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Can the COVID-19 Crisis be a Catalyst for Transition to Sustainable Urban Mobility? Assessment of the Medium- and Longer-Term Impact of the COVID-19 Crisis on Mobility in Brussels

Cathy Macharis†, Sara Tori†, Alice de Séjournet†, Imre Keseru and Lieselot Vanhaverbeke*

Department BUTO, MOBI Mobility, Logistics and Automotive Technology Research Centre, Vrije Universiteit Brussel, Brussels, Belgium

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***Correspondence:**
Cathy Macharis
cathy.macharis@vub.be

†These authors have contributed equally to this work

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In this paper, we investigate what the impact of the COVID-19 crisis was on travel patterns and how it could be a catalyst for the transition toward a more sustainable mobility system. To study this, we use the sustainable mobility framework of the 7A's, namely *Awareness*, *Avoidance, Act and Shift*, *Anticipation of new technologies*, *Actor involvement, Acceleration,* and *Adaptation of behavior*. For each of the first 5A's, we analyze the changes in mobility brought along in the different periods of the COVID-19 crisis. Our mixed methods approach includes a thematic analysis of online press articles and an analysis of traffic and passenger volume data in Brussels, Belgium. Our results show that the measures to stop the spread of the COVID-19 virus had significant consequences for mobility in Brussels by raising *Awareness* of the positive impacts reduced traffic can have on livability. The measures decreased travel demand (*Avoidance*) in general, but especially in the context of commuting and shopping trips which declined in favor of telework and online shopping. The majority of mobility measures that were implemented belong to the *Act and shift* category and they were especially aimed at promoting active mobility like walking. There was also a positive influence on the *Anticipation of new technologies*, as internal combustion engine sales dropped and electric vehicle sales increased. However, the data analysis also shows an incremental return to business-as-usual after the 2020 summer holidays. Parts of this can be linked back to a disregard of *Actor involvement*, resulting in a resistance from stakeholders to several of the measures. We conclude with recommendations based on *Acceleration* and *Adaptation of behavior* on how to support a sustainable transition and lasting behavioral change in the post-COVID era.

Keywords: COVID-19, sustainable mobility, thematic analysis, 7A's of sustainable transition, behavioral change, Brussels

INTRODUCTION

The COVID-19 crisis has triggered unprecedented health protection measures across Europe that limited the movement of people through "(semi-) lockdowns," i.e., measures that restricted the type, distance, time, and duration of movements for an extended time period. On the one hand, the virus, and the measures that ensued to stop its spread, have had a significant impact on travel demand by changing people's travel behavior and their perceptions of different modes of transport. On the other hand, transport supply, i.e., the capacity of public transport, also adapted due to new safety standards.

What has characterized this pandemic is how it has managed to completely uproot most aspects of society in less than a year. In this way, it can be assumed that there will be a "before" and an "after" COVID era. While it has had grave consequences to people's health, jobs, economic activity, and social networks, some potential positive "side effects" have also been recognized with regard to mobility patterns and preferences. It has also highlighted a need for better resilience. In essence, the coronavirus is a "wild card" event, i.e., a low probability but high impact occurrence that is often overlooked in traditional decision making (Mendonça et al., 2004).

From this apparent lack of preparation with regard to the pandemic, the question arises whether the crisis can have a positive impact on the transition toward a more sustainable mobility system. The main barriers to transport innovation and the transition to a more sustainable transport system are the resistance to change and lack of political will (Orcutt and AlKadri, 2009). Crises, however, have been able to create conditions for policy and paradigm change (Kern et al., 2014) as well as behavioral change. Economic crises have been found to influence travel behavior, as they trigger a modal shift from car use to public transport because of affordability problems (Papagiannakis et al., 2018). Köhler et al. (2009) argues for the need for radical rather than incremental technological improvements in transitioning toward sustainable urban mobility. Such radical changes can be brought on by crises.

A global pandemic like COVID-19 may provide an opportunity for transition. This should be coupled with integrated approaches to reduce demand and encourage modal shift. Behavioral and policy changes caused by the pandemic may help to improve environmental conditions (Freire-González and Font Vivanco, 2020). Such improvement can be a result of modal shift and the reduction of travel demand, the redesign, and more balanced use of public space (Honey-Roses et al., 2020); as well as the increased awareness of the environmental impact of transport. Since the primary aim of the measures during the pandemic is to protect human health, i.e., to reduce the spread of the virus (Saadat et al., 2020) and the COVID-19 crisis is still very recent, there is very little evidence available about the possible long-term impacts on urban mobility. Most efforts so far tried to estimate the impact of mobility restrictions on the spread of the virus (Soucy et al., 2020), investigated the impact of mobility restrictions on air quality (Freitas et al., 2020; Saadat et al., 2020), studied the potential modal shift (Teixeira and Lopes, 2020), tried to estimate the extent of the transformation of public spaces after the pandemic (Honey-Roses et al., 2020), and used smartphone data to estimate the effectiveness of lockdown measures (Wellenius et al., 2020).

The effects of the COVID-19 pandemic on mobility in the medium and long term are not immediately obvious. However, within the crisis, we have undergone several different periods that were characterized by varying levels of restrictions. The investigation of the impact of each stage of these restrictions on travel behavior can enable us to get an idea of whether the travel behavior changes will last. In this paper, we investigate how the COVID-19 crisis can support the transition to a more sustainable urban mobility system focusing on Brussels, Belgium. The case of Brussels is particularly interesting as, on the one hand, the city implemented quite strict mobility measures. On the other hand, it is among the regions in Belgium that have been hit the hardest by COVID-19 since the outbreak of the pandemic (Dupondt, 2021).

We approach the topic from two viewpoints. Firstly, we investigate what the impact of the various temporary measures was on travel patterns based on secondary datasets (public operators and government authorities' data) in different periods of the crisis. Secondly, we study the expectations of different actors concerning the immediate and longer-term impacts and the opportunities for behavioral change toward a more sustainable mobility system. This mixed methods approach will highlight the potential for change. Our paper is structured along the essential elements of the sustainable mobility transition, i.e., the 7A's of *Awareness, Avoidance*, *Act and shift, Anticipation of new technologies, Actor Involvement, Acceleration*, and *Adaptation of behavior* (Macharis, 2020). *Awareness* represents tools and campaigns, which can be used to inform governments, companies, and citizens about the societal cost of mobility as sustainable mobility can only succeed if it is understood and accepted by people (Banister, 2008). *Avoidance* covers measures to avoid unnecessary travel, i.e., reduce travel demand, decrease the need for parking places, and reduce vehicle ownership. *Act and shift* represents measures to promote a shift in travel demand to less congested hours and to contribute to a modal shift to sustainable modes. It also covers the shift from car ownership to Mobility-as-a-Service. The fourth A stands for *Anticipation of new technology* (e.g., electric and autonomous vehicles) that can help this transition. *Actor involvement* is the way the different actors participate in the transition process. The transition to sustainable mobility requires concerted and diverse actions from many actors (Banister, 2008). Urban mobility planning and operation usually involves several stakeholders with diverse objectives, including the government (or policy makers), citizens, transport operators, businesses, and transport users (Keseru et al., 2016). They can accelerate or hinder the implementation of new and the extension of existing measures. Therefore, it is important to know the expectations and experiences of these actors toward the COVID-19 related measures. In this paper, we categorize measures that had an impact on mobility during the COVID-19 crisis under the five first A's and investigate how these measures can contribute to the sustainable mobility transition. We finish with recommendations based on the last 2 A's: *Acceleration*, i.e., the need to have a policy framework

pointing toward sustainable options, and *Adaptation of behavior*, i.e., the change in individual behavior.

The paper is structured as follows. First an outline of the methods we used is given. The next sections present the results and the discussion. Then, the final section summarizes findings and gives some concluding remarks.

MATERIALS AND METHODS

Our approach is a mixed method one. First, we collected time series data for different transport modes to see the changes in terms of the first 4A's (*Awareness, Avoidance*, *Act and shift*, and *Anticipation*). We did not perform data analysis for *Actor involvement* because this is more frequently measured through qualitative, and not quantitative, data. Secondly, we performed a reflexive thematic analysis of online press articles to better understand the occurrence of mobility measures and actor sentiments about them. The analysis was structured according to the stages of COVID-19 measures that were taken. Our analysis covers the time between March 18, 2020, and November 18, 2020. We distinguish between six different periods: (1) the pre-COVID period, (2) the strict lockdown, starting on March 18, (3) the gradual release starting on May 18 with the return to school, although some activities resumed earlier, (4) the summer starting on July 1, (5) the schoolyear starting on September 1, and finally (6) the second, light lockdown starting on October 19 with a curfew and the closing of bars and restaurants. Our analysis covers a period of 8 months and ends on November 18 after the extended school holidays.

Data Analysis

To assess the change in mobility for the Brussels region due to the current COVID-19 crisis, secondary data were gathered, from public authorities and transit operators, that reflect the changes in travel behavior i.e., road traffic counts, cycling counts, and public transport occupancy rates.

The changes are assessed by comparing these mobility data for each day of the investigated period to a benchmark measured before the first COVID-19 lockdown. The benchmark period has been chosen as the 7 weeks between two periods of school holidays, from January 6 to February 21, 2020. For each weekday, the mean daily mobility count in the period is calculated as the benchmark. The six periods during the COVID-19 crisis identified above are then compared, for different transport modes, in terms of their mobility volume. In what follows, we will describe these different data sources and the analyses.

First, to assess the changes in road transport, we analyzed data on the amount of vehicles recorded by several detectors put in place in tunnels by the regional mobility department (Brussels Mobility., 2020b)[1]. Due to different tunnels closing at night or in the summer for maintenance, 19 counters were used for our analysis. The night counts (between 10 p.m. and 6 a.m.) were not considered. The data is recorded on an hourly basis which allows for an additional analysis comparing the different periods in terms of mobility throughout the day. We also collected secondary data for car registrations at the national level, which gives insights into car purchase behavior.

Besides traffic counts, the volume of cyclists is counted on several cycling paths (Brussels Mobility., 2020a). Here, 11 counters were considered and, similarly to road traffic, only the volume during daytime was taken into account. The number of cyclists is recorded every 15 min. This also allows for an analysis of the number of cyclists throughout the day and between periods. Because cycling might be influenced by seasonality (Desmet et al., 2019), the change in traffic volume was also compared to the equivalent day in 2019. For this second analysis, only seven counters were already in place in 2019.

Finally, public transport is accounted for by two datasets. Data provided by the national railway operator (SNCB-NMBS) provides the average occupancy rate computed based on the recordings in the busiest section of the train traveling through Brussels. The average daily value is available for all of 2020, along with the average occupancy rates during off-peak hours. This data is used to measure the change in passenger volumes in each of the six periods compared to the benchmark. In addition to this, the Brussels public transport operator (STIB-MIVB) has shared their data on the occupancy rate of their vehicles compared to their own benchmark. The benchmark is here taken as the 3 weeks before the holiday period (February 1st to 21st, 2020). Two datasets are available: one for the underground vehicles with measurements taken in most of the metro stations and a second one for the other vehicles (tram and bus) for which approximately 40% of the fleet is equipped with counters[2]. Some daily data are unavailable as they have been retrieved of the analysis by the operator when specific events (e.g., strikes, public city-wide events) explain an unusual occupancy rate.

Reflexive Thematic Analysis

To analyze the various measures taken and the expectations of different actors concerning the immediate and longer-term impacts along with the opportunities for behavioral change as a result of the crisis in Belgium, a reflexive thematic analysis of online press articles covering the same period has been carried out. Analyzing press articles gives the opportunity to take a wide array of sentiments into consideration, as the press reflects different and diverse viewpoints. Furthermore, even though the exact extent of the relationship between media consumption, social norms, and individual intentions and behavior is still debated, journalism can exert influence on its readers (Vigar et al., 2011). Lastly, as the timeframe covered is very recent, there is a limited number of other available data sources, therefore the press analysis complements our data analysis.

We used a deductive approach, which entails that coding and theme development are carried out based on existing concepts and ideas. A deductive approach provides less rich overall descriptions, but it allows for a more detailed analysis of some parts of the data (Braun and Clarke, 2006). Thematic analysis consists of six steps (Braun and Clarke, 2006). The first phase included reading and selecting the articles to be analyzed. All

[1]Historical data are currently only available upon request.

[2]These public transport datasets were received from both public transport operators for the purpose of this paper and with a non-disclosure agreement.

TABLE 1 | The results of the keyword search.

	Total hits	Hits within timeframe	Selected articles (about Brussels)	Articles removed before coding	Total articles coded
BRUZZ	22,160	1,423	138	40	99
De Morgen	6,213	897	9	8	1
Le Soir	9,373	1,604	58	55	3
Total for all newspapers	37,746	3,924	205	103	103

potential articles based on a keyword search that fell within the timeframe were read to evaluate whether to include them. The pre-selected articles were then read a second time after they were logged into the Nvivo[3] software, which resulted in the further elimination of some articles. For the second step, as we employed a deductive approach, the initial codes were structured around the 5A's, the measures taken (categorized as either favorable to sustainable mobility, or unfavorable to it), the various key actors, and the sentiments expressed by those actors. We also coded according to the locations in Brussels where the measures were being taken, as well as the dates on which the measures were implemented. Step three involves searching for themes. As the analysis was structured around measures and key actors' sentiments, these overarching themes had already been identified. The following codes were applied during the analysis: (1) Dates, (2) Measures, (3) 5A's, (6) Actors, (7) Sentiments, and (8) Locations. Steps four and five, i.e., reviewing and naming themes, were rather limited as the themes had already been identified. Step six involved writing up the results of the analysis.

Part of the thematic analysis focuses on the analysis of sentiments expressed in the news articles, to grasp the expectations and perceptions of key mobility actors in light of the COVID-19 crisis. For this purpose, we divided language units into one of three categories of sentiments: negative, positive, and neutral. In addition, codes were also attributed to identify the actors that were expressing their opinion. The analysis was carried out with regards to the measures introduced during the lockdown and their effects on personal mobility and logistics, as well as with regard to mobility developments in general during the crisis, like changes in travel behavior. Only quotes by stakeholders were used, as journalists often want to give a feeling of objectivity and therefore withhold from using vocabulary that is either clearly positive or negative (Balahur et al., 2013).

For the purpose of the analysis, three online newspapers were consulted. One of the newspapers covers only Brussels (BRUZZ[4]), while the other two have a national scope (De Morgen[5], Le Soir[6] The first newspaper was chosen because of its specific focus on Brussels. The other two were consulted because they are from the other two Belgian regions (Flanders and Wallonia), while still having articles concerning Brussels. This was done to provide a more balanced view on the thematic analysis. Bruzz is only in Dutch, and there is no French-speaking equivalent for it.

In order to avoid duplicate information and coding, articles from De Morgen and Le Soir were only considered for analysis if they contained information that had not been previously reported on by Bruzz. The timeframe within which the articles were selected was from March 18, 2020 (beginning of the lockdown in Belgium) to November 18, 2020 (end of the extended school holidays). To find articles relevant for the analysis, the following keywords were used: "mobility, bike lanes, air quality, teleworking, e-commerce, cars, and public transport." **Table 1** gives an overview of the results.

Articles selected for analysis were based on whether they dealt with measures or effects directly related to the COVID-19 crisis. Articles with regards to mobility interventions already planned or underway before the crisis were excluded as well as articles that did not incorporate sentiments or interventions from key actors. During the process of logging the articles into Nvivo, and before starting to code, some more articles were excluded if it turned out that they were not as relevant for the analysis as initially thought. At the end of the selection process, 103 articles remained for the analysis.

RESULTS

This section presents the results of the data analysis, followed by the results of the reflexive thematic analysis.

Data Analysis

In general, the COVID-19 crisis led to a decrease in mobility throughout 2020. For all modes, the strict lockdown period was when the strongest decrease was encountered: an average on weekdays of −87.35% for train, −55.28% for road traffic, and −28.58% for cycling. Then, the release of the measures in May led to a gradual increase of traffic and a peak was reached at the start of the summer. In August, with the implementation of some new measures, mobility levels decreased slightly, but rose again in September with the start of the schoolyear. Finally, the second, lighter, lockdown led to a new decrease in mobility, although a less severe one than in March. While cycling volumes quickly recovered and overtook pre-lockdown levels, this was not the case for road traffic or public transport occupancies. The following paragraphs will analyze, in greater depth, the mobility changes for these three transport modes across the six time periods.

First, **Figure 1** shows the changes in road traffic levels with the six different periods highlighted with dotted lines.

[3]https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home
[4]https://www.bruzz.be/
[5]https://www.demorgen.be/
[6]https://plus.lesoir.be

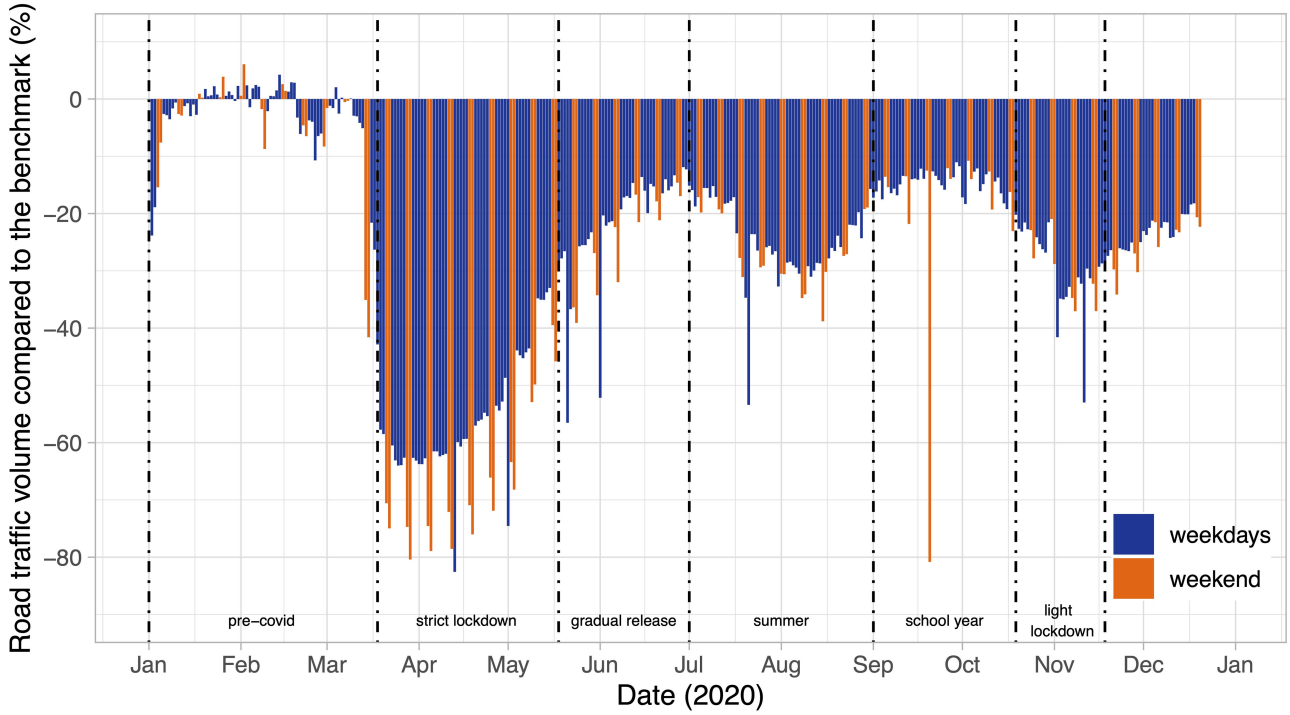

FIGURE 1 | Evolution of road traffic levels in the Brussels Capital region in 2020 compared to the pre-lockdown benchmark (data source: Brussels Mobility). Outliers includes car-free Sunday on September 20 and some public holidays.

With the injunction to "stay at home," traffic levels decreased rapidly mid-March. The average decrease for the lockdown period was, on weekdays, −55.28% when compared to the benchmark. During the gradual release and the summer period, traffic volume decreased by only a quarter (21.94 and 24.41% on weekdays respectively) compared to pre-COVID levels. It increased again with the return to school, reaching an average level only 14.97% lower than normal times. The second and softer lockdown with the curfew led to another, less drastic decrease in traffic, with levels similar to the summer period (−25.84%), although telework measures were still in place. During the strict lockdown the change of traffic volume was stronger in the weekend (−67.18%), a difference with the weekdays that was less significant in the other periods. Concerning traffic levels across the day, the morning and evening rush hours peaks still appear during the week in every period with no strong differences (cf. **Figure 2**). When looking at sales data, sales of combustion engine in Belgium decreased in 2020 (−34.02% for gasoline and −17.77% for diesel), while the sales of electric or hybrid vehicles increased by 170 and 180% respectively (cf. **Figure 3**). Regarding shared vehicles, the Belgian network of shared mobility reported that during the COVID-crisis the use sometimes fell by 80% due to the ban on unessential trips. However, they did not noticed much negative influence on the number of users, which grew by 40.4% in Brussels in 2020 (Autodelen, 2021).

Figures 4–6 show the change in public transport occupancy rates (trains, metros, trams, and buses respectively). Public transport was strongly impacted by the COVID-19 crisis, with occupancy rates decreasing by more than 80% during the strict lockdown period. It increased again during the release period and reached, at the start of the summer, close to half of the benchmark occupancy rate. It decreased again in the summer period, in which occupancy rates are usually anyway lower. The start of the schoolyear is when the highest occupancy rates can be noticed (−30% to −40%), although they did not yet recover to pre-COVID levels. The curfew and new restrictions in October then led to another sharp decrease in public transport use. Across all periods, metros and trains seem to have been more strongly impacted than buses and trams. This can be explained by a large number of commuters using these modes, while bus and tram are favored by pupils going to school or for shorter distances. While the former trips were, in each period, strongly reduced due to telework, the later trips were not always as affected. It can also be seen from the train occupancy data that, across all periods, that these differences are stronger during peak hours than off-peak hours.

Lastly, **Figure 7** presents the daily change in cyclists counted across 2020 compared to the benchmark measured before the COVID-19 crisis. Strong differences between weekdays and weekends can be seen. While before the lockdown, weekends record on average less than half the cyclists of a weekday, at the end of the lockdown, the number of cyclists during the weekend surged (+197.16%). During the gradual release, this surge reached an average change of +237.02% compared to the benchmark. In the weekend, all periods recorded an average number of cyclists superior to the benchmark while during

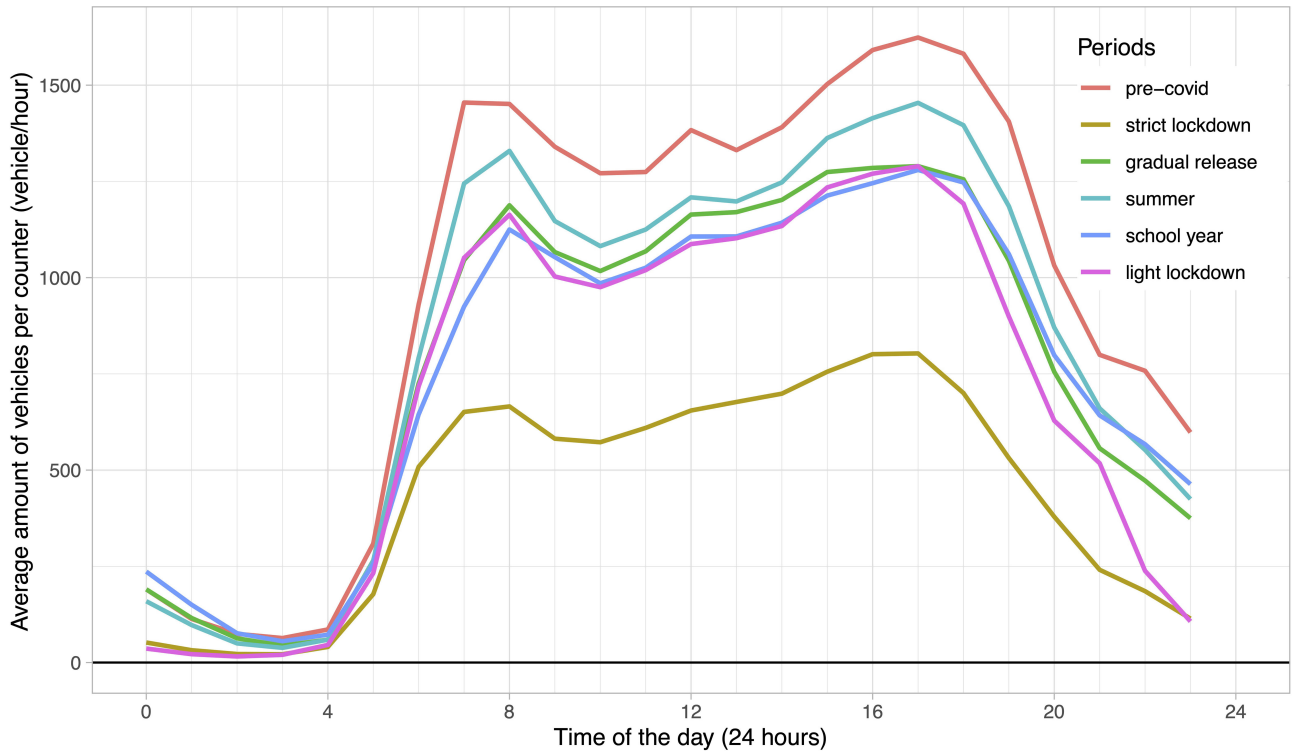

FIGURE 2 | Average road traffic levels per counter during the week and across the day for each of the six considered periods (data source: Brussels Mobility). Due to tunnel closing at night for maintenance, the extreme left and right of the graph are less reliable.

the week only the lockdown period saw a decrease in cyclists (−28.58%). The peak is on the weekend the highest between 2 and 4 p.m. during the strict lockdown, closely followed by the same time window in the release period. This suggests that recreational cycling gained in popularity. Before the crisis, the curve was flatter, with a lower cyclist volume spread across the weekend (cf. **Figure 8**). Although it might be expected that the seasons play a role in these results, a benchmark against the same day in 2019 (cf. **Figure 9**) show a similar increase in the number of cyclists (+171.64% in the weekend during the lockdown).

Looking only at the weekdays, the number of cyclists during the strict lockdown was inferior to the benchmark (−28.58%). Interestingly, cycling counts are only 8.42% lower than the counts of the same period in 2019, showing that this bicycle rise was already underway. For the period before this lockdown, the number of cyclists during weekdays were 79.29% higher than in 2019. Then, during the gradual release, the level rose and were 33.07% above the benchmark. During the school period, they were 40.83% above the benchmark. The summer counts were 6.5% above the benchmark but 34.99% above the counts of 2019. Looking at the time of day in **Figure 10**, two peaks can be observed in the week. The first one used to be around 9 a.m. but it appears to have moved sooner between the two lockdowns. The evening peak is more spread out. It used to be around 5 p.m. and became earlier and longer. Overall, it appears that the increase in cycling was an already ongoing trend, which was amplified during the crisis. Although this rise was first the most visible during weekends, the two periods closest to the normal (release and school periods), show an increase in commuter cyclists as well (cf. **Figure 10**).

Reflexive Thematic Analysis

For the reflexive thematic analysis, in total, 103 articles were coded and analyzed. The majority of the mobility measures identified in the press were favorable to a sustainable urban mobility transition (**Table 2**). Examples of such favorable measures are the implementation of 30 km/h zones, or the closing of Bois de la Cambre, one of Brussels' biggest green areas, to motorized traffic. Unfavorable measures include the cancellation of some implemented bike lanes, the cancellation of all parking fees during the strict lockdown, or the partial reopening of the Bois de la Cambre to motorized traffic. When classified according to the 5A's, the most common mobility measures implemented relate to *Act and shift*. In addition, the majority of measures were taken at the Brussels regional level (34), with the second location being the Schaerbeek municipality.

The majority of favorable mobility measures were implemented in May (26) and June (18), with 12 also implemented in April, and 11 still in October. By contrast, most unfavorable mobility measures were implemented in October (4).

When it comes to sentiments, the majority of actors expressed positive feelings toward the measures taken (68), while 29 were negative and only a small number of actors expressed

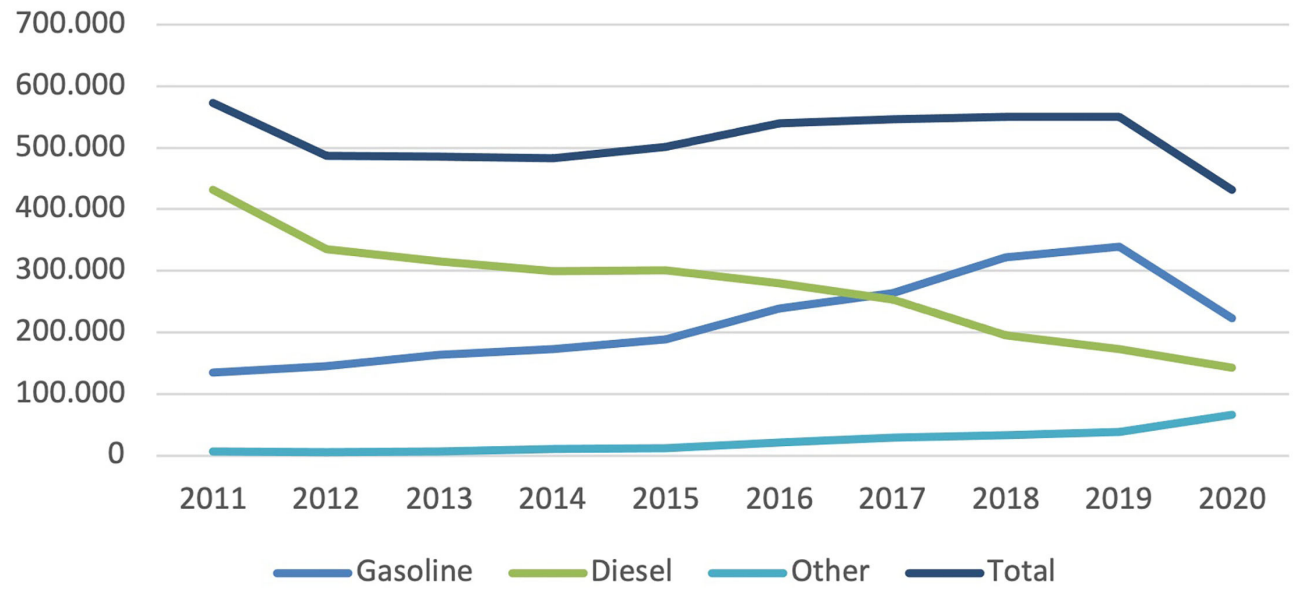

FIGURE 3 | Evolution of the sales of cars in Belgium per fuel type (data source: FEBIAC, 2021).

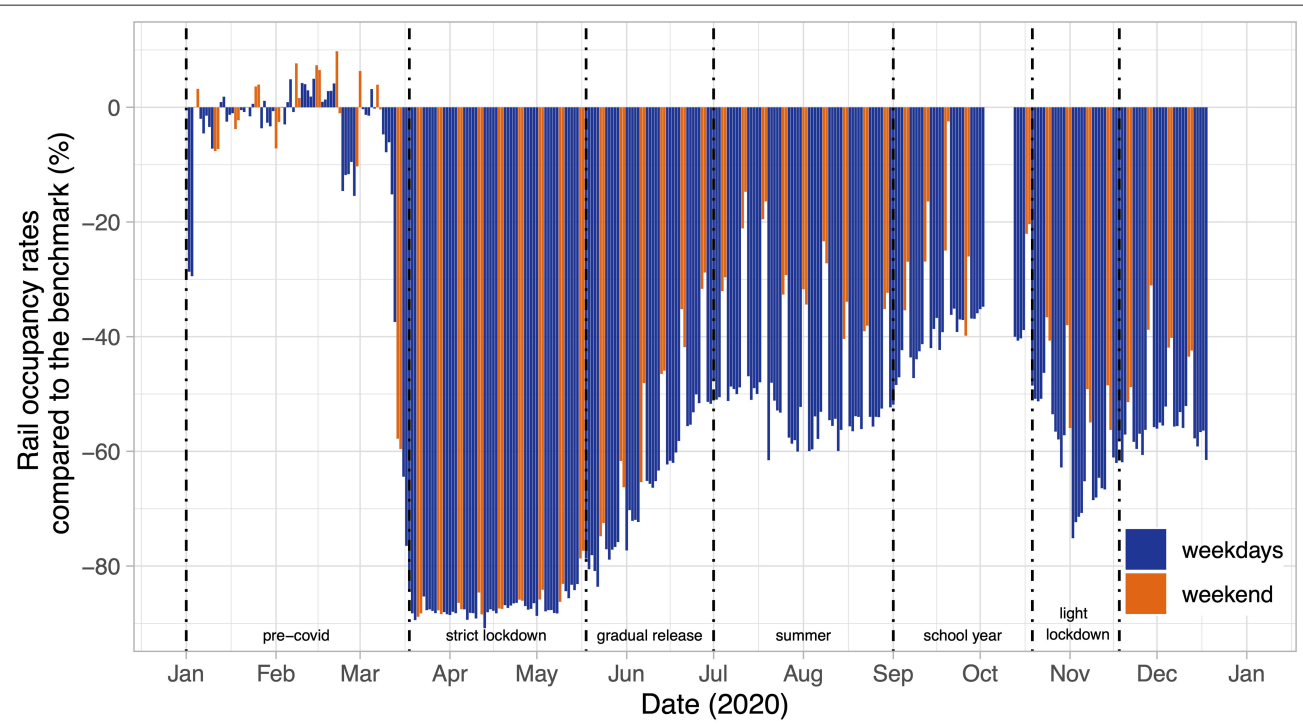

FIGURE 4 | Evolution in the train occupancy rates compared to the pre-lockdown benchmark (data source: SNCB-NMBS). Outliers includes the car free Sunday on September 20 when the occupancy rate almost reached the benchmark.

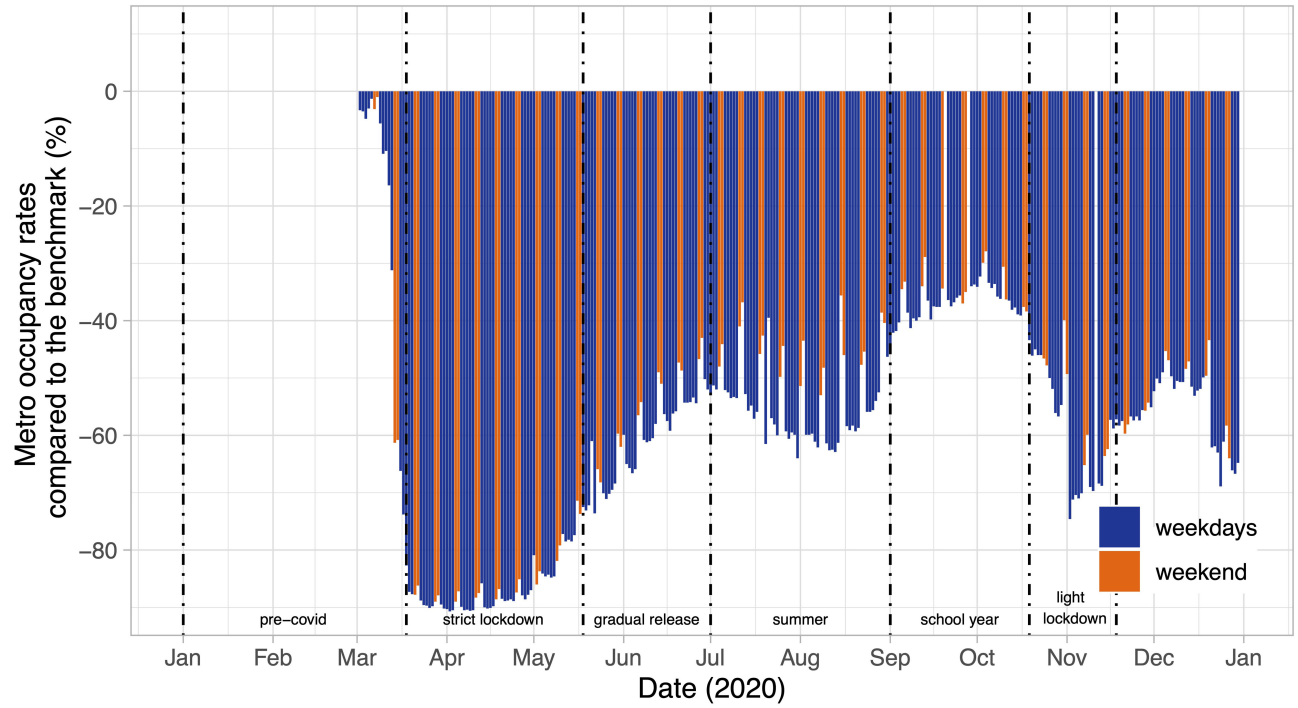

FIGURE 5 | Evolution of the city public transport occupancy rates (metros) compared to their pre-lockdown benchmark (source: STIB-MIVB). Days with unusual values justified by special events were retrieved, by the operator, from the dataset.

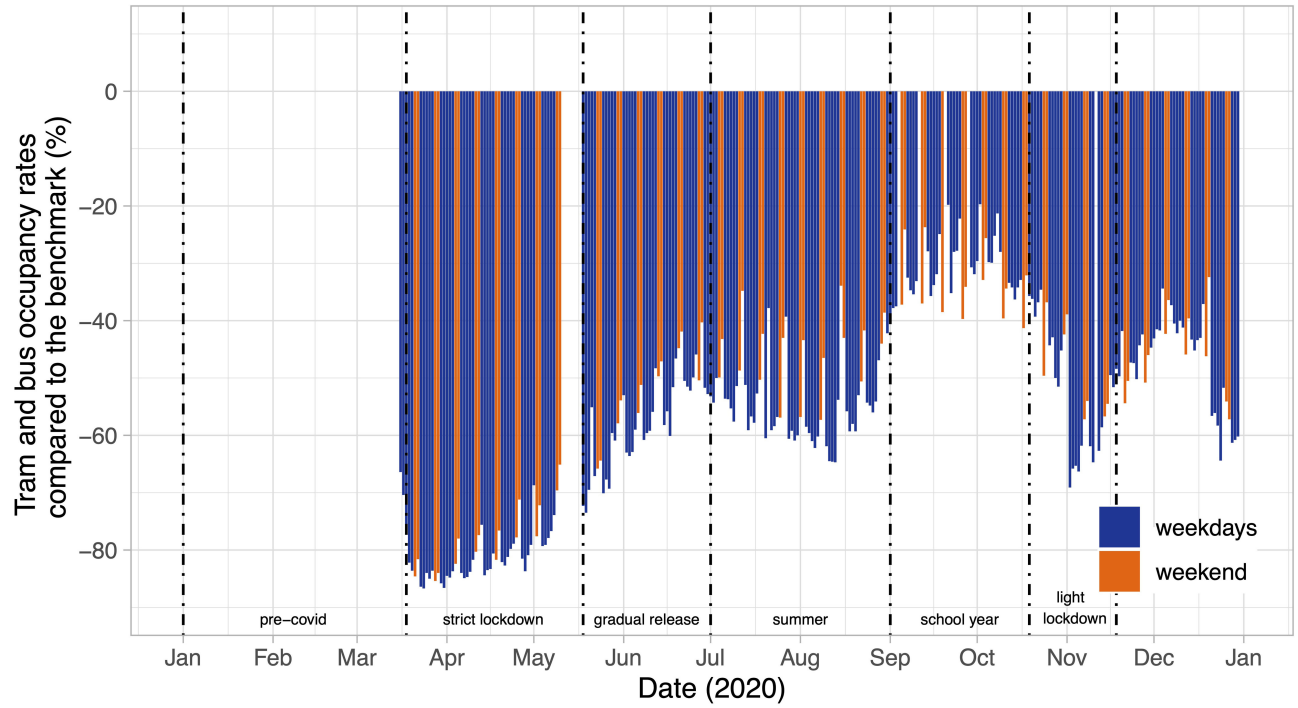

FIGURE 6 | Evolution of the city public transport occupancy rates (trams and busses) compared to their pre-lockdown benchmark (source: STIB-MIVB). Days with unusual values justified by special events were retrieved, by the operator, from the dataset.

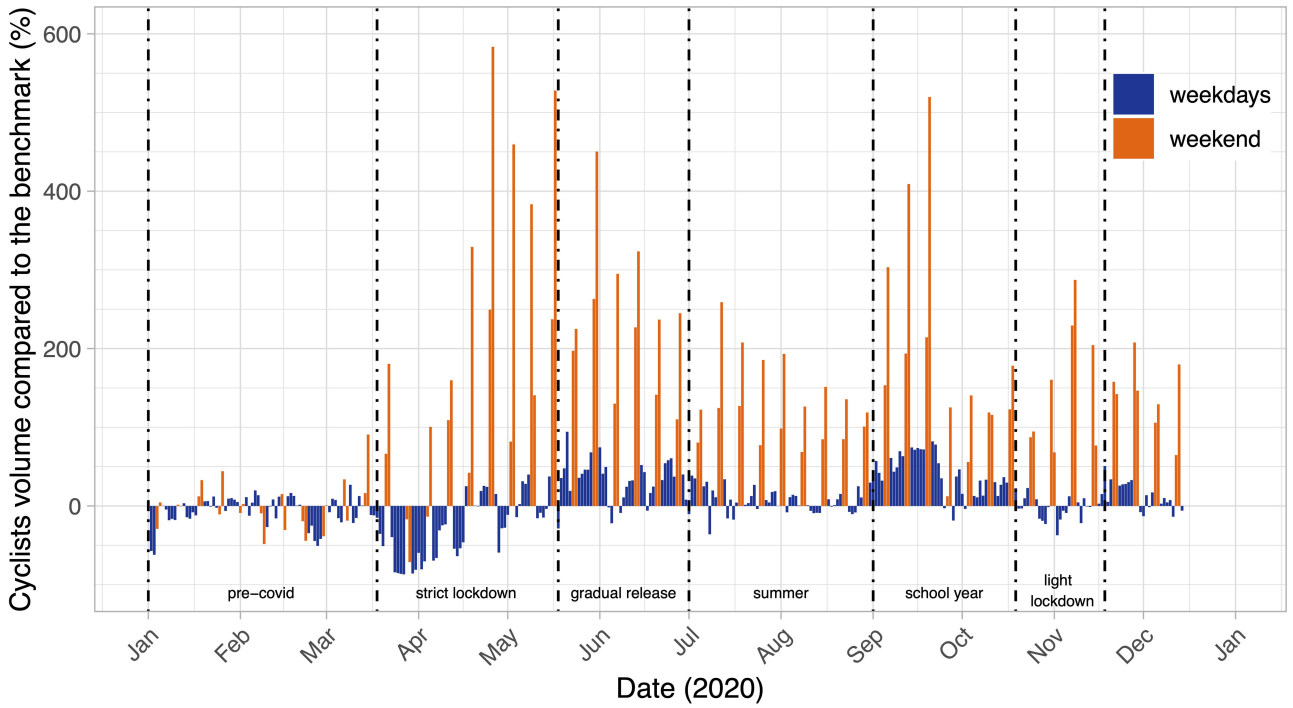

FIGURE 7 | Evolution in bicycle traffic in the Brussels Capital region in 2020 compared to the pre-lockdown benchmark (data source: Brussels Mobility).

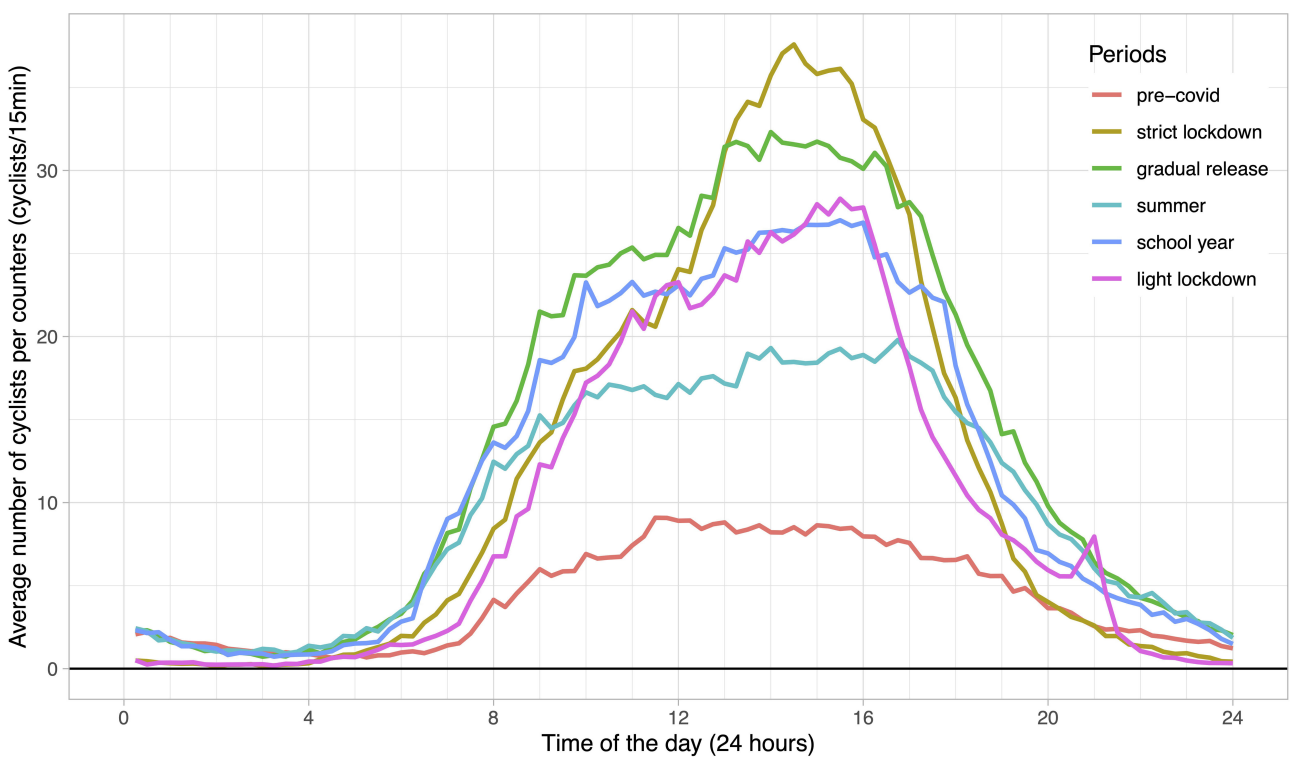

FIGURE 8 | Average bicycle levels per counter during the weekend and across the day for each of the six periods (data source: Brussels Mobility).

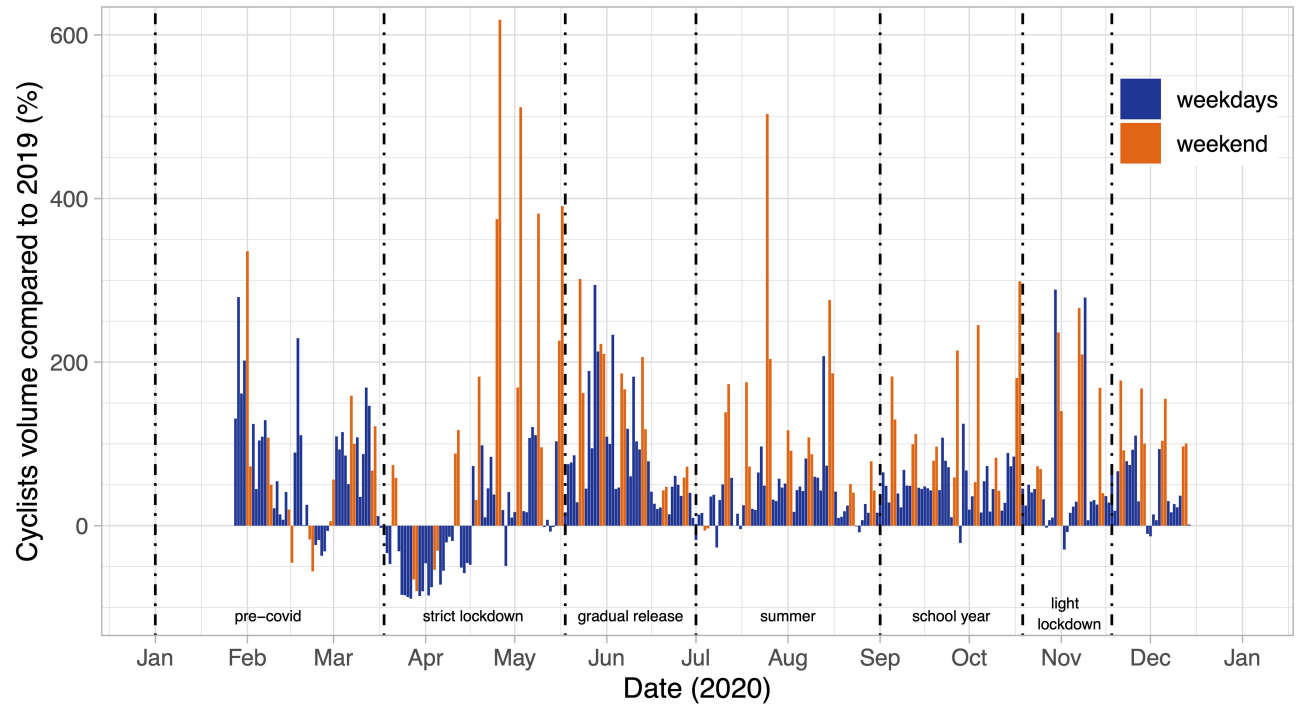

FIGURE 9 | Evolution in bicycle traffic in the Brussels Capital region in 2020 compared to 2019 (data source: Brussels Mobility).

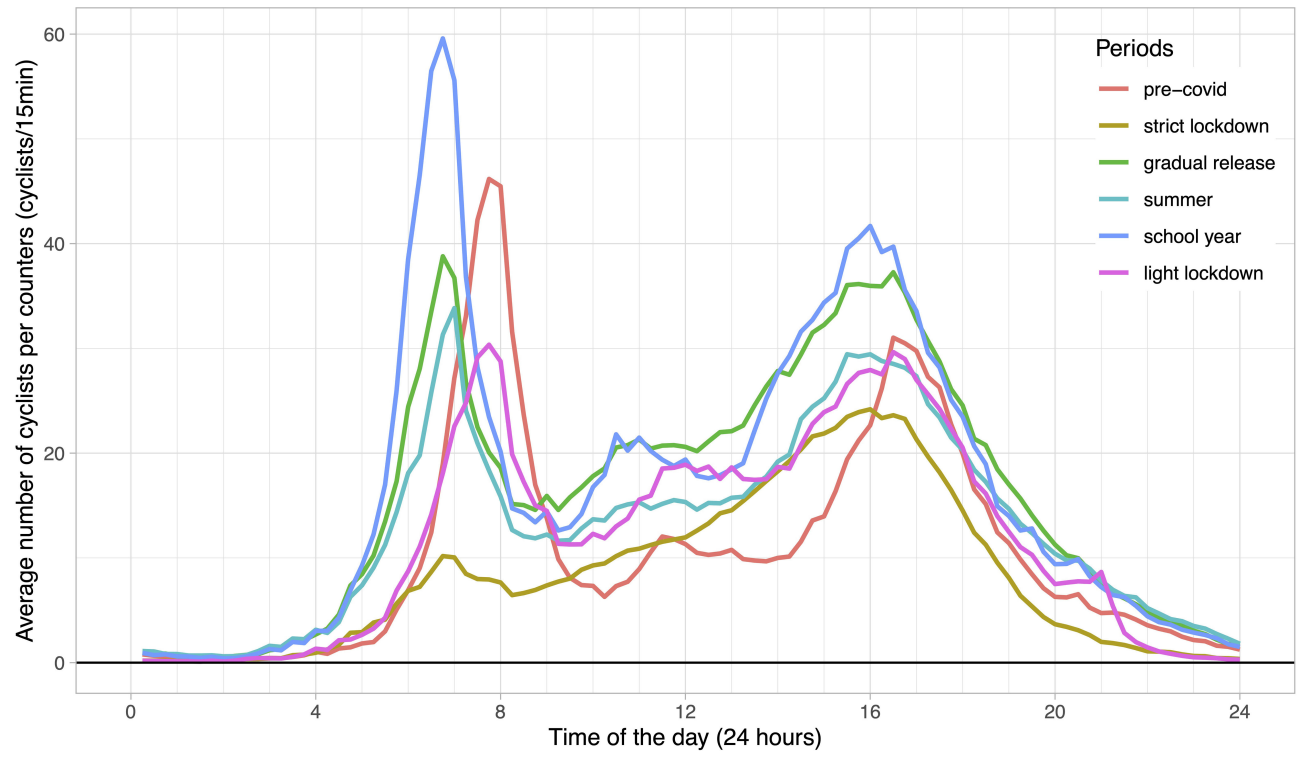

FIGURE 10 | Average bicycle levels per counter during the week and across the day for each of the six periods (data source: Brussels Mobility).

neutral feelings (3). For the assessment of sentiments, they were categorized according to the explicit wording used by actors. If an actor expressed explicit support, this was taken as positive; if they expressed opposition, this was categorized as negative. If no support or opposition was expressed, this was categorized as neutral. **Table 3** gives an overview of the actor groups that were asked for their opinions in the different articles.

When breaking down the sentiments expressed by actor category, we see that most politicians reacted positively to the mobility measures, as well as all citizen organizations (**Table 3**). However, most citizen reactions appear to be negative. Important to know is that 34 out of the 51 positive feelings by politicians were expressed by politicians affiliated with Ecolo-Groen, the green progressive party in Belgium. In Brussels, the minister responsible for mobility is from the Green party.

In order to understand the evolution of sentiments, we also looked at the change in sentiments by month. This analysis showed that most positive interventions across all actor groups took place in May (18) and June (14), with a relatively high number in August (10) and April (9) as well. Negative feelings were mostly expressed in October (7), September (5), and June (5). **Table 4** gives an overview of these findings.

Within the change in sentiments, we took a closer look at how citizen sentiments evolved over the 8-month period. From this analysis, we saw that citizens reacted positively after the initial implementation of the mobility measures (two positive sentiments in April, three in May, two in June, one in July, four in August, and one in September). However, negative sentiments started being expressed later on (one in May, two in June, two in July, one in August, one in September, five in October). An explanation for this evolution toward negative sentiments from citizens could be the way the measures were imposed upon them, without leaving room for public consultation. Another reason could be that they were underrepresented, as they did not get much opportunity to talk in the media.

DISCUSSION

This paper investigates how the COVID-19 crisis can contribute to the transition of the mobility system toward sustainability. A secondary data analysis and a thematic analysis of online press articles for Brussels was shown above. What can we learn now from this in terms of a potential for a breakthrough in the transition toward a more sustainable transport system? We will discuss this along the lines of the 5A's for a sustainable transition.

Awareness

Awareness refers to understanding the impact of mobility choices and behavior. Previously, awareness was considered in the context of being aware of the negative consequences of transport and therefore promoting behavioral change. In the context of COVID-19, however, people suddenly could become aware of the positive consequences of changes in travel demand. From our thematic analysis, we saw that there was a certain realization, during the first, strict lockdown, with regard to what cities could look like in terms of reduced traffic and air pollution. The data

TABLE 2 | COVID-19 mobility measures in terms of favoring sustainable mobility, and in terms of the 5A's.

Code name	Total number of times the code was applied
Favorable mobility measures	93
Unfavorable mobility measures	10
Act and shift	73
Actor involvement	7
Avoidance	5
Awareness	4
Anticipation of new technologies	2

TABLE 4 | Evolution of actor sentiments by months.

Date/Sentiment	Negative	Neutral	Positive
March	0	0	0
April	3	0	9
May	2	3	18
June	5	0	14
July	3	0	5
August	1	0	10
September	5	0	5
October	7	0	4
November	0	0	1

TABLE 3 | Actors involved in the articles and their sentiments.

Actor name	Total number of times the code was applied	Negative sentiment	Neutral sentiment	Positive sentiment
Politician	67	10	3	51
Citizen	19	11	0	8
Citizen organization	7	0	0	7
Business	4	3	0	2
Driver	2	0	0	1
BECI (Brussels Chamber of Commerce)	1	2	0	0
Touring (vehicle insurance and assistance company)	1	1	0	0
UPTR (transport and logistics union)	1	1	0	0

analysis showed that the road traffic level in Brussels was less than half what it was before (−55.28%). This brutal change was an opportunity to experience what a sustainable transition could mean. In the press analysis, several articles highlight the decrease in air pollution as a positive side effect of citizens' restricted mobility, mentioning that citizens do not want to go back to pre-COVID pollution levels. Furthermore, the increase in cycling and recreational cycling during the lockdown (cf. **Figure 7**) led to measures taken in Brussels to further increase the awareness such as a campaign centered around the importance of continuing to bike even after the lockdown, or the initiative "Brussels on Vacation," aimed at making the first COVID-19 summer as livable and enjoyable as possible by reallocating public space now that citizens have rediscovered their neighborhoods.

Avoidance

Our results show that the measures that were initiated by the government primarily to stop the spread of the COVID-19 virus have had significant consequences for mobility in Brussels by reducing travel demand in general, but especially for commuting and shopping which trips were replace with telework and online shopping. During the lockdown period only travel to work, shopping for food, healthcare, post office, bank, fuel stations and when helping somebody were allowed. Physical exercise in the open air in the vicinity of one's home was permitted. All non-essential shops, restaurants bars, cultural institutions and schools closed. Everybody was advised to work from home. Public transport remained operational, nevertheless with a decreased capacity (Decré and Bruggeman, 2020).

The strict lockdown had three major consequences in Brussels:

1. A general and significant mobility decrease occurred in traffic volumes, which was manifested in the data of public transport operators as well as road traffic monitoring systems (cf. **Figure 4**).
2. Telework became the norm overnight. The national labor force survey revealed that 35.9% of the surveyed employees worked at least sometimes from home in the second quarter of 2020. In addition, 41.1% of teleworkers only started working from home as a result of the COVID-19 crisis while they never did before (Statbel, 2020). In the press analysis, telework is the measure that was discussed most often under avoidance, making it seem like the most important consequence on mobility. This is further confirmed by articles mentioning that the Brussels administration, for example, indicated wanting to make telework structural after the COVID-19 crisis, allowing employees to work from home 1–2 days a week. This could entail a potential breakthrough in the implementation of teleworking. However, from the data analysis, we see that after the summer, although telework was still mandatory, traffic volume increased again. This can be seen in both road traffic and public transport data, even though the levels were still, on November 18, below the pre-COVID benchmark. This could indicate a return to business-as-usual.
3. It appears that online shopping has gotten its final breakthrough thanks to the crisis. A study by Comeos, Thomas More College of Applied Sciences and Haute Ecole Louvain shows that in all age categories people bought a product online for the first time during the lockdown. Forty-eight percent of those questioned said they still wanted to buy more via the internet after the lockdown (Knack, 2020). Although our data analysis focused only on transport modes, it is important for a comprehensive analysis to discuss this increase in e-commerce which also appears clearly in the thematic analysis. For example, Bpost, the Belgian postal service operator, underwent a strong increase in the delivery of non-food services, and in August, although the strict lockdown was over, its CEO indicated that the increase was still visible throughout June and July (Jean-François Munster, 2020). The company saw a 43.9% increase in parcel delivery throughout 2020 (bpost, 2020). We also saw that there was a rush from the IT sector to help businesses, who, until then, did not have an e-shop, develop one (Demianoff, 2020). Online shopping can be seen as an avoidance behavior, as people avoid driving to a shop themselves. However, this also generates more traffic by delivery vans. The net effect can be positive in terms of CO_2 emissions, but this depends on many variables among which the behavior of the shoppers. If online shoppers are still making a trip to check the articles in the shop or go and bring it back, the positive effect of having a consolidated milk round is diminished. However, during the lockdown phase and also during the phase in which shops were closed, such omnichannel behavior was not possible, which is beneficial in terms of sustainability (Buldeo Rai et al., 2019).

The main question thus remains whether these avoidance trends will continue in the future. As we have seen, road traffic and public transport indicate a slow increase toward pre-COVID levels. However, we can infer from the data that, although mobility is returning to normal, there has been a significant shift in mode choice, which leads us to the next A (*Act and shift*).

Act and Shift

Under "normal" circumstances, *Act and shi*ft means either a change in mode of transport or a travel shift in less congested hours. In the context of COVID-19, both shifts are relevant. Travel mode shift from public transport to individual modes of transport (e.g., walking, cycling, car, motorbike, micromobility) can relieve pressure on public transport especially in peak hours and ensure that social distancing rules can be followed. Similarly, shifting departure times outside of the peak hours can decrease the occupancy of public transport vehicles.

From our analysis, we see that public transport is the biggest loser of the COVID-19 crisis. During the strict lockdown, occupancy rates were at an all-time low, and even after the summer period, occupancy rates did not go back to pre-crisis levels (see **Figures 4**, **5**). During the first lockdown and right after, this can be linked to both a fear of the virus in public transport, as well as a deliberate act by the government, with the Brussels mobility minister encouraging citizens to walk and cycle to "leave public transport to those who really need it." From the press analysis, we see that most mobility measures implemented by the Brussels government (73) are in line with the effort to promote active mobility, while taking away space from cars or reducing

speed limits. Especially when it comes to cycling, these measures seem like they are having a positive effect on behavior change. During the strict lockdown, cycling decreased, as did mobility in general, but an increase could still be seen during the weekends. However, after the lockdown, a strong increase can also be seen during weekdays (**Figure 7**). This weekday increase is seen best before and after the summer period, suggesting that cycling is increasingly becoming a commuting mode. Although this trend had already started before the COVID-19 crisis, its extent has been accelerated.

Nevertheless, despite the generally positive opinion about the measures and the improvement of environmental conditions, traffic data indicates that after the lockdown public transport lost appeal and car traffic returned to business as usual faster. This may indicate a negative modal shift in response to passengers' fears of using public transport. However, MOBIB data show that once people return to public transport, they also keep using it. It might have the same behavioral changes as after the Brussels attacks in the metro in 2016: the network was disrupted for several weeks but ridership was close to back-to-normal 3 months later (STIB-MIVB, 2017).

Anticipation of New Technologies

The anticipation of new technologies and especially the shift toward an electric vehicle fleet is an important part of the transition. In 2020, internal combustion car sales dropped significantly (−28.54%) while the sales of electric vehicles, however, has increased by 170% (**Figure 3**). Here, the COVID-19 crisis had a clear influence on internal combustion car sales, which dropped significantly (−28.54%). The sales of electric vehicles, however, has increased by 170% (**Figure 3**).

Digitalization can also help to strengthen the basis for the second A—*Avoidance*—by promoting teleworking, online shopping or online services that can replace physical travel. During the pandemic, some ongoing deployment of new technologies have been accelerated especially related to information and communication technologies (ICT) (Freire-González and Font Vivanco, 2020). Information and communication technologies has been used to replace trips for shopping (online purchases), visits to social contacts and leisure activities (online meetings and parties), or for telework (through cloud-based collaborative services and videoconferencing software). From the press analysis, we see as well that digitalization can help *Act and shift* measures. For example, Brussels citizens developed the "Brussels is biking" app, which centralizes all cyclists' needs in a single app. The app indicates, for example, where bike parking spots are located, where repair shops can be found, or dangerous roads through an alert system (Brusselaars Verkiezen Fiets-En Toerismeapp Tot Beste Post-Covid-Apps, 2020).

Actor Involvement

The thematic analysis reveals that most actors, and especially Brussels politicians, expressed positive sentiments with regards to the mobility measures implemented. This is a positive indication for the possibility to make the temporary measures permanent and support an accelerated paradigm change in mobility. However, it must be noted that the majority of politicians that speak up in the articles are affiliated with Ecolo-Groen. Furthermore, the generally positive tone of the measures and mobility impacts in the reviewed press may also support the agenda setting role of press (Walgrave et al., 2008), i.e., shift public opinion toward the issues of sustainable mobility and increase the willingness to change behavior.

It must also be noted that there is an evolution in the sentiments expressed by actors. During the lockdown, the gradual release, and the summer months, sentiments are mostly positive (cf. **Table 4**). When school restarts, the number of positive sentiments decreases, and there is a slight increase in negative sentiments. This could mean that, as the COVID-19 crisis seemed to regularize during the summer, some actors, and most notably some citizens, wanted a "return to normal." This could very well be seen for example around the Bois de La Cambre, one of Brussels biggest parks. The park was quickly closed to cars throughout the lockdown and only partially reopened during the summer, to give citizens easier access to green spaces. However, after the summer, it was the object of heavy discussion, opposing citizens and politicians, to decide whether it would remain closed or not. This exemplifies the fact that, as new measures had to be introduced very quickly, there was no time for feasibility assessments, stakeholder consultations, and participatory planning. In addition to this, most measures are temporary measures that did not require major changes to the infrastructure, which also means that they can be easily revoked. The question then arises whether the quick implementation and the temporary nature of the measures will jeopardize their ability to continue.

CONCLUDING REMARKS

We are living in remarkable times. Times where new habits are made, due to the specific situation we are living in. The COVID-19 crisis has the potential to have a catalyst role in getting to a more sustainable mobility system. Our analysis shows that in many aspects travel behavior has changed in often positive ways on the short and medium term. We also see that even though public transport and parts of the shared mobility sector are suffering from the situation, they are steadily recovering their market share. Through our research, we have brought together multiple data sources to understand what the effects of the COVID crisis are on mobility. Furthermore, we analyze this for the present, but we also try to provide an analysis to anticipate future developments.

The question is then of course whether these changes will last. We answer this question along the lines of the two remaining A's: *Acceleration* and *Adaptation of behavior* (Macharis, 2020). *Acceleration* shows the need to have a policy framework pointing toward sustainable options. It will therefore first be key to adapt the policy framework to perpetuate the new situation and to keep on stimulating change. The ongoing changes that are noticeable through the 5A's need to be formalized. Based on the above analysis we can give the following recommendations. First of all, there is a need for a policy framework that leads to sustainable

mobility. Brussels was lucky that such a mobility framework existed, namely Good Move, which defines the regional mobility plan for the years 2020–2030 The Good Move plan was set up prior to the crisis (Brussel Mobiliteit, 2021). Having such a plan helped to move fast during the pandemic. This mobility plan was the result of an extensive participatory process, and, in a way, the COVID-19 crisis accelerated the implementation of parts of the plan. This existing mobility plan has been used to guide the implementation of mobility measures during the crisis, so we see that, for Brussels, the changes brought on by the pandemic accompany changes already underway. The city, in January 2021, became one of Europe's largest 30 km/h zones, and a regional road user charge for private vehicles is under discussion. In addition, by 2030, a ban on diesel vehicles is planned. These measures will help support the shifts the pandemic accelerated. A solid policy framework directing toward sustainable mobility can therefore support the transition. As we have seen however from *Actor involvement*, it is crucial to get actors on board when implementing these changes, to ensure they last. The Good Move plan was the result of a participatory process, but the rushed implementation was not, resulting in the opposition from several actors described above. Next to that, there needs to be better communication about the positive impacts of these new lifestyles brought on by COVID-19 in terms of climate, air quality, and quality of life. New agreements between employers and employees with regard to telework also need to be formalized, as COVID-19 has potentially led to a breakthrough of telework. It has changed the trust relationship between employers and employees, but it also has an influence on the costs and benefits for each side. These changes should be formalized and better organized in such a way that employees will be stimulated in the future to keep a big part of the telework and teleconference habits they gained. This formalization in the policy framework is especially important because there is the risk that "even as the future disrupts, we remain tied to old patterns of behavior" (Inayatullah, 2008, p. 5). A second important aspect is investment in sustainable transport modes, to ensure that the rise in cycling will be continued. Public transport should not be left behind either, but should instead be supported even more to increase its capacity, so that overcrowded trams and trains become something of the past.

The last question is, of course, whether the behavioral change that we notice will last. This brings us to *Adaptation of behavior*. This A is about the adaptation of our own behavior. In psychology literature, "repetition of a behavior in a consistent context progressively increases the automaticity with which the behavior is performed when the situation is encountered," which is how habits are created (Lally et al., 2010, p. 998). From their research, Lally et al. (2010) concluded that, on average, adapting to a new habit takes 66 days. However, consistency in the repetition of a behavior is required for it to truly become a habit (Lally et al., 2010). The first lockdown, that was most extreme in the changes of the lifestyle was not long enough to last. However, a year into the COVID-19 crisis, people have had to dramatically change the way they live and have seen some of the benefits it brings. There also is a two-way relationship between attitudes and behavior change when it comes to transport (Kroesen et al., 2017). Their research showed that there are "dissonant" bicycle and public transport users, i.e., people who have a positive attitude toward the use of bicycle or public transport, but who, in their behavior, do not often use these. People who experience this dissonance between attitude and behavior are more likely to switch to another mode (Kroesen et al., 2017). The changes brought upon by the COVID-crisis and their implications on mobility could therefore have an important role to play in increasing the share of sustainable transport modes. The strong increase in biking could indicate a realignment between attitudes and behavior, which can have positive implications for biking on the longer term, as people with consonant attitude-behavior patterns are more stable in the long run (Kroesen et al., 2017). Put aside the general mobility avoidance, the lockdown changed attitudes about biking because it became safer (in terms of road safety), more relaxing (less congestion or organizational stress), and thus easier. This led a group of people to change their behaviors, start biking and enter a consonant pattern. However, for public transport, the attitude change was brought on by a different reason: the feeling of safety, in terms of health, decreased. As we can assume or hope for this pandemic safety risk to be removed, public transport ridership can be expected to rise again. While for cycling, this newly acquired positive attitude can be expected to stay, because public policies are going in the direction of improving cycling infrastructure.

This concludes the last two A's employed in our analysis framework. Through this research, we wanted to analyze how this 7A's framework can be used as tool to study and accompany transformations. What we have seen is that it is a promising framework of analysis for system change, that can be used in the context of sustainability transformations.

So what will life after COVID-19 bring us? Some argue that it will be a new "roaring twenties" period, with people traveling even more than before. Some say that the pace of life will be slower, with more telework and less car use. The reality will probably be somewhere in the middle. However, the pandemic has shown us the importance of being prepared for change. As a wild card event, it came and completely disrupted daily life all over the globe, and most (if not all) of us were not prepared. At a Brussels level, there is nothing that could have been done to stop the pandemic from erupting, but there could have been an action plan. For the future of mobility in Brussels, an interesting avenue might be the use of future studies, as developing resilient alternative scenarios for the future can minimize the impact the next crisis will have on the mobility system. Taking advantage of the current crisis as a catalyst for sustainability only makes sense if the future we are working toward is robust enough not to be disrupted negatively next time.

Although we employed a mixed method approach to get as broad a view as possible on our research matter, there are some limitations to our study. Due to the recent nature of the COVID-19 crisis, this paper relies on data sources that may only paint a limited picture of the situation and the expected trends. In the press analysis, for example, citizens, who are directly impacted by these changes, are only the third most cited actors. Therefore, further research could analyze the sentiments of people based on social media contributions. It is also important to note that, at the time of writing, the COVID-19 crisis was far from over. A possible third wave was underway in Belgium, with new

government measures and restrictions on the agenda. These will again probably have a significant impact on travel behavior and require further monitoring and research to support policy makers to make the positive impacts lasting and actually contribute to the sustainable mobility transition.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: The following datasets are publicly available: Bruzz articles, Brussels bike counters, Brussels car counters (historical data on-demand only, but open-source availability is planned); The following dataset is (partially) available behind a paywall: De Morgen articles, Le Soir articles; The following datasets were shared by the responsible public transport operators for the purpose of this study only: city transit occupancy rates data, rail occupancy rates data. Requests to access these datasets should be directed to https://www.bruzz.be/; https://www.demorgen.be/; https://plus.lesoir.be/; https://datastore.brussels/web/data/dataset/9a047e86-3947-424a-84e8-a192f18a735a; https://data.mobility.brussels/bike/api/counts/.

AUTHOR CONTRIBUTIONS

CM: conceptualization idea of the overarching research goals and aims. ST and AS: methodology, respectively thematic analysis, and data analysis. CM, ST, AS, and IK: validation and verification of results and writing of the article. IK and LV: verification and review of the article. All authors contributed to the article and approved the submitted version.

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