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Relationships between Teleworking and Travel Behavior in the Brazilian COVID-19 Crisis

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Abstract: The COVID-19 pandemic caused a significant shift towards teleworking, resulting in changes in travel patterns. The relationship between teleworking and individual travel behavior is crucial for transportation planning and policymaking. Thereby, this article investigates the relationships between teleworking, COVID-19, and mobility patterns in Brazil during two different periods of the COVID-19 pandemic. Given the exceptional nature of recent events, it is crucial to conduct studies related to teleworking during the pandemic crisis to contribute relevant information and evidence to the literature on this phenomenon. Such research has the potential to provide new insights and perspectives that enhance our understanding of the challenges and opportunities associated with teleworking. Two different approaches were used in the methodological procedure. The first approach used exploratory analysis to study public aggregated data related to the beginning of the pandemic, followed by a cluster analysis and a multinomial logit model. The second approach, relative to a longer relaxation period of sanitary/health measures, collected disaggregated self-reported data using an online survey, which were analyzed through non-parametric tests. The results show a strong relationship between the teleworking regime and the frequency of trips, especially for work purposes. It also highlights the influence of economic development and the region of Brazil in the kind of work regime. The continuation of studies, such as this one, in current periods is important for analyzing possible impacts, such as the reduction in congestion, vehicle emissions, and to enable the use of teleworking as a demand management policy.

Keywords: travel behavior; post-pandemic policies; teleworking; mobility changes; information and communication technologies

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1. Introduction

Due to the new coronavirus (COVID-19) pandemic, which began in late 2019 and spread rapidly around the world, countless actions, such as social distancing, quarantine, and lockdown, were undertaken in many different countries to contain the spread of the virus [1]. The implementation of teleworking was one of the measures suggested by the World Health Organization [2] so that companies could continue operating and keep their employees safe. The restrictive measures required quickly adopting teleworking as an approach to avoid the agglomeration of workers and to prevent the spread of the virus [3].

However, there was no prior planning related to this emergency implementation, which resulted in numerous challenges. In fact, this crisis triggered by the COVID-19 pandemic caused many sudden structural changes in companies and in employees' routines [4]. Although large companies considered definitively adopting teleworking, the change in the work arrangement must be carried out gradually due to the numerous issues involved (legal and labor, health, safety, and the right to disconnect). However, only the popularization of teleworking and possible changes in mobility patterns were addressed in this paper, without taking into account any labor issues.

This study analyzes the relationships between teleworking, COVID-19, and mobility patterns in Brazil using two different approaches. The first uses secondary data, denominated in this study as public aggregated data, related to the 2020 COVID-19 pandemic. The second analysis (primary data) is based on individual, self-reported primary data, collected in the context of mass vaccination—with more than 76% of the population fully vaccinated [5]—and the relaxation of social distancing measures in 2022. The first approach, based on aggregated data, consisted of a brief exploratory analysis and, subsequently, a multivariate analysis including a sequential application of the cluster analysis technique and multinomial logit model. The second approach is based on experimental planning, questionnaire design, data collection, and non-parametric tests to evaluate the relationships of interest.

COVID-19 impacted travel behavior in diverse manners. There was an important reduction in out-of-home activities [6], as well as an increase in teleactivities and teleworking in general [7]. This article brings an important reflection regarding post-pandemic periods and how teleworking popularization can impact mobility and contribute as a demand management policy.

This paper contains six sections in addition to the introduction. Section 2 presents a brief bibliographical review of behaviors during the pandemic and in teleworking. Section 3 describes the tools used and the method proposed. Section 4 discusses the results obtained in the first approach, using aggregated public data. Section 5 describes the results of the second approach based on self-reported primary data. Section 6 presents a brief discussion regarding the main results; and finally, Section 7 draws the main conclusions of this study, as well as its methodological restrictions and suggestions for future work.

2. Literature Review

2.1. Behaviors during the Pandemic

The COVID-19 pandemic changed people's lifestyles and impacted the economy, politics, science, culture, and many other areas of life in society [8]. There were numerous measures implemented around the world so as to contain the spread of the virus and slow down the evolution of the pandemic. Implementing these containment measures impacted everyday mobility [9]. Travel, especially by public transport, underwent a considerable decrease during the pandemic [4,10–12]. The restrictions imposed by social distancing and the fear of contagion by the virus led many people to change their travel mode or how they carry out their activities [9]. There was a notable reduction in out-of-home activities [6], as well as an increase in teleactivities in general [7].

Even before the pandemic, the effects of teleactivities on travel behavior were already investigated, mainly taking into account substitution and complementarity [13]. However, the crisis caused by the COVID-19 pandemic changed the situation to some extent: travel restrictions imposed, as a result of the restrictive measures put in place to maintain social distancing and prevent the spread of the virus, triggered teleactivities to be implemented more intensely, thus leading to an even greater impact on mobility [14–16]. In this context, one of the measures suggested by the World Health Organization [2] for companies to continue operating safely was the implementation of teleworking.

2.2. Teleworking

Although this practice is over 40 years old [17], the teleworking phenomenon does not have a universal definition, which makes it difficult to understand [18]. The Eurofound and International Labor Office [19] defines teleworking as work outside the employer's premises, using Information and Communication Technologies (ICTs), such as computers, tablets, and cell phones. Teleworking is a work format that allows for a wide variety of work arrangements that can differ in terms of duration, location, and frequency. With regard to duration, teleworking can be carried out full time (full day), part time, or only at convenient times. This work format can be performed from different locations, mostly from the worker's home. It may also occur weekly at different frequencies [20].

The teleworking arrangement is now a part of the work organization in other historical contexts, concomitant with the on-site work format in companies. However, it was only during the COVID-19 crisis that this modality began to be set up as a mandatory arrangement [21]. Work relationships had to be adapted due to social distancing measures, but without enough time for adequate structuring and planning. Companies were forced to adopt telecommuting on an emergency basis, and employees had to quickly adapt to the new work arrangement [22]. Companies had to invest resources in remote communication equipment and tools, in addition to introducing internal rules to implement teleworking. For the workers, the challenge of implementing emergency-based teleworking largely consisted of having to quickly learn new technologies, as well as reconcile family and work life, as work, leisure, school, and domestic activities had to share the same environment [23].

Despite the challenges faced by the emergency implementation of teleworking, this work arrangement has several advantages when its implementation is planned. Based on the literature, Contreras, Baykal, and Abid [24] listed some of the opportunities and risks of telecommuting for workers. Some of the benefits include greater job satisfaction, greater autonomy and flexibility, favoring the worker's quality of life, fewer distractions, greater productivity, and more job opportunities for women and people with disabilities, among other advantages. Some of the disadvantages are social and professional isolation, home–work conflicts, worker exhaustion, and lack of motivation. Nguyen [1] also mentions advantages such as the reduction in stress and interruptions, producing greater work satisfaction, in addition to reducing travel costs and better use of time. Due to the experience acquired during the COVID-19 pandemic and due to the numerous benefits of telecommuting, both for companies and for workers, it is expected that this work arrangement will be increasingly adopted worldwide [25].

For decades, the effect of teleworking on travel behavior could not be properly acknowledged, especially in terms of its possible influence on reducing travel. As this practice was not very popular, especially in Brazil, investigating its relationship with mobility was not conclusive [26–28]. Currently, due to the pandemic, the popularization of its practice enabled a more in-depth investigation. As a matter of fact, the decrease in the number of trips was due to the pandemic and not necessarily to telecommuting. Considering the persistence of the practice of teleworking and teleactivities in post-pandemic scenarios, the investigations can be more comprehensive. Therefore, this paper presents data from two very different contexts: (1) the first year of the pandemic—2020; (2) and a period of "return" to normalcy characterized by a greater relaxation of social isolation—2022. Figure 1 illustrates the relationship between teleworking and mobility and the influence of the pandemic on the formation of new individual travel habits.

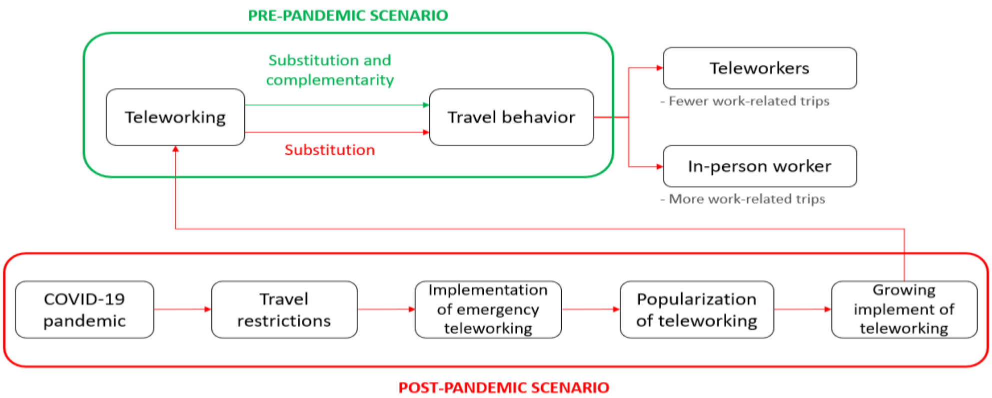


Figure 1. Context of insertion of teleworking during the COVID-19 pandemic (past studies—green color; research gaps—red color).

3. Materials and Method

3.1. Database

3.1.1. Secondary Data

The first dataset used in this study comes from different sources, as listed in Table 1. The data were organized so that each Brazilian state was the unit of analysis between May and November 2020.

Table 1. Collected public data and its respective sources.

Secondary Public Data	Source
Daily percentage travel variations for workplaces in relation to the baseline, for each Brazilian state.	COVID-19 Community Mobility Reports [29]
Number of people in teleworking (potential). Potential teleworking ranking. Gross domestic product (GDP) per capita ranking. Teleworking potential percentage.	Institute of Applied Economic Research (IPEA)—Conjuncture Letter No 47 [30]
Number of people effectively teleworking. Percentage of people engaged in teleworking. Gini index.	Institute of Applied Economic Research (IPEA)—Conjuncture Letter No 50 [31]
Mean labor income effectively received. Mean labor income usually received.	Institute of Applied Economic Research (IPEA)—Conjuncture Letter No 48, 49 and 50 [32–36]
Profile of employed and active people regarding gender, age, color, education, service sector, and economic activity. Profile of people in teleworking regarding gender, age, color, education, service sector, and economic activity.	Institute of Applied Economic Research (IPEA)—Conjuncture Letter No 52 [37]
Unemployment rate. Percentage of people employed and away from work due to social distancing in the total employed population. Proxy of the informality rate of employed people.	Brazilian Institute of Geography and Statistics—National Household Sample Survey: PNAD COVID-19 [38]
Number of daily cases and deaths.	Monitors COVID-19 [5]

Regarding daily percentage differences in trips, the baseline value is represented by a median value for that weekday for a period of five weeks prior to the pandemic (3 January to 6 February 2020). These values were used to calculate the average percentage change in trips to workplaces, for each of the federative units in each month of analysis.

The COVID-19 Community Mobility Reports [29] provide insights into changes in response to policies aimed at combating COVID-19. These reports track movement trends over time by geography and across different categories of places, such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential areas.

The conjuncture letters from the Institute of Applied Economic Research (IPEA) [30–37] are bulletins that contain indicators and notes on the economic outlook, providing broad and diversified analysis of the recent performance of the Brazilian economy and projections for the coming months and years. Specifically, the conjuncture letters used in this study include information from the pandemic period, collected through the National Household Sample Survey: PNAD COVID-19 [38].

Finally, Monitors COVID-19 [5] is a system that groups and analyzes COVID-19 data in Brazil and worldwide. This online tool allows users to monitor the pandemic and its trends in Brazilian states and municipalities using graphs and maps.

3.1.2. Primary Data

The second database analyzed in this study discusses a questionnaire distributed over the Internet used to obtain information regarding the profile of workers, including work regime, commuting characteristics, and cognitive engagement and proficiency in Information and Communications Technologies (ICTs).

The first section was about socioeconomic characteristics in order to understand the worker's profile. Data such as age, gender, place of residence, level of education, vehicle ownership, and work regime were collected. The second section was intended only for teleworkers, containing questions about the influence of the pandemic on the adoption of teleworking, the frequency of use of this work arrangement, and how the company monitors and assists teleworkers. An additional section was applied for those who started the regime due to the pandemic to collect travel data in the period prior to teleworking. The third section obtained data on the commuting routine of all workers, such as frequency, duration, average travelled distances, travel modes, and trip purposes. Finally, the last section of the online survey was aimed at collecting data on the use of Information and Communication Technologies by all workers, with the aim of relating proficiency in technologies with telework. Tables 2–4 describe the frequency of the variables regarding socioeconomic characteristics, travel, and Information and Communication Technologies factors considering the work regime, respectively. Table 3 presents travel characteristics only related to work trips.

Table 2. Socioeconomic and work regime in the sample obtained.

Variable	In-Person		Part-Time Teleworking		Full-Time Teleworking		Total	
Gender	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Female	78	61.4%	26	50.0%	35	51.5%	139	56.3%
Male	47	37.0%	26	50.0%	33	48.5%	106	42.9%
Other	2	1.6%	0	0.0%	0	0.0%	2	0.8%
Age	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
18–24	25	19.7%	16	30.8%	22	32.4%	63	25.5%
25–30	46	36.2%	24	46.2%	25	36.8%	95	38.5%
31–35	14	11.0%	5	9.6%	9	13.2%	28	11.3%
36–40	9	7.1%	1	1.9%	5	7.4%	15	6.1%
41–45	10	7.9%	3	5.8%	3	4.4%	16	6.5%
46–50	14	11.0%	1	1.9%	4	5.9%	19	7.7%
51–55	6	4.7%	1	1.9%	0	0.0%	7	2.8%
56–60	3	2.4%	1	1.9%	0	0.0%	4	1.6%
61 or more	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Educational level	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Complete high school	13	10.2%	0	0.0%	1	1.5%	14	5.7%
Incomplete undergraduate degree	20	15.7%	9	17.3%	18	26.5%	47	19.0%
Complete undergraduate degree	80	63.0%	35	67.3%	34	50.0%	149	60.3%
Master's degree	10	7.9%	7	13.5%	13	19.1%	30	12.1%
Doctoral degree	4	3.1%	1	1.9%	2	2.9%	7	2.8%
Region	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
North/Northeast	32	25.2%	7	13.5%	4	5.9%	43	17.4%
Midwest	4	3.1%	0	0.0%	4	5.9%	8	3.2%
South	9	7.1%	1	1.9%	2	2.9%	12	4.9%
Southeast	82	64.6%	44	84.6%	58	85.3%	184	74.5%
Car ownership	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
0	17	13.4%	9	17.3%	20	29.4%	46	18.6%
1	65	51.2%	27	51.9%	32	47.1%	124	50.2%
2	37	29.1%	11	21.2%	11	16.2%	59	23.9%
3 or more	8	6.3%	5	9.6%	5	7.4%	18	7.3%

Table 3. Travel and work regime in the sample obtained.

Variable	In-Person		Part-Time Teleworking		Full-Time Teleworking		Total	
TF (work) general	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	38	29.9%	7	13.5%	50	73.5%	95	38.5%
Until 3 times/month	8	6.3%	15	28.8%	15	22.1%	38	15.4%
Until 3 times/week	3	2.4%	19	36.5%	2	2.9%	24	9.7%
Between 3 and 5 times/week	56	44.1%	7	13.5%	1	1.5%	64	25.9%
More than 5 times/week	22	17.3%	4	7.7%	0	0.0%	26	10.5%
TF (work) on foot	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	100	78.7%	40	76.9%	64	94.1%	204	82.6%
Until 3 times/month	10	7.9%	4	7.7%	2	2.9%	16	6.5%
Until 3 times/week	3	2.4%	4	7.7%	0	0.0%	7	2.8%
Between 3 and 5 times/week	11	8.7%	4	7.7%	2	2.9%	17	6.9%
More than 5 times/week	3	2.4%	0	0.0%	0	0.0%	3	1.2%
TF (work) bicycle	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	120	94.5%	51	98.1%	65	95.6%	236	95.5%
Until 3 times/month	4	3.1%	0	0.0%	2	2.9%	6	2.4%
Until 3 times/week	1	0.8%	0	0.0%	0	0.0%	1	0.4%
Between 3 and 5 times/week	2	1.6%	1	1.9%	1	1.5%	4	1.6%
More than 5 times/week	0	0.0%	0	0.0%	0	0.0%	0	0.0%
TF (work) ride	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	90	70.9%	36	69.2%	63	92.6%	189	76.5%
Until 3 times/month	10	7.9%	7	13.5%	4	5.9%	21	8.5%
Until 3 times/week	4	3.1%	6	11.5%	1	1.5%	11	4.5%
Between 3 and 5 times/week	18	14.2%	3	5.8%	0	0.0%	21	8.5%
More than 5 times/week	5	3.9%	0	0.0%	0	0.0%	5	2.0%
TF (work) driver	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	47	37.0%	24	46.2%	59	86.8%	130	52.6%
Until 3 times/month	6	4.7%	12	23.1%	5	7.4%	23	9.3%
Until 3 times/week	11	8.7%	6	11.5%	1	1.5%	18	7.3%
Between 3 and 5 times/week	46	36.2%	6	11.5%	2	2.9%	54	21.9%
More than 5 times/week	17	13.4%	4	7.7%	1	1.5%	22	8.9%
TF (work) public	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	96	75.6%	38	73.1%	61	89.7%	195	78.9%
Until 3 times/month	6	4.7%	10	19.2%	5	7.4%	21	8.5%
Until 3 times/week	4	3.1%	3	5.8%	1	1.5%	8	3.2%
Between 3 and 5 times/week	20	15.7%	1	1.9%	1	1.5%	22	8.9%
More than 5 times/week	1	0.8%	0	0.0%	0	0.0%	1	0.4%
TF (work) app	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	92	72.4%	33	63.5%	61	89.7%	186	75.3%
Until 3 times/month	23	18.1%	10	19.2%	7	10.3%	40	16.2%
Until 3 times/week	9	7.1%	4	7.7%	0	0.0%	13	5.3%
Between 3 and 5 times/week	2	1.6%	3	5.8%	0	0.0%	5	2.0%
More than 5 times/week	1	0.8%	2	3.8%	0	0.0%	3	1.2%
TF (work) taxi	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
None	126	99.2%	51	98.1%	67	98.5%	244	98.8%
Until 3 times/month	1	0.8%	0	0.0%	1	1.5%	2	0.8%
Until 3 times/week	0	0.0%	1	1.9%	0	0.0%	1	0.4%
Between 3 and 5 times/week	0	0.0%	0	0.0%	0	0.0%	0	0.0%
More than 5 times/week	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Table 3. *Cont.*

Variable	In-Person		Part-Time Teleworking		Full-Time Teleworking		Total	
TT (work)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Less than 15 min	48	37.80%	16	30.80%	3	4.40%	67	37.4%
15–30 min	44	34.60%	13	25.00%	5	7.40%	62	34.6%
30–45 min	7	5.50%	7	13.50%	1	1.50%	15	8.4%
45–60 min	6	4.70%	3	5.80%	1	1.50%	10	5.6%
1–2 h	7	5.50%	7	13.50%	4	5.90%	18	10.1%
More than 2 h	3	2.40%	2	3.80%	2	2.90%	7	3.9%
TD (work)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Less than 1 km	11	8.70%	1	1.90%	1	1.50%	13	7.2%
1–5 km	45	35.40%	19	36.50%	6	8.80%	70	38.7%
6–10 km	26	20.50%	8	15.40%	3	4.40%	37	20.4%
11–15 km	18	14.20%	6	11.50%	1	1.50%	25	13.8%
More than 15 km	21	16.50%	12	23.10%	3	4.40%	36	19.9%

Legend: TF = travel frequency; TT = travel time; and TD = travel distance.

Table 4. ICTs and work regime in the sample obtained.

Variable	In-Person		Part-Time Teleworking		Full-Time Teleworking		Total	
Confidence to handle computers (ICT Cognitive Engagement 1)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	1	0.8%	0	0.0%	0	0.0%	1	0.4%
2	3	2.4%	0	0.0%	0	0.0%	3	1.2%
3	10	7.9%	1	1.9%	2	2.9%	13	5.3%
4	22	17.3%	4	7.7%	6	8.8%	32	13.0%
5	91	71.7%	47	90.4%	60	88.2%	198	80.2%
Ability to solve computer problems (ICT Cognitive Engagement 2)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	9	7.1%	1	1.9%	1	1.5%	11	4.5%
2	8	6.3%	2	3.8%	2	2.9%	12	4.9%
3	17	13.4%	6	11.5%	3	4.4%	26	10.5%
4	38	29.9%	13	25.0%	21	30.9%	72	29.1%
5	55	43.3%	30	57.7%	41	60.3%	126	51.0%
Ease to become acquainted with new computer programs (ICT Cognitive Engagement 3)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	2	1.6%	0	0.0%	0	0.0%	2	0.8%
2	4	3.1%	0	0.0%	0	0.0%	4	1.6%
3	13	10.2%	1	1.9%	3	4.4%	17	6.9%
4	31	24.4%	13	25.0%	17	25.0%	61	24.7%
5	77	60.6%	38	73.1%	48	70.6%	163	66.0%
Preference for computer jobs (ICT Cognitive Engagement 4)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	10	7.9%	0	0.0%	0	0.0%	10	4.0%
2	12	9.4%	1	1.9%	1	1.5%	14	5.7%
3	15	11.8%	6	11.5%	9	13.2%	30	12.1%
4	32	25.2%	8	15.4%	16	23.5%	56	22.7%
5	58	45.7%	37	71.2%	42	61.8%	137	55.5%
Interest on new computer technologies (ICT Cognitive Engagement 5)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	6	4.7%	0	0.0%	1	1.5%	7	2.8%
2	3	2.4%	1	1.9%	2	2.9%	6	2.4%
3	23	18.1%	3	5.8%	7	10.3%	33	13.4%
4	29	22.8%	12	23.1%	19	27.9%	60	24.3%
5	66	52.0%	36	69.2%	39	57.4%	141	57.1%

Table 4. *Cont.*

Variable	In-Person		Part-Time Teleworking		Full-Time Teleworking		Total	
Proficiency in virtual meeting platforms use (ICT Proficiency 1)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	6	7.9%	0	0.0%	0	0.0%	6	2.4%
2	11	8.7%	1	1.9%	0	0.0%	12	4.9%
3	20	15.7%	1	1.9%	0	0.0%	21	8.5%
4	36	28.3%	9	17.3%	12	17.6%	57	23.1%
5	54	42.5%	41	78.8%	56	82.4%	151	61.1%
Proficiency in activity management platforms use (ICT Proficiency 2)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	10	7.9%	0	0.0%	1	1.5%	11	4.5%
2	16	12.6%	4	7.7%	4	5.9%	24	9.7%
3	34	26.8%	13	25.0%	13	19.1%	60	24.3%
4	35	27.6%	15	28.8%	13	19.1%	63	25.5%
5	32	25.2%	20	38.5%	37	54.4%	89	36.0%

3.2. Methodological Procedure

The methodological procedure was divided into two sets of sequential steps as the present article is based on two different approaches at different times of the COVID-19 pandemic. The first one (Figure 2a) analyzes the public data presented in Section 3.1.1, and the second approach (Figure 2b) analyzes the data from the primary data collection described in Section 3.1.2.

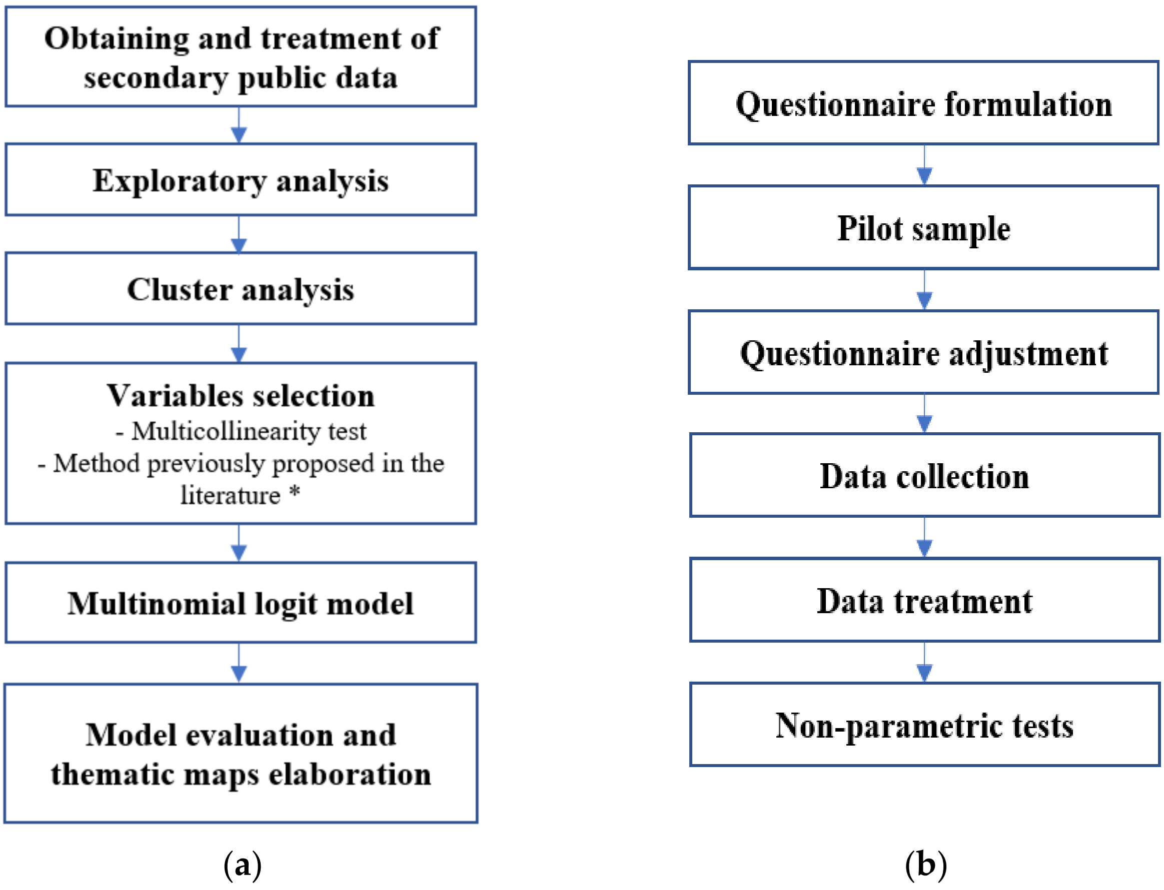


Figure 2. Methodological procedure adopted in the first (**a**) * [39] and second approach (**b**).

3.2.1. Methodological Procedure Adopted in the First Approach

The initial stage of this approach consisted of analyzing aggregate data about teleworking, socioeconomic information on teleworkers, and commuting during the pandemic. First, the dataset was treated so that the unit of analysis was each Brazilian state in each month between May and November 2020. A brief exploratory analysis was conducted to understand the main characteristics of the variables under study and their relationships.

After the exploratory analysis, a cluster analysis technique was applied to discretize the variable 'average percent change in trips to workplaces' from the COVID-19 Community Mobility Reports [29]. This method is generally used to group observations according to common characteristics, forming clusters that must present high homogeneity among their elements and high heterogeneity among different clusters [40–42]. This choice was made not only to aggregate groups with similar levels of percent change, but also to distinguish positive from negative variation in the workplace movements. This would not be possible if the percent change were used directly in a linear regression model.

The clustering procedure used was the K-means algorithm [43,44], an algorithm that partitions a set of observations into a predetermined number of clusters, ensuring that each observation belongs to the cluster with the nearest centroid and that the observations within each cluster are as similar as possible. The discretization was performed for 5 clusters, which allowed for isolating positive from negative values in different groups.

Then, a multinomial logit model was conducted to identify the specific factors associated with the changes in workplace movements. The membership of each observation cluster obtained at this stage was used as the dependent variable in this model. The multinomial logit was adjusted based on random utility functions that result from a combination of explanatory variables related to individuals and alternatives [45]. The utility of an alternative i (with $i = 1, 2, 3, 4,$ or 5) perceived by an individual j is composed of its true utility (V_{ij}) plus a perception error (ε_{ij}) that follows the cumulative Gumbel distribution, as shown in Equation (1) [46]:

$$U_{ij} = V_{ij} + \varepsilon_{ij}. \tag{1}$$

In general, the utility function presents the configuration of Equation (2):

$$V_{ij} = \alpha_i + \beta_i \cdot x_{1ij} + \ldots + \gamma_i \cdot x_{mij} \tag{2}$$

where

V_{ij}: deterministic term of the utility of alternative i for individual j;
x_{mij}: explanatory variables related to alternative i or to individual j;
m: the number of variables;
α_i, β_i, γ_i: coefficients to be estimated.

Once the utility function of each alternative is defined, the probability of the alternative being chosen is given by:

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_{k=1}^{n} e^{V_{kj}}} \tag{3}$$

where

P_{ij}: the probability of alternative i being chosen by individual j;
n: number of alternatives.

It is important to mention that the values of the x_{mij} coefficients $(\alpha_i, \beta_i, \ldots, \gamma_i)$ are estimated through maximization of the likelihood function $L(\alpha_i, \beta_i, \ldots, \gamma_i) = \prod_i \prod_j {P_{ij}}^{I_{ij}}$, where I_{ij} is the indicator function that specifies whether individual j was classified into the alternative i (1) or not (0) [47].

Given that the database has a high number of explanatory variables compared to the number of observations, the variables that would best represent each utility function had to be chosen. Thus, the method developed by Caldas, Pitombo, and Assirati [39] was applied. This strategy uses the classification and regression tree (CART) algorithm to reduce the number of parameters to be estimated without compromising the quality of the model. Its core strategy is to select the independent variables that present the relevant explanation of variability for each utility function. Therefore, some independent variables could be included for only some of the 5 utility functions. For a detailed methodological explanation, the reader is referred to Caldas, Pitombo, and Assirati [39] and Gomes, Caldas, and Pitombo [48]. With this reduced set of variables, the Variance Inflation Factor (VIF) was also calculated to evaluate any remaining multicollinearity in the data. In addition to the highly correlated variables, those exhibiting any ambiguous information were also excluded. The purpose of this step was to remove explanatory variables that could be problematic to the adjustment of the multinomial logit model.

After these preliminary steps, the independent variables used in the multinomial logit model were: percentage of people employed and away from work due to social distancing in the total employed population; the percentage of those engaged in remote work; potential teleworking ranking; and the Northern Region. Finally, several models were calibrated. Non-significant parameters were removed at each step considering a 90% confidence level until a final model with all significant parameters was obtained. Thematic maps were also prepared to better visualize and discuss the results obtained.

With the chosen model, a confusion matrix was produced with the complete sample to measure the accuracy of the model by comparing estimated values and observed values. The chi-square test of adherence [49] was adopted to verify whether the distribution of individuals into the classes produced by the model matched that of the observed values. This test is carried out by calculating the significance of the chi-square statistic obtained as demonstrated in Equation (4).

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \quad (4)$$

where

χ^2: value of the chi-squared test;

O_i: observed number of cases in each category;

E_i: estimated number of cases in each category, calculated from the theoretical expected distribution.

3.2.2. Methodological Procedure Adopted in the Second Approach

The initial step of the second approach consisted of conducting a literature review to identify socioeconomic factors related to the work regime (remote or in-person) that affect individuals' commuting behavior. Based on this review, a questionnaire was prepared and the participants were recruited through a non-probabilistic sampling method known as snowball sampling [50]. The questionnaire was distributed online through social media platforms, and participants were asked to share the questionnaire with their colleagues and social networks to reach a wider pool of potential participants. The criteria for recruiting research participants in this study were individuals who met the following requirements: (1) 18 years or older, (2) residing in Brazil, and (3) currently working. Considering the selection bias inherent to this type of procedure, especially regarding income and level of education, it is emphasized that the results will not be extrapolated to the population, limiting the interpretations to the sample of the present study. The form was first applied to a pilot sample to correct the instrument's preliminary inaccuracies. Finally, the final questionnaire was applied to obtain data regarding the profile of the workers, work regime, commuting characteristics, and cognitive engagement and proficiency in ICTs. It is worth mentioning that due to the multidimensional nature of the ICT cognitive engagement concept, five items from the scale developed by Zylka et al. [51] related to positive self-concept and interest in ICTs were prepared to investigate this aspect.

After initial data processing, the different work regimes (full-time teleworking, part-time teleworking, and in-person work) were compared with socioeconomic variables, mobility variables, and those related to cognitive engagement and ICT proficiency. That required conducting two types of statistical tests of hypotheses to indicate whether the difference between the regimes for each of these variables is significant: chi-square test and Wilcoxon rank sum test.

The chi-square statistical test evaluates the null hypothesis of the lack of association between work regime and the variable under analysis [49]. If the statistical result was significant to corroborate de alternative hypothesis, new tests were carried out between the pairs of regimes (full-time teleworking and in-person work; full-time telework and part-time telework; and part-time teleworking and in-person work), in order to verify the difference observed between the groups. The Wilcoxon rank sum test, in turn, was undertaken to verify the null hypothesis that the probability distributions of the variable of interest in the different groups analyzed came from the same population [52]. For this test, the analyses were carried out directly between pairs of regimes.

Finally, it is important to emphasize that in all cases in which the null hypotheses were rejected, an exploratory analysis was also carried out on the distribution of the variables between the compared groups to characterize these differences. Table 5 describes the tests performed for the different groups of variables, as well as the hypotheses tested, and Table 6 describes some computational packages used during the research.

Table 5. Characterization of the variables in the final questionnaire and comparative statistics tests.

Group	Variable	Scale	Levels	Hypothesis	Tests
Socioeconomics	Gender	Nominal	Female; male; other	**H0:** *there is no association between socioeconomic variables and work regimes.* **H1:** *there is an association between socioeconomic variables and work regimes.*	Chi-squared [49]
	Age	Ordinal	18–24; 25–30; 31–40; 41–50; 51–60; 61 or more		
	Educational level	Ordinal	Complete high school; incomplete undergraduate degree; complete undergraduate degree; master's degree; doctoral degree		
	Region	Nominal	City and state		
	Car ownership	Ordinal	0; 1; 2; 3 or more		
	Type of work	Nominal	In-person; part-time teleworking; Full-time teleworking		
Travel	Average time	Quantitative	-	**H0:** *there is no difference between quantitative travel related variables and work regimes.* **H1:** *there are differences between quantitative travel related variables and work regimes.*	Wilcoxon Rank Sum Test [52]
	Average distance	Quantitative			
Travel	Travel frequency (by purpose and travel mode)	Ordinal	None; until 3 times/month; until 3 times/week; between 3 and 5 times/week; more than 5 times/week	**H0:** *there is no association between travel variables and work regimes.* **H1:** *there is an association between travel variables and work regimes.*	Chi-squared [49]
	Travel time (by purpose, on main travel mode)	Ordinal	Less than 15 min; 15–30 min; 30–45 min; 45–60 min; 1–2 h; more than 2 h		
	Travel distance (by purpose, on main travel mode)	Ordinal	Less than 1 km; 1–5 km; 6–10 km; 11–15 km; more than 15 km		
ICTs	Confidence to handle computers (ICT Cognitive Engagement 1)	Ordinal	Agreement scale (1: completely disagree to 5: completely agree)	**H0:** *there is no association between ICTs related variables and work regimes.* **H1:** *there is an association between ICTs related variables and work regimes.*	Chi-squared [49]
	Ability to solve computer problems (ICT Cognitive Engagement 2)	Ordinal			
	Ease to become acquainted with new computer programs (ICT Cognitive Engagement 3)	Ordinal			
	Preference for computer jobs (ICT Cognitive Engagement 4)	Ordinal			
	Interest on new computer technologies (ICT Cognitive Engagement 5)	Ordinal			
	Proficiency in virtual meeting platforms use (ICT Proficiency 1)	Ordinal			
	Proficiency in activity management platforms use (ICT Proficiency 2)	Ordinal			

Table 6. Tools used in each methodological stage.

Methodological Stage	Software and Packages	Database
Cluster analysis	R Language: Factoextra [53]	Public aggregated data (secondary data)
Multinomial logit	R Language: Rpart [54] Python Language: Biogeme [55]	Public aggregated data (secondary data)
Non-parametric tests	R Language: Rcompanion [56]	Self-reported data (primary data)

4. Results Relative to the 2020 Aggregated Data: Secondary Data

This section presents the main results obtained in each of the sub-steps of the methodological procedure adopted in the first approach.

4.1. Preliminary Exploratory Data Analysis

From the collected data, an exploratory analysis was conducted to understand the characteristics of the variables under study. The profile of Brazilian teleworkers, from May to November 2020, was mostly composed of young and middle-aged female workers with a high level of education. With the exception of gender, which traditionally presents a predominance of males according to the literature [19,57–59], the characteristics found are in line with studies carried out in other places [58–60].

Based on the analysis of work-related variables, only a small portion of the observations have more than 10% of people employed in remote work. The potential percentage of remote work showed an average value of 20.58% in the study period, a value below that found by Dingel and Neiman [61] and by Goés, Do Nascimento, and Martins [30] of 25.7% and 22.7%, respectively. The gap between the percentage of people employed in remote work and the potential percentage of teleworking possibly indicates that there are professionals who could work remotely but chose or were forced to maintain a conventional work arrangement.

Table 7 shows the mean values of two variables for each of the months in question. It is observed that the month of May corresponds to the highest average percentage of people employed in remote work and the lowest average of the mean percentage change in workplaces. In fact, the period between April and July 2020 showed an increasing trend in the incidence of COVID-19 cases in Brazil [5]; and therefore, many workers adopted the teleworking arrangement, and consequently, stopped commuting to their workplaces. Similarly, the downward trend between August and November 2020 resulted in the easing of restrictive measures, leading many workers—who were on leave or working remotely—to return to in-person work.

Table 7. Average values of the variables in each month.

Variable	May	June	July	August	September	October	November
Percentage of people engaged in teleworking (%).	10.94	10.53	9.52	9.08	8.41	7.71	7.34
Average percentage travel variations for workplaces in relation to the baseline (%).	−25.47	−18.51	−13.73	−7.49	−5.78	−1.55	0.64

4.2. Cluster Analysis Results

Table 8 shows an information summary of each of the five clusters obtained and Figure 3 shows the distribution of observations within each cluster. It is observed that most of the observations are contained in clusters 3 and 4, indicating the predominance of a slight to very slight decrease in the average percentage change of workplaces during the period. The resulting five groups comprise the choice set for the subsequent calibration of the multinomial logit model.

Table 8. Summary of the cluster analysis for the variable "average percentage travel variations for workplaces in relation to the baseline".

Cluster	Minimum (%)	Maximum (%)	Number of Observations	Description
1	−43.94	−24.33	26	High decrease
2	−23.68	−14.19	34	Moderate decrease
3	−13.81	−7.06	49	Slight decrease
4	−6.81	−1.00	46	Very slight decrease
5	−0.03	10.87	34	Increase

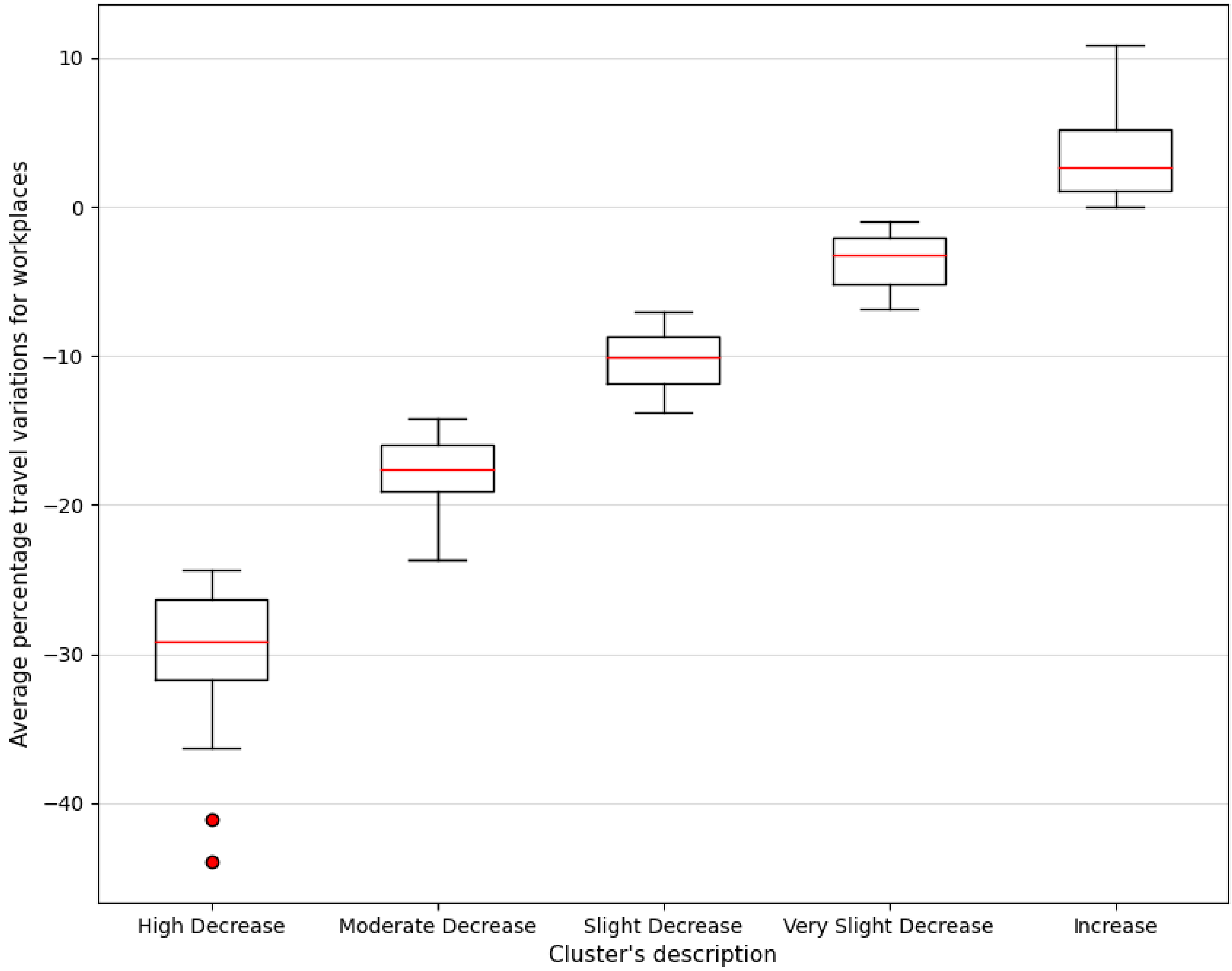


Figure 3. Distribution of observations within each cluster.

4.3. Multinomial Logit Model Results

The utility functions were defined taking the utility of cluster 2 as a reference (i.e., $V_{2j} = 0$, as shown in Equation (6). This cluster was chosen as a reference value because it has an intermediate number of observations and also because it is not one of the extreme behavior clusters (high commuting decrease or increase). Equations (5)–(9) show the defined utility functions. Table 9 presents the description of the explanatory variables used. Table 10 presents the main descriptive statics of independent variables.

$$V_{1j} = ASC_1 + B_{1,POA_j} \cdot POA_j + B_{1,POTR_j} \cdot POTR_j \tag{5}$$

$$V_{2j} = 0 \quad (6)$$

$$V_{3j} = ASC_3 + B_{3,POA_j} \cdot POA_j + B_{3,RTELET_j} \cdot RTELET_j \quad (7)$$

$$V_{4j} = ASC_4 + B_{4,POA_j} \cdot POA_j + B_{4,POTR_j} \cdot POTR_j \quad (8)$$

$$V_{5j} = ASC_5 + B_{5POA_j} \cdot POA_j + B_{5,POTR_j} \cdot POTR_j + B_{5,NORTH_j} \cdot NORTH_j \quad (9)$$

Table 9. Description of the explanatory variables and parameters used in the model.

Variable and Parameter		Description
(A)	POA_j	Percentage of employed and away from work people due to social withdrawal in the total employed population (%).
(B)	$POTR_j$	Percentage of people engaged in teleworking (%).
(C)	$RTELET_j$	Potential teleworking ranking (1 to 27).
(D)	$NORTH_j$	(0) No; (1) yes
(E)	$B_{ivariablej}$ (i = alternative, variable j = association to predictor variables for each individual)	Coefficients
(F)	ASC_i (i = alternative)	Alternative-specific conditional logit

Table 10. Descriptive statistics of independent variables.

Variable	Count	Mean	Std	Minimum	25%	50%	75%	Maximum
$POTR_j$	189	9.075	4.594	3.1	6.2	7.9	10.1	25.8
POA_j	189	8.958	7.399	1.5	3.4	6.3	12.0	35.2
Variable $NORTH_j$	**n**	**%**						
0	140	74.1%						
1	49	25.9%						

The resulting final model has all significant parameters at a confidence level of 90%, as shown in Table 11. The values of the parameters related to the percentage of people employed and away from work (POA_j) shows that when the value of this variable is increased, the chances of a high decrease in trips are 5.108 times greater relative to a moderate decrease in trips. Furthermore, it is noticed that the chances of an increase in trips to workplaces are 75.5% lower than the chances of a moderate decrease in trips. Thus, it appears that the percentage of people away from in-person work is directly proportional to the reduction in trips to workplaces.

Similarly, the values of the parameters related to the percentage of people employed in remote work ($POTR_j$) indicate that for a unit increase in the percentage of people employed in remote work, the state is 2.851 times more likely to belong to the high decrease group than to the moderate decrease group. In fact, the higher the percentage of people performing remote work, the lower the number of work trips. This fact is in agreement with the values of the estimated parameters.

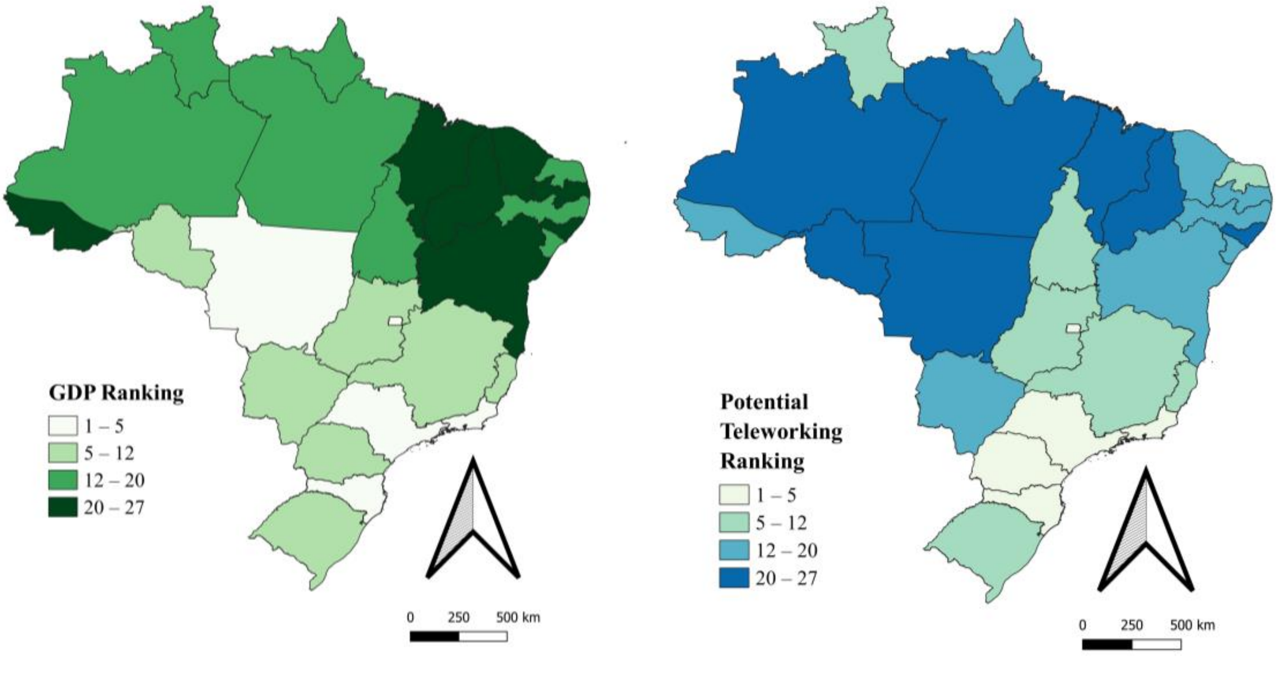
The potential telecommuting ranking variable was present only in the utility function of cluster 3 (Equation (7)). The results indicate that when the value of this variable is increased, the chances of obtaining a slight decrease in trips are 7.4% greater in relation to a moderate decrease in trips. In fact, increasing this variable means a lower potential for teleworking (since higher numbers indicate a worse ranking position), and consequently, a greater number of trips to workplaces.

Table 11. Results of multinomial logit model.

	Cluster	Independent Variable	β	Odds Ratio (OR)	*p*-Value
1	High decrease	(Intercept)	−42.313		0.026 **
		POA_j	1.631	5.108	0.022 **
		$POTR_j$	1.047	2.851	0.052 *
3	Slight decrease	(Intercept)	2.795		0.000 ***
		POA_j	−0.355	0.701	0.000 ***
		$RTELET_j$	0.071	1.074	0.021 **
4	Very slight decrease	(Intercept)	12.170		0.000 ***
		POA_j	−0.806	0.447	0.000 ***
		$POTR_j$	−0.730	0.482	0.000 ***
5	Increase	(Intercept)	15.579		0.000 ***
		POA_j	−1.408	0.245	0.000 ***
		$POTR_j$	−1.096	0.334	0.000 ***
		$NORTH_j$	3.712	40.944	0.000 ***

* *p*-value < 0.10; ** *p*-value < 0.05; and *** *p*-value < 0.01.

Although no economic variable was included in the model, Figure 4 shows that there is a relationship between the Brazilian state's GDP and its potential teleworking percentage. In general, high GDP values correspond to high teleworking potential. In fact, studies show that teleworking is usually associated with a high level of education, and consequently, with a high income [57,59,62].



(**a**) (**b**)

Figure 4. Ranking of the Brazilian states according to the GDP (**a**) and potential teleworking (**b**).

The value of the estimated parameter indicates that a North state increases the odds of belonging to the increase group in 40.944 times than to belonging to the reference category (moderate decrease). In general, this means that the North region is more likely to experience an increase in trips than a moderate decrease in trips to workplaces.

In fact, Figure 3 shows that the North region has part of its Brazilian states in the worst ranking positions of potential teleworking. According to Goés, Martins, and Nascimento [63], the North region of Brazil contributed with only 3.3% of people working remotely in 2020, which indicates a probable major use of the conventional work arrangement, and consequently, a large number of trips to workplaces.

To carry out the evaluation and analysis of the estimated model, some statistics were calculated. The Akaike information criterion (AIC) [64] presented a value of 285.942. The rho-squared and adjusted rho-squared values obtained for the final model were 0.573 and 0.530, respectively.

Based on the calibrated model, the clusters of each observation were estimated, and the classifications obtained were used to compare with the observed values matrix, as shown in Table 12. Finally, the chi-square test of adherence was applied to compare the classification obtained by the model with the observed data (Table 13).

Table 12. Comparison between estimated and observed matrix and overall model hit rate.

Observed Cluster	Estimated Cluster					Correct %
	1	2	3	4	5	
1	25	1	0	0	0	96.1%
2	1	20	12	0	1	58.8%
3	0	6	27	16	0	55.1%
4	0	1	8	33	4	71.7%
5	0	1	1	10	22	64.7%
Global %	13.8%	15.3%	25.4%	31.2%	14.3%	67.2%

Table 13. Chi-squared test of adherence.

Cluster	Observed n	Estimated n	Residual
1	26	26	0.0
2	34	29	5.0
3	49	48	1.0
4	46	59	−13.0
5	34	27	7.0
Test statistics			
Chi-squared		5.562	
Degrees of freedom		4	
Significance level		0.234	
Reference distribution's value: $\chi^2 = 7.779$			

H_0: observed and estimated values from classifications are similar. H_1: observed and estimated values from classifications are significantly different.

The estimated model showed a hit rate of 67.2%. The class with the lowest percentage of correct predictions (55.1%) was cluster 3 (slight decrease), which had most of its observations classified as cluster 4 (very slight decrease). On the other hand, cluster 1 (high decrease) had only one of its observations classified as cluster 2 (moderate decrease), which was the class with the highest percentage of correct prediction (96.1%).

The chi-square test of adherence was performed to verify whether the classification predicted by the model matches the observed values. In this test, the null hypothesis (H_0) assumes that the two classifications are similar, while the alternative hypothesis (H_1) assumes that there is no similarity between them. The results show a value of $\chi^2_{obs} = 5.562$ lower than the reference value $\chi^2 = 7.779$ for degree of freedom 4 and $\alpha = 0.1$. This indicates that the null hypothesis cannot be rejected; that is, the values estimated by the model are similar to the observed values.

5. Results Related to Primary Data—Year 2022

This section presents the main results obtained in each of the sub-steps of the methodological procedure adopted in the second approach.

5.1. Characteristics of the Pilot Sample

The pilot questionnaire was applied between 1 and 3 April 2022, obtaining responses from four individuals, two males and two females, with an average age of 37.8 years and standard deviation of 12.4 years. Two of the individuals were conventional (in-person) workers and two were full-time teleworkers. In addition, three of them had a postgraduate education and one completed high school. The average response time obtained was approximately 8 min and 34 s.

In fact, it was decided to utilize the pilot sample solely for the purpose of reviewing the questions and evaluating the appropriateness of the respondents' response times, rather than for estimating the minimum sample size required for the final questionnaire. This decision was based on the challenges associated with obtaining an adequate number of responses using snowball sampling.

5.2. Characterization of the Final Sample Obtained

The application of the final questionnaire took place between 12 April and 30 June 2022. A total of 247 responses were obtained from 63 cities in 18 Brazilian states. Most respondents work in person (51.4%), while the rest are split between part-time teleworkers (21.1%) and full-time teleworkers (27.5%). This shows a balance between telecommuters and in-person workers in the sample, but does not reflect the distribution observed in the Brazilian population, which was approximately 13% of teleworkers during the pandemic [31]. It is observed that the sample of in-person workers is represented by a majority of females (61.4%) as well as full-time teleworkers (51.5%), while the sample of part-time teleworkers is equally divided between females and males. As for age, teleworkers are concentrated in the 18 to 24 and 25 to 30 age ranges, representing approximately 35% of respondents, while in-person workers are older compared to teleworkers.

Regarding the place of residence, the answers were grouped by region, adding the North and Northeast regions. Thus, teleworkers are concentrated in the Southeast region (where 84.6% of part-time workers and 85.3% of full-time workers live), while 64.6% of in-person workers are located in this region and 25.2% of them are concentrated in the North/Northeast regions. For car ownership in the sample, the responses predominantly showed that individuals own a single car. Regarding the level of education, it appears that most teleworkers have a higher education (observed in 67.3% of part-time and 50.0% of full-time workers), as well as in-person workers (63.0%). However, it is observed that overall, the teleworkers' level of schooling is higher compared to in-person workers. This also shows a biased sample, considering that in Brazil, the basic level of education is 46.1% for people aged 25 years or more, according to the Brazilian Institute of Geography and Statistics (IBGE) [65]. This sample bias can be attributed to the snowball sampling procedure, and is commonly found in similar studies in the literature [66–68].

Regarding the type of company in which respondents work, the connection with private companies predominates in all regimes. In-person employees have the highest percentage of public companies (31.5%) and self-employed workers (10.2%). Finally, regarding the most used travel mode for work, for in-person workers, 50.4% use their own car or motorcycle, followed by public transport, with 18.9%. Part-time teleworkers mostly use their own car or motorcycle (42.3%), public transport (15.4%), and Uber or similar (15.4%). For full-time teleworkers, most do not use any travel mode (80.9%); however, those who do, use their own car or motorcycle or public transport (7.4% in both).

In short, in-person workers are mostly female, aged between 25 and 30, residing mainly in the Southeast region, and only have one car. They completed higher education, work in private companies, and travel to work mainly with their own car. For full-time teleworkers, the sample profile is the same as for in-person workers, except for the travel mode, which does not apply to the majority. As for part-time teleworkers, the sample profile is similar to in-person workers, except for the equal split between female and male genders.

5.3. Comparisons between Socioeconomic Characteristics, Region of Origin, and Work Regime

Table 14 shows the tests comparing socioeconomic variables, region of origin, and work regime. First of all, the first test was carried out in order to compare a socioeconomic variable and work regime. For example, for comparison between gender and work regime (df = 4 and χ^2 = 3.363) the null hypothesis was corroborated, which indicates that there is no association between gender and work regime. For this case, pairwise tests were not carried out. However, for comparison between education level and work regime (df = 8 and χ^2 = 19.501), the null hypothesis was rejected, which indicates an association between education level and work regime. For this case, pairwise tests were carried out to better analyze the differences between pairs of work regimes and education levels.

Table 14 also shows the χ^2 statistics, degrees of freedom (df), and *p*-value results, considering all regimes and pairwise regimes. The χ^2 statistics references were also included taking into account a 95 percent confidence level.

Analyzing the pairwise comparisons, one can see that the difference in the level of education is found essentially in the comparison between in-person workers and full-time teleworkers. In fact, it is observed that while the lowest level of education in the group of in-person workers is a complete secondary education (corresponding to 10.2% of individuals), only 1.5% of full-time teleworkers have this same degree of instruction, and of these, more than 75% have a complete or incomplete higher education. This finding was expected due to what was observed in the study by Góes, Martins, and Nascimento [31]. Another important result was the difference observed between teleworkers and in-person workers according to the residential region. There is a greater concentration of in-person workers in the North and Northeast regions, as well as a greater concentration of teleworkers in the Southeast region. This result was also expected due to the fact that the Southeast region is composed of states that have greater economic development and a greater volume of careers dependent on teleworking [30]. Such results were also observed in the first approach of this article (Figure 4).

5.4. Comparisons between Mobility and Work Regime

Considering the quantitative variables related to individuals' commuting to their workplaces, Table 15 shows the *p*-values of the Wilcoxon tests.

In fact, there are differences in both variables when comparing in-person work and full-time teleworking, an expected result since one regime requires daily commutes while the other can be carried out without any type of commuting. The same result occurs when comparing full teleworking and part-time teleworking. Moreover, in the comparison between the in-person work regime and the part-time teleworking, it appears there are no differences seen for the sample under analysis.

Regarding the variables related to the workers commuting, Table 16 shows the results of the chi-square tests. There was a significant association between the work regime and the frequency of trips for all travel modes (general), specifically for car trips (both as a lift and as a driver), for public transport, and for transportation mobility app. We also can associated work regimes and frequency of trips for all other trip purposes.

Table 14. Results of the chi-squared tests of socioeconomic variables and work regime—all regimes and between pairs of regimes.

Variable	Regime Work		Chi-Square Statistic					
			χ^2 (*p*-Value) df for Pairs of Regimes					
	χ^2 (*p*-Value) df	χ^2 Reference (95%)	In-Person vs. Full-Time Teleworking	χ^2 Reference (95%)	In-Person vs. Part-Time Teleworking	χ^2 Reference (95%)	Full-Time Teleworking vs. Part-Time Teleworking	χ^2 Reference (95%)
Gender	3.363 (0.186) 4	9.49	-		-		-	
Age	13.581 (0.653) 10	18.31	-		-		-	
Educational level	19.501 (0.007) 8	15.51	13.647 (0.011) 4	9.49	6.960 (0.141) 4	9.49	4.087 (0.405)	9.49
Region	18.999 (0.002) 6	12.59	13.529 (0.001) 3	7.81	7.906 (0.047) 3	7.81	5.029 (0.164) 3	7.81
Car ownership	10.145 (0.112) 6	12.59	-		-		-	

Legend. H_0: there is no association between socioeconomic variables and work regimes. H_1: there is an association between socioeconomic variables and work regimes.

Table 15. Results of the Wilcoxon tests of the variables average distance and travel time with work regime—between regime pairs.

Variable	*p*-Value (for Pairs of Regimes)		
	In-Person vs. Full-Time Teleworking	In-Person vs. Part-Time Teleworking	Full-Time Teleworking vs. Part-Time Teleworking
Average travel distance	0.000	0.338	0.000
Average travel time	0.000	0.021	0.000

Legend: H_0: there is no difference between travel quantitative variables and work regimes. H_1: there is difference between travel quantitative variables and work regimes.

Table 16. Results of the chi-squared tests for the categorical travel variables—all regimes and between pairs of regimes.

Variable	Regime Work		Chi-Square Statistic					
			χ^2 (*p*-Value) df for Pairs of Regimes					
	χ^2 (*p*-Value) df	χ^2 Reference (95%)	In-Person vs. Full-Time Teleworking	χ^2 Reference (95%)	In-Person vs. Part-Time Teleworking	χ^2 Reference (95%)	Full-Time Teleworking vs. Part-Time Teleworking	χ^2 Reference (95%)
TF (work) general	143.780 (0.000) 8	15.51	67.388 (0.000) 4	9.49	64.751 (0.000) 4	9.49	53.519 (0.000) 4	9.49
TF (work) on foot	14.357 (0.069) 8	15.51	-		-		-	
TF (work) bicycle	2.442 (0.956) 8	15.51	-		-		-	
TF (work) ride	28.037 (0.000) 8	15.51	15.321 (0.003) 4	9.49	9.753 (0.034) 4	9.49	12.848 (0.002) 4	9.49

Table 16. *Cont.*

Variable	Regime Work		Chi-Square Statistic					
			χ^2 (*p*-Value) df for Pairs of Regimes					
	χ^2 (*p*-Value) df	χ^2 Reference (95%)	In-Person vs. Full-Time Teleworking	χ^2 Reference (95%)	In-Person vs. Part-Time Teleworking	χ^2 Reference (95%)	Full-Time Teleworking vs. Part-Time Teleworking	χ^2 Reference (95%)
TF (work) driver	72.389 (0.000) 8	15.51	51.231 (0.000) 4	9.49	21.868 (0.001) 4	9.49	23.294 (0.001) 4	9.49
TF (work) public	28.512 (0.001) 8	15.51	11.576 (0.013) 4	9.49	17.257 (0.001) 4	9.49	5.983 (0.083) 4	9.49
TF (work) app	18.863 (0.012) 8	15.51	9.691 (0.024) 4	9.49	4.794 (0.300) 4	9.49	16.021 (0.000) 4	9.49
TF (work) taxi	4.498 (0.416) 8	15.51	-		-		-	
TF (market) general	18.780 (0.014) 8	15.51	14.251 (0.003) 4	9.49	13.401 (0.008) 4	9.49	1.625 (0.818) 4	9.49
TF (leisure) general	20.322 (0.006) 8	15.51	13.244 (0.010) 4	9.49	11.091 (0.021) 4	9.49	1.948 (0.763) 4	9.49
TF (health) general	20.269 (0.013) 8	15.51	13.203 (0.009) 4	9.49	17.203 (0.002) 4	9.49	0.920 (0.935) 4	9.49
TF (O) on foot	15.716 (0.037) 8	15.51	13.720 (0.006) 4	9.49	7.076 (0.135) 4	9.49	2.007 (0.726) 4	9.49
TF (O) bicycle	9.633(0.273) 8	15.51	-		-		-	
TF (O) ride	17.222 (0.032) 8	15.51	8.486 (0.071) 4	9.49	3.839 (0.436) 4	9.49	17.026 (0.002) 4	9.49
TF (O) driver	15.375 (0.046) 8	15.51	7.119 (0.130) 4	9.49	6.033 (0.194) 4	9.49	10.788 (0.027) 4	9.49
TF (O) public	5.174 (0.760) 8	15.51	-		-		-	
TF (O) app	5.333 (0.715) 8	15.51	-		-		-	
TF (O) taxi	5.292 (0.260) 8	15.51	-		-		-	
TT (work)	124.160 (0.000) 10	18.31	94.282 (0.000) 5	11.07	7.734 (0.264) 5	11.07	58.824 (0.000) 5	11.07
TT (market)	13.519 (0.325) 10	18.31	-		-		-	
TT (leisure)	22.214 (0.033) 10	18.31	16.918 (0.009) 5	11.07	6.167 (0.397) 5	11.07	8.077 (0.238) 5	11.07
TT (health)	11.038 (0.540) 10	18.31	-		-		-	
TD (work)	137.110 (0.000) 8	15.51	114.720 (0.000) 4	9.49	6.102 (0.304) 4		55.253 (0.000) 4	9.49
TD (market)	18.913 (0.032) 8	15.51	11.160 (0.046) 4	9.49	10.930 (0.040) 4		5.675 (0.330) 4	9.49
TD (leisure)	20.012 (0.033) 8	15.51	12.019 (0.036) 4	9.49	14.138 (0.013) 4		3.412 (0.678) 4	9.49
TD (health)	11.719 (0.307) 8	15.51	-		-		-	

Legend: TF = travel frequency; O = all other purposes beyond work; TT = travel time; and TD = travel distance. H_0: there is no association between travel-related variables and work regimes. H_1: there is an association between travel related variables and work regimes.

In the comparisons between pairs of regimes, there was a difference in the distribution of the frequency of work-related trips (overall) in all combinations. In fact, and as expected, the frequency of trips increases according to the level of in-person work carried out by individuals, where about 61% of in-person workers make three or more trips per week, contrasting with approximately 21% of part-time teleworkers and 1.5% of full-time teleworkers. There is also a similar pattern in the frequency of work-related trips in car mode (both as a passenger and as a driver). Regarding the frequency of trips in the mobility application mode, the difference is seen when comparing the full-time teleworking regime with the others, but only due to its low use by full-time teleworkers.

With regard to the frequency of use of public transport considering the work regime, the difference is seen when comparing the in-person work regime with the others, since approximately 16% of in-person workers use this travel mode three or more times a week, while less than 2% of teleworkers use this mode. Additionally, considering work-related trips, the differences in travel time and distance occur predominantly between full-time teleworkers and the other regimes, although this is mostly due to the fact that there is practically no commuting in remote work. In fact, this option includes around 75% of full-time teleworkers, both in terms of distance and travel time.

Considering all the other purposes together, it is observed that the difference in the walking mode occurs only between the in-person work regime and the full-time teleworking regime, where about 35% of full-time teleworkers use this travel mode three or more times a week, in contrast to approximately 15% of in-person workers. Considering all the other purposes together, the difference in car mode (both as a ride and as a driver) occurs between full and part-time teleworking regimes, with more than half of full-time teleworkers not using this travel mode, in contrast to approximately 36% of part-time teleworkers. Specifically, it appears that in-person workers make fewer trips to the market/store than teleworkers (about 36% of them do not make any trips for this purpose, in contrast to 19% of part-time teleworkers and 20% of full-time teleworkers). Likewise, in-person workers also make fewer leisure-related trips (approximately 19% of them do not make any trips for this purpose, contrasting with 6% of part-time and full-time teleworkers) and health (36% do not make trips for this purpose, in contrast to 25% of part-time and full-time teleworkers). With regard to travel distances for market and leisure purposes, it appears that teleworkers choose closer locations (between 1 km and 10 km) than in-person workers. In addition, approximately 76% of full-time teleworkers travel up to 30 min for leisure-related purposes, compared to 57% of in-person workers.

5.5. Comparisons between ICT Cognitive Engagement and Proficiency and Work Regime

For the relationships between the variables related to ICTs and work regimes, Table 17 summarizes the main results of the statistical tests performed.

Table 17. Results of the chi-squared tests for the variables related to cognitive engagement and ICT proficiency—all regimes and between pairs of regimes.

Variable	Regime Work		Chi-Square Statistic					
			χ^2 (*p*-Value) df for Pairs of Regimes					
	χ^2 (*p*-Value) df	χ^2 Reference (95%)	In-Person vs. Full-Time Teleworking	χ^2 Reference (95%)	In-Person vs. Part-Time Teleworking	χ^2 Reference (95%)	Full-Time Teleworking vs. Part-Time Teleworking	χ^2 Reference (95%)
ICT Cog. Engagement 1	12.978 (0.087) 10	18.31	-		-		-	
ICT Cog. Engagement 2	11.308 (0.176) 10	18.31	-		-		-	
ICT Cog. Engagement 3	10.706 (0.213) 10	18.31	-		-		-	
ICT Cog. Engagement 4	22.243 (0.005) 10	18.31	11.619 (0.018) 4	9.49	12.939 (0.010) 4	9.49	1.476 (0.761) 4	9.49
ICT Cog. Engagement 5	10.576 (0.224) 10	18.31	-		-		-	
ICT Proficiency 1	48.259 (0.000) 10	18.31	34.514 (0.000) 4	9.49	22.065 (0.000) 4	9.49	2.6622 (0.531) 4	9.49
ICT Proficiency 2	23.062 (0.003) 10	18.31	18.666 (0.001) 4	9.49	7.4236 (0.110) 4	9.49	4.1535 (0.397) 4	9.49

Legend: ICT Cog. Engagement 1: confidence to handle computers; ICT Cog. Engagement 2: ability to solve computer problems; ICT Cog. Engagement 3: ease to become acquainted with new computer programs; ICT Cog. Engagement 4: preference for computer jobs; ICT Cog. Engagement 5: interest on new computer technologies; ICT Proficiency 1: proficiency in virtual meeting platforms use; and ICT Proficiency 2: proficiency in activity management platforms use. H_0: there is no association between ICT related variables and work regimes. H_1: there is association between ICT related variables and work regimes.

There is a significant difference in the preference for carrying out work on a computer (ICT Cognitive Engagement 4) between the in-person and teleworking regimes, since 85.29% of full-time teleworkers and 86.53% of part-time teleworkers responded that they agreed (levels 4 and 5) with the statement related to this item ("I prefer to work on a computer or cell phone than to work with manual methods"), while 70.87% of in-person workers gave the same response. Similarly, there is a significant difference in familiarity with virtual meeting platforms (ICT Proficiency 1) between these same work regimes, with 100% of full-time teleworkers and 96.16% of part-time teleworkers responding that they agreed (levels 4 and 5) with the statement related to this item ("I am very familiar with virtual meeting platforms"), while only 70.87% of in-person workers gave the same response. These results were expected, since computer and cell phone use are quite common in the context of teleworking, as well as online meetings. There is also a significant difference in proficiency in the use of activity management platforms (ICT Proficiency 2) between the in-person work regime and the full-time teleworking regime, as 73.53% of full-time teleworkers responded that they agreed (levels 4 and 5) with the assertion related to this item ("I am very familiar with platforms for managing and monitoring work activities"), while only 52.76% of in-person workers equally agreed with the assertion. This result is also in line with expectations, since in the context of teleworking, the activities cannot be managed and monitored in person, requiring the use of a platform or software.

6. Discussions Regarding the Main Findings

Taking into account the first approach, with the secondary public data, the application of cluster analysis led to the identification of five groups, used as dependent variable for the calibration of the multinomial logit model in which the utility functions were defined, and the resulting final model has all significant parameters at a confidence level of 90%. It was found that the percentage of people opting for remote work is directly proportional to the reduction in trips to workplaces. Indeed, studies showed that the restrictive measures imposed by COVID-19 led to a greater adoption of teleactivities (including teleworking), resulting in significant impacts on mobility [14–16,69]. Although no economic variables were included in the model, the potential teleworking percentage was included, and it is widely recognized that remote work is typically associated with a high level of education, and consequently, high incomes [57,59,62]. The estimated model showed a global hit rate of 67.2%, and the chi-square test of adherence results show that the values estimated by the model are similar to the observed values.

The primary data, used in the second approach, allowed for obtaining the profile of workers in different regimes. In-person workers have a greater concentration in the North and Northeast regions, as shown by Góes, Martins, and Nascimento [37]. They are mostly female, aged between 25 and 30, and only have one car. They have usually completed a higher education, work in private companies, and travel to work in their own car. In comparison, in-person workers make more work trips than the other regimes, and less trips for leisure, market, and health. These workers have a slightly lower technological engagement than teleworkers.

Full-time teleworkers have almost the same profile as in-person workers, except for the travel mode used for work trips, which does not apply to the majority. They are concentrated in the Southeast region, which has greater economic development and a wider range of careers dependent on teleworking. These results are also consistent with those found by Góes, Martins, and Nascimento [37]. Their study found that the majority of full-time teleworkers were located in this region, and the full-time teleworker profile was similar to that found in this study, in which the majority of women engaged in remote work had a high level of education and ranged between 20 and 49 years of age. Full-time teleworkers are the ones with a lower frequency for work trips but are also the ones that do more trips to the market, usually to closer locations. For the ICTs, these workers have more engagement with computers, cell phones, virtual meetings, and managing work platforms, as these are commonly used in teleworking.

For part-time teleworkers, the profile is similar to in-person workers. Those are concentrated also in the Southeast region. Considering mobility, part-time teleworkers are similar to in-person workers, except that they make more trips for leisure and health purposes. Concerning ICTs, they are similar to full-time teleworkers.

7. Conclusions, Contributions, and Research Constraints

7.1. Summarizing the Findings and Main Conclusions

This article generated two distinct analyses related to the relationship between teleworking, mobility, and economic development. These relationships were investigated in the first approach, associating them with the decrease in work trips through public data aggregated at the Brazilian state level and related to the beginning of the COVID-19 pandemic (year 2020). It can be concluded that economic development is positively associated with teleworking, which in turn influences a decrease in trips, as verified in some studies in the literature [30,61].

However, conclusions regarding only the first approach tend to be biased, since the data refer to the beginning of the pandemic. Thus, the decrease in trips was mandatory and was due to health-related measures. The pandemic heightened the use of Communication and Information Technologies, and consequently, teleworking. Therefore, there are a series of simultaneous interrelationships that can be addressed in future work.

The second approach, however, brings disaggregated and self-reported data in a period of greater relaxation of pharmacological measures and closer to normality. Thus, the relationship between the teleworking regime and the frequency of trips is highlighted, especially for work-related purposes. In addition, the influence of the Brazilian region on the work regime was also proven in the previous approach.

The main findings regarding the second approach were:

- Socioeconomic and Region: Education level and country region are associated to regime work;
- Travel characteristics: Average travel distance and average travel time are also associated to regime work;
- Travel characteristics: Travel frequency of work trips are also related to regime work;
- ICT cognitive engagement and proficiency: Preference for computer jobs, proficiency in using virtual meeting platforms, and proficiency in using activity management platforms are also associated to regime work.

7.2. Methodological Constraints and Future Studies

Considering the first approach, our research did not test interaction terms. We also did not conduct statistical tests to conclude about the interaction term model improvement. The interaction test may be conducted with the Wald chi-squared test or a likelihood ratio test comparing models with and without the interaction term. However, we suggested testing interaction terms for future studies in order to improve the model and the interpretation regarding the relations.

It should be noted that the study was conducted at a local level, and its conclusions cannot be extrapolated to the Brazilian or the global population. The findings are confined to a case study based on a non-probabilistic sample and are aimed at comprehending the phenomenon within this specific sample.

It is recommended, in the future, to replicate the collection at a later period, carefully applying sample proportionality in relation to the Brazilian states. Teleworking is proven to be a new reality, especially for many private companies, and could be an interesting mobility management policy. However, the permanent change in the regime must be carried out cautiously, and one should bear in mind the legal and labor matters, as well as health, safety, and the right to disconnect. This paper, however, only addressed the popularization of teleworking and possible impacts on mobility and did not consider the labor issues raised.

7.3. Contributions

The COVID-19 changes in urban mobility should bring some positive implications striving for a more sustainable, democratic, and safe transportation system. The focus of the goal should be to support positive impacts of the mobility changes observed during the pandemic. Costa et al. [11] suggest increasing infrastructure for active modes, reforming ridesourcing service regulations, implementing car demand management strategies, and improving urban public transport quality. One of the most important potential public policies should be implementing strategies to support teleworking as a form of traffic demand management.

Finally, this study brings important contributions, seeing that by preserving the practice of teleworking and new habits, in a post-pandemic scenario, investigations related to substituting trips, particularly work-related trips, can be very opportune.

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Institutional Review Board Statement: For this type of non-interventional study, which involves voluntary participation, ethical approval is not required by the Ministry of Health—National Council of Health. In any case, the anonymity of all participants was assured; they were fully informed why the research was being conducted and that no personal risks were associated with the survey.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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