance between not performed and performed with changes was altered from April to May (Fig. 4b). In April, 58% of the students performed educational activities with some changes, and in May, only 39%, enhancing the proportion of students not performing the

![Fig. 1. Trip patterns.](image-url)

Table 2
Behavior changes during pandemics and intention after pandemics.

| Factor          | Variable | Categories         | no changes | not performed | performed with changes | higher frequency | lower frequency |
|-----------------|----------|--------------------|------------|---------------|------------------------|------------------|-----------------|
| Variable investigated | Behavior | work               | 15%        | 17%           | 68%                    |                  |                 |
|                  |          | education          | 12%        | 43%           | 89%                    |                  |                 |
|                  |          | essential consumption* | 9%        | 2%            |                        |                  |                 |
|                  |          | general consumption** | 12%        | 27%           |                        |                  |                 |
|                  |          | service**          | 12%        | 27%           |                        |                  |                 |
| Intention        | contrary | work               | 45%        | 20%           | 35%                    |                  |                 |
|                  | favorable| education          | 58%        | 13%           | 29%                    |                  |                 |
|                  |          | essential consumption* | 51%        | 39%           |                        |                  |                 |

* Responses collected only on April.

** Responses collected only on May.
activities, from 32 in April to 49% in May.

Regarding the study routine (Fig. 4c), most of the undergraduate students (64%) had the activities interrupted, either by the pause promoted by the educational institution or voluntarily. The typical profile of undergraduate students is those with secondary schooling level and under 30 years-old. The proportion concerning the maintenance of studying activities performed remotely was higher among graduate students (63%).

Respondents that had low-frequency trips for studying (Fig. 4d), as well as for work activities, were the ones that maintained, individually, a higher proportion of traveling without routine changes (23%). No daily trips and only 5% of the trips with frequency from 3 to 6 days per week were performed without changes. For public transport users (Figs. 4e), 61% of respondents were unable to maintain education activities, and this proportion was higher in comparison to users of individual modes of transport (45%). 71% of the trips by active modes were performed with changes. Students with lower income and age were also more impacted, representing 69% and 67% of the pupils not able to perform activities, respectively (Fig. 4g and h).

Purchases of essential products (Fig. 5) were carried out predominantly in an alternative way, unregarding the risk level (no risk 90% and risk 86%). 7% of the people in risk groups (or with a person in the

Table 3
Chi-square analysis between contributing attributes and activities.

| Variable                        | Work     | Education | Essential Consumption* | General Consumption** | Service*** |
|---------------------------------|----------|-----------|------------------------|-----------------------|-----------|
|                                 | p-value  | X²        | p-value                | X²                    | p-value   |
| Size of city                    | 0.233    | 2.9       | 0.657                  | 1.0                   | 0.181     |
| Level of risk                   | 0.109    | 4.4       | 0.026                  | 7.3                   | 0.037     |
| Social distancing               | 0.866    | 0.3       | 0.029                  | 7.1                   | 0.047     |
| Time                            | 0.164    | 3.6       | 0.008                  | 9.7                   |           |
| Work status                     | 0.023    | 11.4      | 0.140                  | 6.9                   | 0.764     |
| Education status                | 0.510    | 3.3       | 0.000                  | 38.4                  | 0.409     |
| Trip frequency                  | 0.000    | 39.1      | 0.000                  | 44.5                  | 0.846     |
| Transport mode                  | 0.217    | 5.8       | 0.004                  | 15.4                  |           |
| Gender                          | 0.877    | 0.3       | 0.118                  | 4.3                   | 0.211     |
| Schooling                       | 0.022    | 14.8      | 0.044                  | 29.8                  | 0.005     |
| Income                          | 0.134    | 9.8       | 0.000                  | 48.0                  | 0.053     |
| Income pandemic                 | 0.185    | 3.4       | 0.998                  | 0.004                 | 0.415     |
| Age                             | 0.313    | 9.4       | 0.001                  | 42.2                  | 0.007     |

Fig. 2. Chi-square p-value for dependent variables concerning behavior changes (a) and intention post-pandemic.

* Responses collected only in April
** Responses collected only in May
household in risk) (Fig. 5a) have had halted essential goods purchase. 3% of the consumers in the total social distancing did not perform purchases of these products. Also, 81% of people in partial isolation and 91% in total isolation consumed essential products in an alternative way (Fig. 5b).

Only 5% of transit users increased the frequency of shopping trips for general goods, and 57% did not change this rate of recurrence (Fig. 6a). For active (51%) and individual motorized modes (48%), theses trips were mostly reduced in frequency. Relatively to other behavior changes, active modes were the ones that presented the highest proportion of increased frequency (27%). This behavior should be further investigated but may be associated with increased purchases from neighbor establishments, often characterized by smaller enterprises and less product diversification. Respondents who performed low-frequency trips for shopping (general goods) presented the highest proportional increment of frequency (27%). This behavior was more frequent among students (Fig. 6b). At least 83% of the trips more frequently performed on a routine basis had their frequency reduced.

Undergraduate students (Fig. 6c) were the ones that mainly maintained the routine regarding the purchase of general products during the pandemic (51%). The groups of respondents with higher schooling levels (Fig. 6d) – master or doctorate (34%) and pg diploma (38%), higher income levels (Fig. 6e) – from 5 to 10 thousand reais and income higher than 10.000 reais (less than 35% both), and older respondents (Fig. 6f) – from 50 to 59 and older than 60 (less than 33%), represented a lower proportion of no changes concerning general goods shopping habits, showing more flexibility while performing this purchasing activity.

The reduction in the frequency of trips to access services (Fig. 7a) was the primary behavior among different social distancing groups; respondents in partial isolation (63%) and total isolation (79%). Undergraduate students (Fig. 7b) were the people that presented the highest proportion of unchanged behavior (36%), but all categories of students mostly lowered trips for service purposes. Concerning the trip frequency (Fig. 7c), all groups of respondents have mostly lowered the frequency. Aligned with general product consumption trips, service ones with the lowest frequency in the routine presented the highest proportion of no changed behavior (31%). Regarding gender-biased behavior (Figs. 7d), 74% of the women reduced the frequency of trips to service access in contrast to men, whose frequency reduction was carried out by 59% of respondents.

4.3.2. Intentions concerning behavior after the pandemic

Regarding the intention to change behavior after the pandemic, it was observed that variables related to the characteristics of the activity might be more influential than socioeconomic variables. The situation experienced in performing these activities in a new routine is then more decisive for the permanent adoption of behavior.

Considering the intention to maintain the solutions for working activities adopted during the pandemic, in April (Fig. 8a), the majority of respondents declared having no autonomy to decide (49%). There is an increase in the proportion of respondents opposed to maintaining alternative solutions from April (28%) to May (52%), which reassures the statistical relationship between perception of solutions and time in social distancing.

Also, self-employed workers (Fig. 8b) presented the highest declared autonomy while deciding to keep the solution adopted to work during social distancing (83%) and the highest proportion of workers that are contrary to maintaining the solution (50%). Private workers have the lowest proportional autonomy to decide (53%), and, among these, 31%
intend to keep the changes after the pandemic. Still, in relation to work, the respondents who stated that they often travel three to six times a week for this activity are the group with the least autonomy to decide if maintaining the solution adopted throughout the pandemic (43%) and are also the group with the highest proportion of workers that are favorable to maintaining the solution. The workers who carried out activities with some routine change along the social distancing were also those with less autonomy in deciding how to maintain these changes (40%). Most of the workers who did not experience changes during the pandemic are against maintaining any adjustments after this period (73%).

The intention to maintain solutions for performing educational activities without displacement after the pandemic is dependent on the city size. The proportion of respondents in favor of maintaining activities is higher in larger cities (20%) as opposed to cities with less than one million inhabitants (8%) (Fig. 9a). Between April and May (Fig. 9b),
the proportion of people willing to maintain the solution fell from 25% to 9%, and people against increased (35%–65%). According to Fig. 9c, postgraduate students are those with the highest proportion of respondents favorable to keeping educational solutions (25%). As for work activities, among people who performed study activities by alternative means (Fig. 9d), there is the highest proportion of people favorable to maintaining the changes (20%).

Considering the intention to maintain alternative solutions for purchases of essential goods (Fig. 10), respondents in total isolation presented a higher proportion of people in favor of change (40%) than those who remained partially in isolation (30%).

5. Policy lessons for post-COVID-19

The results concerning changes in behavior and travel patterns during the pandemic, along with the expectations for the post-pandemic
times, highlight some opportunities and challenges for urban and transportation planning in the Brazilian context. Some of these are discussed in this section, enlightened by the findings of this work.

As presented in the literature review, urban planning oriented to sustainable urban mobility, both in the short and long terms, may compromise issues related to inequalities in access to the city. Solutions
based exclusively on urban mobility, usually promoted through increases in capacity or speed, are not always available to the entire population and tend to encourage urban sprawl, increasing the demand for faster but less efficient transportation systems. More holistically, accessibility-oriented planning, with a focus on sustainability and equity, has been considered the best approach to address urban mobility issues and its impacts on citizens’ quality of life through the promotion of more lively, human and equitable places (Cervero et al., 2017; Garcia et al., 2018). This paradigm allows the development of public policies that consider not only the levels of accessibility to activities but also allow less spatial and economic segregation, more significant social equity, and improvements in urban efficiency globally.

The changes in the planning paradigm require the rescue of the understanding that transportation is a demand derived from the desire to have its needs met (Levine et al., 2019). Therefore, travel behavior is influenced by other aspects, such as ‘needs and desires’, ‘locations of activities’ and ‘travel resistances,’ reflecting the interaction between three subsystems: Activity, Land Use, and Transport subsystems (Lopes et al., 2019; Van Wee, 2002). As the demand for travel results from this interaction, routine assessments of travel quality or speed are insufficient to reveal whether transport needs are being met. If the objective of transport is not the movement, but access, then the concept of accessibility emerges as more appropriate for this purpose, as Levine et al. (2019) argue “that the derived-demand framework compels an accessibility perspective and establishes accessibility as the appropriate evaluative framework for transportation planning.”

The situation experienced during the Covid-19 pandemic is unique and has substantial impacts on the city and the mobility structure. Social distancing, the more effective NPIs concerning the transmission containment of COVID-19, is evaluated employing information with frequent updating rates, which usually reflect levels of mobility of citizens. These measures, such as data from mobile applications and cellular telephony, are relevant to evaluate increased or reduced mobility but do not reflect access to activities that are an essential part of people’s routine in urban areas. Also, in countries with extreme inequality of access to opportunities such as Brazil, these databases present an economic bias, being collected in higher intensity from information generated by the most economically favored population. Other factors not investigated in this study may corroborate the reduction of demand: the intention to avoid future trips, as a form of prevention; economic impacts, with reduced employment and income.

In this context, to investigate the reduction of transportation demand in the short and long terms, it is necessary to understand behavioral differences between socioeconomic groups during the pandemic and their intention to change in order to maintain alternatives adopted to perform essential activities and mitigate the impacts of social distancing. We can analyze travel reduction from two perspectives that impact urban and transport planning: (i) when activities are not performed, and (ii) when activities are carried out without the need to travel.

There are important inequalities considering the possibilities of carrying out essential activities without traveling and the intention of maintaining these activities after social distancing. The pandemic brings
more impacts on self-employed professionals due to the halting of work activities. Also, people who routinely make less frequent trips with working purposes are those with less affected travel routine. Public and private workers usually have a more extensive routine regarding the weekly frequency of trips to the workplace. Thus, it is possible to infer that self-employed workers are those who, in addition to suffering from the cessation of work, presented fewer possibilities for change in terms of work routine. Professional qualification is also related to routine changes during the pandemic. The higher the level of education, the greater the possibilities to carry out activities in an alternative way, and minor occurrences of professional activity halt. This phenomenon is also observed for essential educational activities and general goods shopping.

In the short term, the economically vulnerable population cannot adhere to distancing measures due to the instability and informality of work activities, risking losses on income, and the geographical dispersion between residence and work activity forces this group to daily face crowded transit systems even during the pandemic. Also, remote schooling and work is not an alternative for the majority of the low-income population, due to the lack of access to technology and Internet service. The possibility of changes regarding consumption patterns is only available for higher-income groups, with more intensive use of home deliveries.

Some population groups are vulnerable to the need for displacement to carry out their educational activities and for general purchases, identified through the maintenance of routine even in times of pandemic: young people, with less schooling and low income. We can infer that this vulnerable group faces greater challenges concerning the need for traveling, especially using public transport, in which agglomerations are a reality and contrary to NPIs. The higher proportion of increased frequency for general purchasing per active mode is possibly due to the need for smaller and more frequent purchases. Public transport users have had fewer opportunities to switch from routine to purchasing than those in individual motorized and active modes.

The restriction experienced in the pandemic poses a social policy challenge to ensure that these groups have access to essential resources so that, in the short term, social distance reaches the guidelines recommended as efficient to contain the transmission of COVID-19, aiming at the delaying of the epidemic peak (Candido et al., 2020; ECDC, 2020; Ganem et al., 2020). Ganem et al. (2020) have investigated the correlation among social distancing and the time-dependent reproduction number ($R(t)$) considering data from São Paulo and Rio de Janeiro. The results show a strong correlation between the social isolation index and $R(t)$ and revealed that isolation indexes above 50% lead to $R(t) < 1$ in most cases (89%).

In the medium and long terms, measures are needed to ensure safety for the continuation of on-site activities, especially those completely interrupted. Rethinking the use of public space, offering more open-air spaces, can benefit self-employed professionals and small entrepreneurs, by allowing small establishments to operate by the guidelines of health agencies.

Safe transportation is essential for the reopening of study and consumption activities, especially for the low-income population. More infrastructure for active transport has been considered as an alternative to avoid increased use of individual motorized transport, positively impacting everyone’s lives by improving air quality and promoting consistent physical activity for cyclists, and as a way to help the economic recovery of the cities, especially in developed countries. In developing countries, this agenda was still incipient, and the challenge becomes even greater. Few Brazilian cities have directed efforts to the implementation of bicycle paths, cycle lanes, and the expansion of sidewalks (União Brasileira de Ciclistas - UBC, 2020). The use of cars and motorcycles may be intensified, delaying the goals for sustainable urban mobility.

According to a report produced by the National Association of Urban Transport Companies (NTU, 2021), in the Brazilian context, since March 2020, operating companies have adopted sanitization and social distancing measures in public transport by bus. The most recurrent measures adopted in public transportation by bus are disinfection by nebulization; no more cash for fare payment; distancing markers; passenger limitation; body disinfection tunnel; temperature measurement.

Passenger demand fell as much as 80% in the first weeks of the crisis, in March 2020. In February 2021, the average reduction was 40.8%. The reduction in the services’ supply has always registered a lower average than the demand decline. The average decrease in the level of supply reached 57.2% in April 2020 and dropped progressively, reaching 20.8% in February 2021. With the losses resulting from the reduction in demand, 18 operating companies and 3 operating consortiums interrupted the provision of service since March 2020, either by temporary suspension, shutting down of the activity, contract suspension or intervention of the public power assuming responsibilities in the operation.

In Fig. 11 we can verify the reduction in the mobility for the Brazilian population concerning the pandemic time frame. For all activities, we verify that the major reduction in mobility happened at the beginning of the pandemic state. Nevertheless, the changes regarding the baseline scenario (Google, 2021) were incrementally reduced in time. For transit stations, we realize from this data, that there was a decrease of almost 60% on the people’s mobility in March/April of 2020 and a gradual increase up to the baseline until January 2021. Since the beginning of this year, there were reductions on mobility to these facilities up to April and the increase after this month.

In general, the results of this study indicate that some work, study, and commercial activities were maintained during the period of social isolation, with a significant reduction in travel. Once access to the desired activities is provided without the need for displacement, what opportunities can arise for urban and transportation planning?

On the one hand, for a share of private and public sector employees, there is the intention to incorporate alternative means to perform essential activities in their usual routines, especially among those who traveled most often to the workplaces. This perception brings an opportunity to the public sector and companies to promote flexible face-to-face work hours, with partial adoption of the home office. This opportunity reveals the potential for demand management policies aimed at reducing peak travel and commuting, bringing positive impacts to people’s quality of life in the urban environment. The reduction of demand may result in reduced pressure on existing infrastructure and possibilities to reshape the use of public space in line with sustainable development agendas, favoring the return of travel-dependent activities and safe access for the most affected groups.

On the other hand, the demand reduction in the public transport system, in this case, intensified by other social impacts resulting from the pandemic, reinforces the need to review public transport financing models adopted in Brazilian cities, based on the supply-demand balance and mostly sustained by the users of the system.

6. Final remarks and further investigation

The results presented in this paper revealed that the behavior concerning the performance of activities could not be considered independent of the frequency of travel for work, education, services, shopping in general. According to Huang et al. (2020), the most affected economic activities are travel-dependent businesses, such as educational institutes and public transportation, corroborating our analysis. The sectors that are critical to sustaining human life, such as workplaces, residential areas, restaurants, and shopping sites, have been recovering rapidly worldwide. Also, self-sufficient and self-sustainable cities concerning economic activity regions have recovered faster than regions relying on global supply chains (Huang et al., 2020). We cannot still evaluate the recovery of these economic sectors in the Brazilian context, but these essential activities are the ones mostly performed with alternative solutions during the pandemic.

The results corroborate the thought that access to activities is an
important driver of urban planning and transport policies, since indicators based exclusively on mobility may be insufficient to reflect the objective of transport. Changes in people’s mobility levels in the urban context are not necessarily related to changes in the population’s access to activities, which can enhance or compromise the quality of life and distributive justice in society. Planning based on accessibility, considering the integration between the location of urban subsystems activities, transport, and land use, allows greater efficiency among the most diversified solutions to the problems of access to daily activities. In this context, there is an opportunity for a more equitable redesign of public space and targeting of social and urban policies to the most disadvantaged groups. Nevertheless, this paradigm shift is currently a challenge for the different actors involved in solving urban structural problems, especially in developing countries. Thus, the academy has sought to develop research on the need to structure more holistic analyses to support the decisions of the different actors involved in urban planning, through studies that integrate the location of activities, land use and transport structure (Banister, 2008; Macario, 2014).

For future studies, we recommend local investigations, considering the location of activities as an important factor in understanding the impact of social distancing in daily life. Also, a follow-up of the analyses presented in this paper should be performed to understand post-pandemic behavior, especially in developing countries that have strong inequalities and, therefore, the impacts on economic activities affect a population group more severely.

Author contributions

Conceptualization, L.S.F.P.B.; methodology, L.S.F.P.B. and R.L.M.d.O.; software, R.L.M.d.O.; formal analysis, L.S.F.P.B. and R.L.M.d.O.; writing—original draft preparation, L.S.F.P.B. and R.L.M.d.O.; writing—review and editing, L.S.F.P.B. and R.L.M.d.O. All authors have read and agreed to the published version of the manuscript.

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Data source: Google Mobility Report (Google, 2021)

Fig. 11. Reduction in the mobility for the Brazilian population concerning the pandemic time frame.
