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# The motivations for using bike sharing during the COVID-19 pandemic: Insights from Lisbon

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ABSTRACT

Urban mobility has been severely impacted by the coronavirus pandemic, with public transport (PT) particularly affected due to infection risks and fears. The promotion of alternative modes of transport such as bike sharing systems (BSS) has gained a new drive as a possible way of providing an alternative to PT and limit a potential surge in private car use.

In this study, we provide insights on the motivations for using bike sharing during the COVID-19 pandemic through a survey to the BSS users of Lisbon (entitled *GIRA*). Before the coronavirus pandemic, the most influential motivations were those connected to the BSS' *Service Coverage & Quality* (such as the convenient location of BSS stations near the users' destinations or the availability of shared e-bikes) as well as to the *Personal Interests & Well-being* of BSS users (namely the pleasure of cycling as well as the perceived environmental and health benefits). With the emergence of the COVID-19 pandemic, although the motivations of *Service Coverage & Quality* continue to be the most valued by respondents, the motivations associated with using BSS to avoid PT and to maintain a social distance during the trip are now as important as the motivations linked to *Personal Interests & Well-being*. Furthermore, new users who have joined bike sharing during COVID-19 give more importance to the *Social Influence* (such as seeing other people using the system or the influence of their social circle) comparatively to those who were already users before the pandemic and continue to use BSS.

This research provides evidence on the importance of bike sharing to the resilience of urban transport systems, particularly during disruptive public health crises. It supports that BSS should continue to operate during the coronavirus pandemic as such systems offer a transport alternative to PT that is perceived to be capable of preserving a physical distance.

## 1. Introduction

The severity of the coronavirus pandemic and the subsequent policy responses to limit its spread have disrupted nearly every aspect of normal life, with physical interactions now considered as an extremely high-risk behaviour due to potential COVID-19 infection. As a consequence, mobility has been severely restricted in order to limit social contacts, leading to massive reductions in travel demand. For instance, the Netherlands registered a 55% drop in the number of trips conducted comparatively to 2019, with almost 80% of the population reducing their outdoor activities (de Haas, Faber, & Hamersma, 2020). Similar impacts were observed worldwide, in all

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countries that implemented major lockdowns (Bucsky, 2020; Hadjidemetriou, Sasidharan, Kouyialis, & Parlikad, 2020; Sharifi & Khavarian-Garmsir, 2020; Google, , 2020).

Public transport (PT) has been particularly affected by the pandemic due to infection risks. With the potential transmission risk posed by having large numbers of people in close proximity inside enclosed and frequently overcrowded vehicles, governments have discouraged PT use during COVID-19 (GOV.UK, 2020). This has caused unprecedented ridership drops in PT systems across the world (Gkiotsalitis & Cats, 2021). For example, New York City's subway, one of the biggest subway systems in the world, suffered a 90% ridership drop during the height of the city's lockdown (Teixeira & Lopes, 2020), with ridership still 70% below pre-pandemic levels even after the lockdown being lifted (Wang & Noland, 2021). Not only PT ridership has felt to historic lows, but also the perceived risk of infection has led to a widespread increase in the public's aversion towards PT usage (Gkiotsalitis & Cats, 2021). In the Netherlands, more than 90% of respondents from a representative survey have now negative attitudes towards PT, with the study showing an association between the fear of becoming infected and a preference for personal modes of transport (de Haas et al., 2020). Likewise, in Chicago a similar survey found 93% of the respondents to consider PT as having a medium to extreme risk of infection (Shamshiripour, Rahimi, Shabanpour, & Mohammadian, 2020). In contrast, the use of the private car has been much less affected than PT, with lower mobility decreases and lower perceived risks of infection (Sharifi and Khavarian-Garmsir, 2020). For comparison, in the previously mentioned study from Chicago, 86% of the respondents considered car travel as safe (Shamshiripour et al., 2020). Consequently, and bearing in mind that PT ridership is expected to continue to be affected throughout the duration of the pandemic (and, perhaps, even after), there is a risk of a modal shift from public transport to the car. Such shift would exacerbate the numerous negative externalities associated with car use (Douglas et al., 2011).

Cycling could be a potential alternative both to PT and car use during a pandemic such as COVID-19, capable of providing an efficient, affordable, environmentally friendly, and healthy transport alternative (Ellison & Greaves, 2011; Handy, van Wee, & Kroesen, 2014; Rabl & de Nazelle, 2012). Cycling becomes a particularly attractive alternative within the COVID-19 context, characterized by the geographical limitations on travelling, where short trips at the local level have gained a new relevance (de Haas et al., 2020) and on which the bicycle is especially competitive (J. Dekoster, 1999; Ellison and Greaves, 2011). Of the several measures promoting cycling use, arguably amongst the most notorious is the implementation of bike sharing systems (BSS) (Pucher & Buehler, 2017). Several benefits have been linked to BSS, particularly their ability to increase the number and diversity of cyclists, foster synergies with PT (including by alleviating some of the pressure from overcrowded services) and to be a competitive transport alternative capable of reducing car use (Teixeira, Silva, & Moura e Sá, 2020).

As such, it is important to investigate how are bike sharing systems performing during the coronavirus pandemic, including on how the impacts of COVID-19 have affected the behaviour of BSS users. A crucial research direction is to explore if the coronavirus has changed the reasons for using bike sharing. For instance, faced with a perceived risk of infection for using public transport, users may now value much more using bike sharing as an alternative to PT. It is vital to investigate the motivations for using bike sharing during pandemic health crisis such as the coronavirus not only to design systems better prepared to these types of disruptive events, but also to gain insights on the potential contribution of BSS towards increasing the resilience of urban transport systems.

The present study builds upon the existent research on the motivators to BSS use by assessing motivations related to the impacts of COVID-19 and comparing their importance with the other known facilitators of BSS usage prior to the pandemic. Furthermore, motivations linked to new BSS innovations, namely the availability of shared e-bikes that provide additional advantages such as less effort to cycle or increase trip's range, are also included. Consequently, and by employing a survey to the BSS users of Lisbon (entitled *GIRA*), this study aims at providing evidence to the following research question:

- *What are the most important motivations for using bike sharing before and during COVID-19?*

Several researchers expect that this pandemic will lead to long term changes in travel behaviour such as a greater preference for private modes of transport over PT or a decrease in travel demand due to higher levels of teleworking (de Haas et al., 2020; De Vos, 2020; Shamshiripour et al., 2020; Sharifi & Khavarian-Garmsir, 2020). Effective policymaking could determine if the potential structural changes induced by COVID-19 will contribute to more resilient and sustainable transport systems namely by promoting active modes of transport. On the contrary, the absence of decisive policies during this pandemic could lead to a more unsustainable future where current decarbonization efforts fail due to a major surge in car use. The insights from this study may support policymakers ensuring that the first scenario becomes a reality by providing evidence on how BSS can meet the mobility needs of citizens during disruptive events such as the current coronavirus pandemic.

## 2. Literature review

### 2.1. Motivations and barriers for using bike sharing before COVID-19

Amongst the most consistent findings from the literature is convenience being one of the major motivations for joining bike sharing (Ricci, 2015; Fishman, 2016). For instance, Fishman, Washington, Haworth, & Mazzei, 2014 quantified the motivators and barriers for joining the BSS of Brisbane and Melbourne (Australia) by surveying users and non-users. Among users, convenience was the most important factor for joining, followed by having BSS stations close to the workplace (which is in itself also associated with convenience), while to non-users car convenience was one of the main barriers for joining (Fishman et al., 2014). The existence of BSS stations close to residential and work locations is crucial on the decision to use bike sharing (Bachand-Marleau, Lee, & El-Geneidy, 2012; Fishman, Washington, Haworth, & Watson, 2015; Hosford et al., 2018; Raux, Zoubir, & Geyik, 2017). For example, in their qualitative study of the main barriers and facilitators for BSS use in Brisbane, Fishman, Washington, & Haworth, 2012 found the existence of BSS stations close to home and workplaces paramount on the decision of non-users to consider using BSS. Convenience is also closely connected to travel time savings (Fishman et al., 2014), which is often cited as one of the main perceived personal benefits of BSS (Ricci, 2015). For instance, in New York City, considering BSS the fastest mode of transport was amongst the factors associated with frequent users (Reilly, Noyes, & Crossa, 2020). Equally, in the surveys of London's BSS conducted by TfL (2011), the main motivation, among members, to join the scheme was BSS being quicker than their previous mode.

Another factor influencing BSS adoption is the easiness of using the system itself. Features such as the amount of time and effort needed to sign up to use the system or even the operating hours can influence the decision to join or not bike sharing. In fact, among the main identified barriers for using Brisbane's BSS in the focus groups conducted by Fishman et al., 2012 was the lengthy sign up process and the system being only available between 5 a.m. and 10p.m. The fact of the system not being opened 24/7 was especially criticized as it hindered the possibility of providing a mobility option when PT was less available (Fishman et al., 2012). Likewise, the perceived ease of using bike sharing has been identified as positively influencing attitudes and intentions of use (Chen & Lu, 2016; Wu, Wu, Wen, Cai, & Li, 2019).

The affordability and the flexibility provided by shared bikes have also been positively correlated with influencing the decision to use BSS. Financial savings are often cited as a reason for shifting to BSS (Ma, Yuan, Van Oort, & Hoogendoorn, 2020; Reilly et al., 2020; TfL, 2011), especially among lower-income groups (Fishman, 2016; McNeil, Broach, & Dill, 2018; Ogilvie & Goodman, 2012; Reilly et al., 2020) and students (Molina-Garcia et al. (2015)). Not owning a bicycle (Hosford et al., 2018) or using bike sharing to avoid the inconveniences of personal cycling such as parking, theft and maintenance are also among the reasons stated by users for switching to BSS (Bachand-Marleau, Lee, & El-Geneidy, 2012; Ma et al., 2020).

Moreover, using BSS to access PT is important for a proportion of users. Murphy and Usher (2015) revealed that 39% of users of Dublin's BSS were integrating BSS with other modes, of which 56.3% were combining with rail and 35.2% with bus. Similarly, Bachand-Marleau, Lee and El-Geneidy (2012) found, among others, the combination of cycling and PT trips to be a significant predictor for BSS use. These results are echoed by the analysis of London's BSS, with the surveys conducted by TfL (2011) showing that between 39% (wave 1) and 41% (wave 2) of respondents used BSS as part of a longer trip, mostly combining with PT (by order of use: train, subway and bus).

Environmental and health concerns are as well strong indicators of BSS usage behaviours (Cerutti, Martins, Macke, & Sarate, 2019; Fishman et al., 2014; Hosford et al., 2018; Wang, Douglas, Hazen, & Dresner, 2018). For instance, in the users' surveys conducted by TfL, the fact of BSS being perceived as an healthier option is one of the main reasons for using it, with environmental concerns, although in a lesser degree, also mentioned (TfL, 2011). Furthermore, perceived environmental and health benefits have been found to positively influence intentions to use BSS among users and non-users (Chen & Lu, 2016; Kim, Choi, Kim, & Fujii, 2017; Wang et al., 2018). For example, in Taipei (Taiwan), Chen & Lu, 2016 found that the green perceived usefulness, translated in emission and congestion reductions as well as health benefits, positively influenced green intentions of use in both users and non-users.

Interestingly, fun and enjoyment in using bike sharing is also highly regarded by its users (Chen, 2016; Fishman et al., 2014), especially among casual users (TfL, 2011), with perceived fun to use positively influencing usage intention towards BSS (Wu et al., 2019). This is in line with other studies of cycling in general, where cyclists find their commute more relaxing and exciting comparatively to other modes (Heinen, van Wee and Maat, 2010), with the enjoyment of cycling having a great influence on the final decision to cycle (Heinen and Handy, 2012).

Lastly, having a supportive social environment fosters the adoption and usage of bike sharing (Chen, van Lierop, & Ettema, 2020; Wang et al., 2018). The trendy status (Bachand-Marleau et al., 2012), as well as seeing people using the system positively influence BSS use (Fishman et al., 2012). Indeed, the prevalent view of the focus groups in Fishman et al., 2012 study was that seeing other people in the city using the BSS was the best possible promotion.

However, there are important barriers that hinder BSS usage. First, in countries with mandatory helmet laws, the need to wear helmets when using a BSS has been associated with lower usage rates, although the provision of helmets at BSS stations seems to alleviate this problem (Ricci, 2015; Fishman, 2016). Furthermore, the fact of many of these systems requiring the use of smartphones or credit/debit cards constitutes a barrier for disadvantaged groups (low-income, less educated and ethnic minorities), leading to an under-representation of such groups among BSS users (Goodman & Cheshire, 2014; McNeil, Broach, & Dill, 2018; Ogilvie & Goodman, 2012; Ursaki & Aultman-Hall, 2016).

More importantly, safety concerns are among the main barriers to BSS use (Fishman, 2016), which not only affects bike sharing but also cycling in general (Heinen, van Wee and Maat, 2010; Heinen and Handy, 2012). For instance, in the focus groups study conducted by Fishman et al., 2012 of non-cyclists, cyclists and BSS users, safety emerged as a key concern for all groups. Two major safety concerns were identified: the lack of cycling infrastructure (such as cycling lanes or paths) as well as dangerous drivers' behaviour, with non-users being particularly sensitive to the lack of dedicated cycling infrastructure (Fishman et al., 2012). This is corroborated by the existence of cycling infrastructure, namely bike lanes, being positively associated with the generation of BSS trips (Buck & Buehler, 2012; Noland, Smart, & Guo, 2016). Increasing the safety of using bike sharing, by providing cycling infrastructure or implementing traffic calming measures, could also address the gender imbalance among BSS users, which is skewed towards men (Ricci, 2015; Fishman, 2016), as female users were found to be more sensitive to traffic conditions (Wang & Akar, 2019). Indeed, in countries such as the Netherlands with extensive dedicated cycling networks and where cycling injury rates are very low, women cycle as much as men (Pucher & Buehler, 2008).

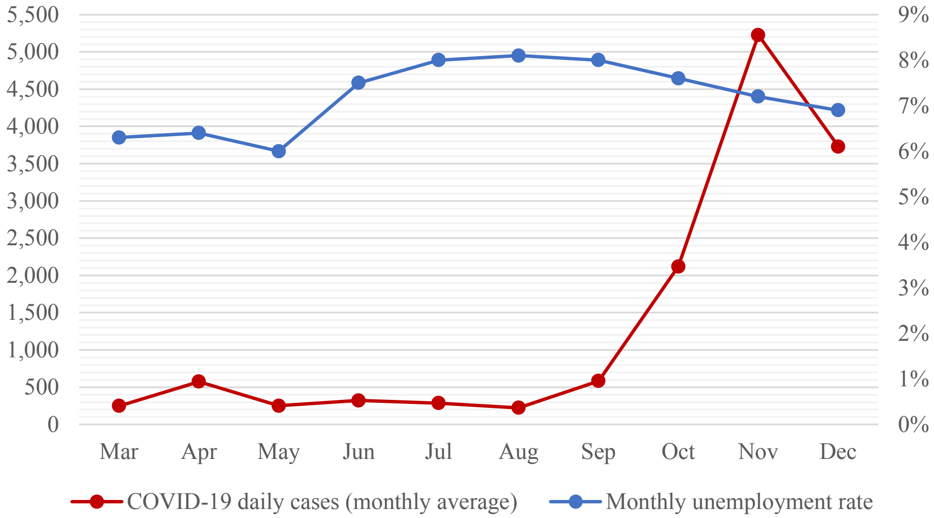


**Fig. 1.** Variation in the number of COVID-19 new daily cases per month (DGS, 2021) and in the monthly unemployment rate (INE, 2021) in Portugal throughout 2020.

## *2.2. Use of bike sharing during COVID-19*

Most studies explored the resilience of bike sharing to the coronavirus pandemic by analysing ridership data. As in virtually all other modes of transport, BSS registered a ridership decline during the lockdown periods (Bucsky, 2020; Hu, Xiong, Liu, & Zhang, 2021; Shang et al., 2021; Teixeira & Lopes, 2020). However, evidence also points to bike sharing sustaining lower ridership drops (Bucsky, 2020; Hu et al., 2021; Teixeira & Lopes, 2020), an increase in its average trip duration (Hu et al. 2021; Padmanabhan, 2021; Shang et al., 2021; Teixeira & Lopes, 2020) and faster recoveries comparatively to other modes (Hu et al. 2021; Wang & Noland, 2021). Taking advantage of the extensive open data policy of New York City, Teixeira & Lopes, 2020 compared the performance of the city's subway and bike sharing systems during March 2020 at the height of the COVID-19 lockdown. Teixeira & Lopes, 2020 found evidence demonstrating BSS to be more resilient than the subway to the COVID-19 pandemic, registering lower ridership drops and an increase in BSS trips' average duration, suggesting a possible modal shift from some subway users to bike sharing. These findings are supported by Pase et al. (2020). Also analysing the performance of New York City's bike sharing and subway systems during March 2020, Pase et al. (2020) observed that while the decline of subway ridership was felt throughout all the city's boroughs, there were boroughs where BSS ridership actually increased, particularly in the areas served by subway stations. Extending this analysis on the same case-study to the period after lockdown, Wang & Noland, 2021 found the BSS ridership to recover to the pre-pandemic levels, while subway ridership was still just 30% of the levels registered before COVID-19.

The resilience of bike sharing to the COVID-19 pandemic comparatively to other modes of transport was also observed in other cities. In Budapest, Bucsky (2020) found bike sharing to register the lowest ridership drop (2%) comparatively to an overall 57% decrease in mobility, with PT being the most affected mode (80% drop). Likewise, in Chicago, Hu et al. 2021 observed that, even though all modes registered severe ridership drops during the height of the lockdown, bike sharing had the fastest recovery not only when comparing with PT but also comparatively to walking and driving.

Complementing the findings from analysing BSS trip data, a smaller number of studies employed travel behaviour surveys aimed at users of bike sharing. A emerging pattern from such surveys is that bike sharing is considered to be safer regarding the infection risk of COVID-19 than using PT or taxi, but perceived as less safe than using personal modes such as the car and walking (Nikiforiadis, Ayfantopoulou, & Stamelou, 2020; Shamshiripour et al., 2020). Nikiforiadis, Ayfantopoulou and Stamelou (2020), explored the safety perceptions of users from a small BSS in Thessaloniki (Greece). The study found that the respondents who considered BSS as safe had higher odds of using the system, leading the authors to highlight the need for BSS operators to implement specific measures aimed at decreasing the infection risk of COVID-19 (Nikiforiadis, Ayfantopoulou and Stamelou, 2020). However, Jobe & Griffin, 2021 reveal that in addition to implementing safety measures, operators also need to better communicate their COVID-19 prevention efforts in order to increase the attractivity of bike sharing during the pandemic. Analysing the BSS of San Antonio (USA), Jobe & Griffin, 2021 found that even though the system's operator had implemented several measures to minimize the COVID-19 transmission risk of using bike sharing, only 57% of the surveyed respondents were aware of such efforts.

Thus, most of the existing literature exploring the impacts of COVID-19 on bike sharing focus on analysing trip data provided by the BSS operators. Only a few studies explore changes in the individual behaviour of BSS users due to COVID-19 and, of those, most focus on observing changes in travel behaviour and exploring the safety perception of using BSS comparatively to other modes. To the best of our knowledge only one study has so far explored the factors for using bike sharing during the COVID-19 period (Bergantino, Intini, & Tangari, 2021), but the study did not specifically explored differences between the pre and pandemic periods and was mostly focused on non-users. As such, our study complements the current state of knowledge by providing a unique view on the motivations for using

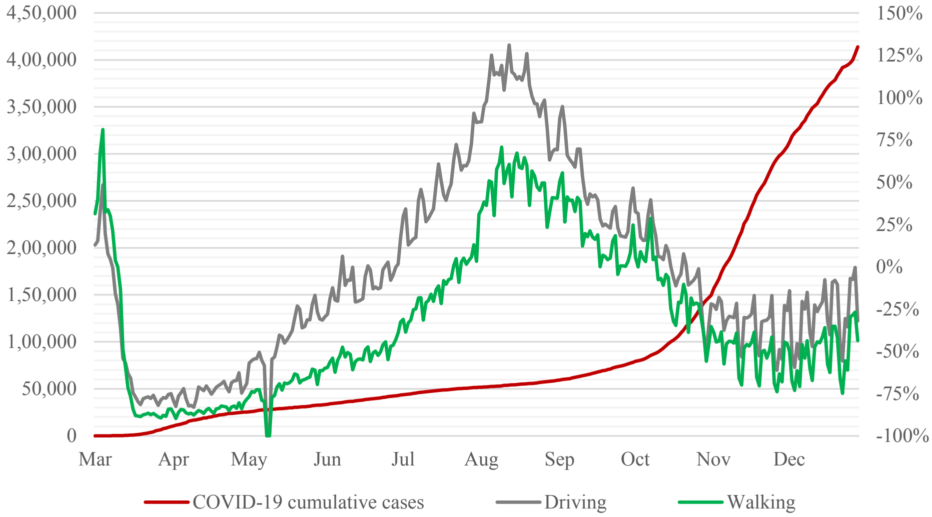


**Fig. 2.** Percentual changes in driving and walking mobility trends (comparatively to 13 January 2020) (Apple, 2021) versus the increase in the number of COVID-19 cases (DGS, 2021) in Portugal throughout 2020.

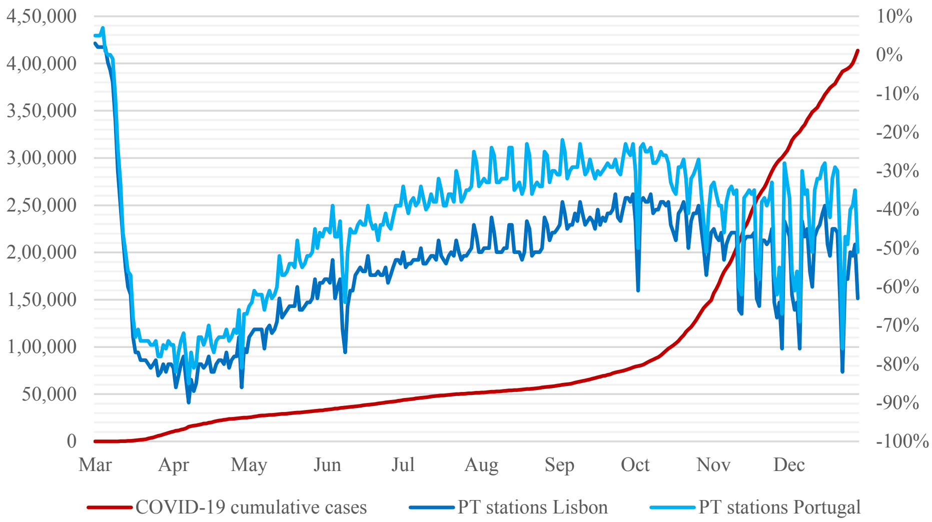


**Fig. 3.** Percentual changes in Lisbon's PT mobility trends (comparatively to a 5-week median baseline between January 3 and February 6, 2020) (Google, 2020) versus the increase in the number of COVID-19 cases (DGS, 2021) in Portugal throughout 2020.

bike sharing during the COVID-19 comparatively to the pre-pandemic period. Furthermore, it introduces motivations specifically related to the coronavirus and explores differences in the motivations of different users, particularly of those who have joined BSS during COVID-19.

## 3. Case-study

### *3.1. The municipality of Lisbon and the impacts of COVID-19*

With 504,964 inhabitants, Lisbon is the most populous municipality as well as the capital of Portugal. Like the rest of the country, Lisbon is characterized by being heavily car dependent, with 45.1% of its commuting trips conducted by car, while cycling represents only 0.6% of the modal share (INE, 2018).

As in most European countries, COVID-19 has impacted Portugal through a two-wave pattern in reported cases, with a first wave occurring during the spring and a second much more devastating wave occurring at the beginning of autumn (Fig. 1). The first wave started on March 2nd, 2020, with the first confirmed case of COVID-19 in Portugal (DGS, 2021). Just 16 days later, Portugal declared the State of Emergency, and the country entered a full lockdown period which ended on May 3rd. Although the COVID-19 pandemic

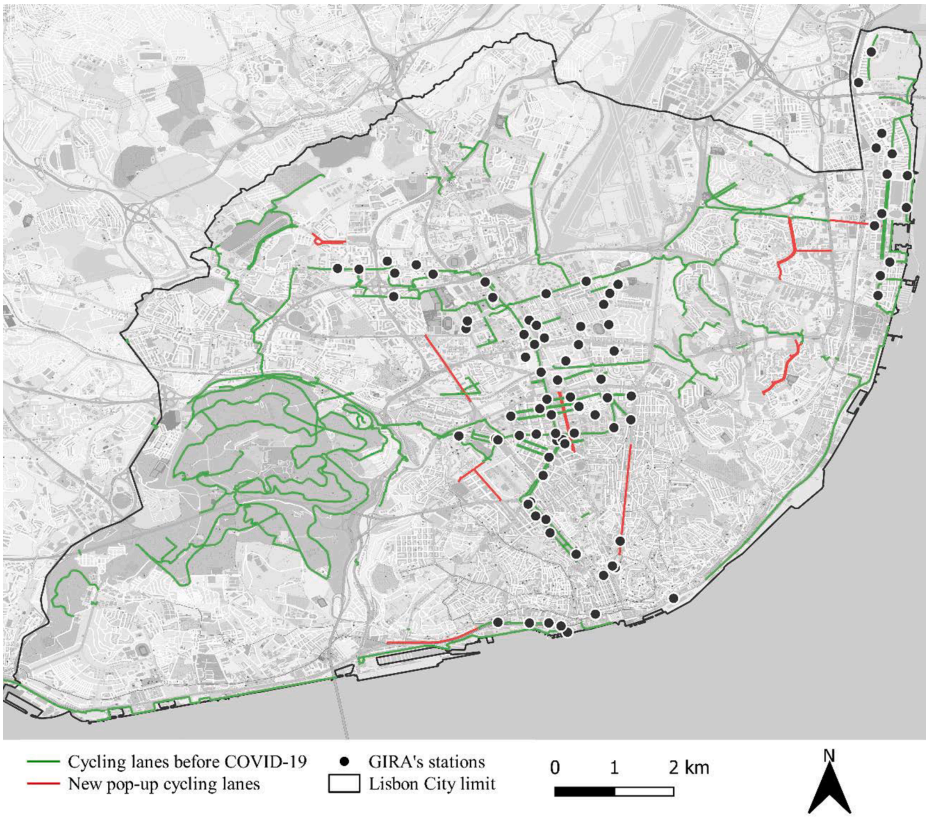


**Fig. 4.** Existing cycling infrastructure and location of *GIRA's* stations within the city of Lisbon.

seemed to be under control during the summer months, by the beginning of autumn the number of cases started to increase again, leading to a new State of Emergency that gradually reintroduced restrictive measures, culminating with a new full lockdown implemented at the beginning of 2021.

Fig. 1, Fig. 2 and Fig. 3 reveal the COVID-19 impacts on the Portuguese economy and mobility trends. Fig. 1 compares the monthly unemployment rate with the monthly average number of new COVID-19 daily cases throughout 2020. Although the unemployment rate has increased from 6.3% in March to 8.1% in August, stabilizing at 6.9% in Dezember, this increase was mitigated by the temporary layoff programme implemented by the Government aimed at covering up to 100% of the employees' wages in businesses particularly affected by the pandemic (Segurança Social, 2020).

We took advantage of Apple and Google Mobility Reports to explore the mobility patterns throughout 2020. Fig. 2 presents the changes in mobility trends of driving and walking provided by Apple (2021), while Fig. 3 presents the changes regarding access to PT stations provided by Google (2020). Only Google (2020) provides data regarding Lisbon, all the remaining data is for the whole country. Furthermore, as the databases used different baselines, we cannot directly compare the changes in PT with changes in driving or walking. Nonetheless, we can observe that in both graphs the mobility demand falls sharply during each wave, recovering during the summer months. Still, while during summer driving and walking surpassed the baseline levels, PT ridership never fully reaches the pre-pandemic levels. Reports from PT operators in Lisbon provide additional evidence of the devastating impact of COVID-19 on PT, with the city's subway system registering a 51% ridership drop in 2020 comparatively to 2019 (Metropolitano de Lisboa, 2021).

### *3.2. Lisbon's cycling strategy and bike sharing system*

The promotion of cycling as a mode of transport has been gaining prominence in Lisbon in recent years. Since 2016, the municipality began the implementation of a 100 km dedicated cycling network, complemented by traffic calming measures and bike parking facilities (Câmara Municipal de Lisboa, 2020b). Concurrently, in 2017, the municipality implemented a public owned BSS, called *GIRA*, consisting of 700 shared bikes (2/3 e-bikes) and 83 stations. Fig. 4 presents the implemented cycling network and the location of *GIRA*'s stations, with these interventions being mainly concentrated in the city centre and along the riverside.

Bike counts carried out before COVID-19 in strategic points of the city indicate encouraging signs of an increase in cycling use as the number of cyclists increased 817% between 2016 and 2018, with 34% of all observed cycling trips in 2018 being conducted by *GIRA*'s users (Félix, Cambra, & Moura, 2020).

In response to the impacts of the COVID-19 pandemic, Lisbon announced the implementation of an additional 76.5 km of new pop-

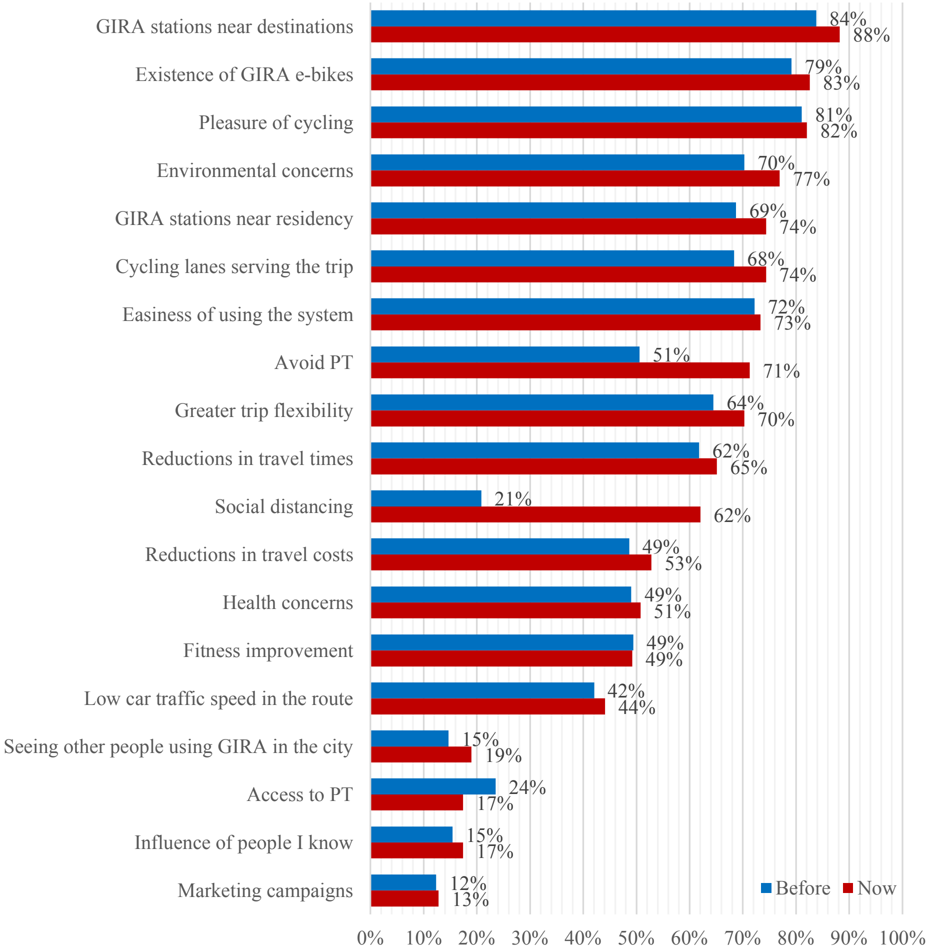


**Fig. 5.** Motivations for using *GIRA* ranked according to the respondents' importance assessment before (N = 259) and during COVID-19 (N = 195) (for easier reading only the combined percentage of the two highest ratings - *important* and *very important* - is displayed).

up cycling lanes (Fig. 4 presents in red the pop-up lanes already operational at the time of this study), complemented by new bike parking facilities and the establishment of an initiative to subsidize the purchase and repairing of personal bicycles (Câmara Municipal de Lisboa, 2020a). Likewise, new expansions of *GIRA* were announced, including the deployment of new shared e-bikes. By 2030 the municipality plans to have a 200 km dedicated cycling network and to have *GIRA* covering the entire city (Câmara Municipal de Lisboa, 2020b). Bike counts conducted by the municipality in 2020 support this cycling strategy, as they registered a 25% increase in cycling use between 2019 and 2020 (Moura, Félix and Reis, 2020).

## 4. Methodology

### *4.1. Survey design and implementation*

A survey was designed and implemented aimed at assessing the main motivations for BSS use as well as the impacts of COVID-19 on those motivations. Respondents were asked to rate the importance of 19 motivations (Fig. 5) on their decision to use *GIRA* using a Likert measurement scale ranging from 1 (*not important at all*) to 5 (*very important*). In addition to the several motivations identified in the literature as influencing BSS usage before COVID-19 (Section 2.1.), we added the motivation of social distancing due to the characteristics of this pandemic. Standard socioeconomic and demographic as well as travel behaviour questions were also included.

In order to assess the coronavirus impact on the motivations for using bike sharing, we began by informing the respondents that throughout the survey we would ask them, in specific questions, to compare their current daily routines and behaviour (during COVID-19) with a time when the pandemic did not affect their lives (we suggested, comparing with the first two months of 2020). Next, we asked the respondents about their current relationship with *GIRA*:

A. *Being a GIRA user before and during the COVID-19 pandemic*
B. *Have joined GIRA during the COVID-19 pandemic*

**Table 1**
Comparison of the general statistics between the samples of the 2020 and 2019 surveys.

| | | 2020 survey (N = 294) | *GIRA*'s operator 2019 survey (N = 4970) |
|---|---|---|---|
| Place of residence | Lisbon City | 86% | 71% |
| Gender | Female | 39% | 33% |
| | Male | 61% | 67% |
| Age | < 18 | 1% | 1% |
| | 18–24 | 16% | 14% |
| | 25–34 | 28% | 29% |
| | 35–44 | 24% | 30% |
| | 45–54 | 25% | 19% |
| | > 54 | 6% | 7% |
| Education | Basic Education | 0% | 2% |
| | Secondary Education | 13% | 15% |
| | Higher Education | 87% | 83% |
| Employment status | Working | 72%[a] | 84%[b] |
| | Not working | 4% | 2% |
| | Retired | 2% | 2% |
| | Studying | 21% | 12% |
| With a *GIRA* annual subscription | | 94% | 90% |
| With a driving's license | | 89% | N/A |
| With a PT monthly pass | | 46% | 39% |
| Car available for use | | 78% | 84% |
| Bicycle available for use | | 59% | 51% |

[a] Does not include working students.
[b] Includes working students.

C. *Being a GIRA user before the COVID-19 pandemic, but have stopped using the system*

Respondents were asked to retrospectively rate their motivations for using *GIRA* before COVID-19 (groups A and C) and in the current situation (groups A and B). To the respondents who were *GIRA* users before COVID-19 and continue to use the system (group A) we requested them to compare the importance of each motivation before and during COVID-19. Consequently, we were able to categorize our respondents into two "distinct" periods of analysis:

- **Before COVID-19**, comprised by the combination of the retrospective questions asked to the respondents that continue to use the system (group A) and to the former users (group C)
- **During COVID-19**, constituted by the combination of the answers from the new users (group B) and the answers of the respondents that continue to use the system in relation to the current situation (group A)

Furthermore, the respondents who stopped using the system were asked to choose if their reason for quitting the system was a consequence of the COVID-19 or if it was because of other reasons not related to the pandemic. According to their answer, the respondents were requested to select, from a defined set of options, their reasons for quitting (multiple choice was allowed).

The survey was performed in an online-only format, being available between September and October 2020. It was disseminated through social media (including in the official pages of parish councils, cyclists and bike sharing user groups as well as neighbourhood associations), local press and universities' mailing lists. The time needed to complete the survey was between 10 min and 15 min. A total of 442 respondents opened the survey and indicated to use or have used *GIRA*, of which 294 completed the survey.

### 4.2. Statistical analysis

Descriptive statistics were utilized to analyse the socioeconomic and demographic profile of the respondents, their main mode of transport as well as for an initial examination of the motivations for BSS use.

We have employed exploratory factor analysis (EFA) with the objective of summarizing and reducing the motivations for using BSS into a smaller number of representative factors (Field, 2013b; Hair et al., 2014). As the main purpose for the EFA was to reduce our original motivations into a smaller and more manageable number of latent factors, we have applied Principal Component Analysis (PCA) as the method for factor extraction[1] (Field, 2013b; Hair et al., 2014). The number of factors to extract was decided through the eigenvalue and scree plot criteria (Field, 2013b; Hair et al., 2014). Variables with no significant correlations ($r < 0.3$), very high correlations ($r > 0.8$) or with significant cross-loadings were excluded (Field, 2013b). To achieve a simpler and more meaningful factor matrix, we applied the orthogonal rotation *VARIMAX*[2]. Lastly, we utilized the reliability coefficient *Cronbach's α* to assess the internal

[1] We have also employed the alternative common factor analysis (specifically Principal Axis Factoring) and obtained the same factor matrix.
[2] We tested the oblique rotation method *Oblimin* but as the obtained correlation matrix between the factors revealed no significant correlations ($r<0.3$), we can assume our factors to be independent and, therefore, an orthogonal rotation is preferred (Field, 2013b).

**Table 2**
Demographic and socioeconomic characteristics of the respondents profiled according with their current relationship with *GIRA* (no longer using, continue to use or joined recently).

| | | Former users (N = 99) | | Users before and during COVID-19 (N = 160) | | New users (N = 35) | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| Place of residence | Lisbon City | 76 | 77% | 146 | 91% | 31 | 89% |
| | Lisbon Metropolitan Area | 23 | 23% | 14 | 9% | 4 | 11% |
| Gender | Female | 32 | 32% | 63 | 39% | 21 | 60% |
| | Male | 67 | 68% | 97 | 61% | 14 | 40% |
| Age | < 18 | 1 | 1% | 1 | 1% | 1 | 3% |
| | 18–24 | 13 | 13% | 22 | 14% | 12 | 34% |
| | 25–34 | 29 | 29% | 40 | 25% | 13 | 37% |
| | 35–44 | 20 | 20% | 44 | 28% | 6 | 17% |
| | 45–54 | 25 | 25% | 46 | 29% | 3 | 9% |
| | > 54 | 11 | 11% | 7 | 4% | 0 | 0% |
| Education | Basic Education | 0 | 0% | 0 | 0% | 1 | 3% |
| | Secondary Education | 9 | 9% | 22 | 14% | 7 | 20% |
| | Higher Education | 90 | 91% | 138 | 86% | 27 | 77% |
| Employment status | Working | 71 | 72% | 121 | 76% | 21 | 60% |
| | Not working | 3 | 3% | 8 | 5% | 2 | 6% |
| | Retired | 4 | 4% | 1 | 1% | 0 | 0% |
| | Studying | 21 | 21% | 30 | 19% | 12 | 34% |
| With a *GIRA* annual subscription | | 90 | 91% | 155 | 97% | 30 | 86% |
| With a driving's license | | 93 | 94% | 141 | 88% | 27 | 77% |
| With a PT monthly pass | | 45 | 45% | 68 | 43% | 21 | 60% |
| Car available for use | | 83 | 84% | 126 | 79% | 21 | 60% |
| Bicycle available for use | | 67 | 68% | 92 | 58% | 13 | 37% |

consistency of our factors (Hair et al., 2014).

To determine the most important motivations for using bike sharing and to compare between the periods before and during COVID-19, we subjected the obtained factors from the EFA to a one-way repeated measures ANOVA. Repeated measures ANOVA is used when we want to compare more than two group means where the participants are the same in each group (Field, 2013d). In our case we aim to compare the importance of each factor resulting from the EFA among all factors and in each of the two distinct periods. As an additional validation of our results, we also conducted the Friedman test with pairwise Wilcoxon Signed Ranks post-hoc tests, which is the non-parametric equivalent to the one-way repeated measures ANOVA (Field, 2013c), and obtained the same results[3]. Similarly to other non-parametric tests, the Friedman test uses ranks to compare the data (Field, 2013c). Lastly, we employed independent-samples *t-tests* (Field, 2013a) to explore possible differences on the motivational factors between the respondents who have recently joined and those who were already users before the pandemic and continue to use the system. Like in the case of ANOVA, we also used the non-parametric equivalent of the independent-samples *t-test* to validate our results: the Mann-Whitney *U* test (Field, 2013c). The Friedman test with pairwise Wilcoxon Signed Ranks post-hoc tests as well as the Mann-Whitney U tests are presented in Appendix A. The statistical analyses were all conducted on IBM SPSS Statistics, version 26 for Windows.

### *4.3. Sample description*

A total of 294 respondents completed the survey. We start by analysing in Table 1 the representativeness of our sample by comparing it with a larger survey conducted by *GIRA*'s operator between January and February 2019 (Moura and Félix, 2019).

The average respondent in our sample lives in the city of Lisbon (86%), is male (61%), has a higher education degree (87%) and is employed (72%). The vast majority of respondents have an annual subscription of *GIRA* (94%). Moreover, having a driving's license (89%) and access to a car (78%) is more prevalent than having a PT monthly pass (46%) or a personal bicycle (59%).

Overall, our sample is similar to the results obtained by *GIRA*'s operator, albeit it presents a higher share of respondents living in the city of Lisbon. Furthermore, our sample has a higher share of students and a lower share of respondents working. This can be explained, on the one hand, by different methodological considerations (the survey from *GIRA*'s operator considered working students in the working category contrary to our survey) and, on the other hand, by a rise on unemployment resulting from the COVID-19 crisis (Fig. 1). Likewise, our sample presents a higher share of users having a PT monthly pass. Two explanations are presented. Firstly, we asked the respondents if they have or usually have a PT monthly pass, not specifying a period which could have led to an underestimation of the COVID-19 effect. Secondly, on April 2019 (between the period of the two surveys) the Portuguese Government implemented a major nationwide restructuring of PT monthly passes, which led to significant savings and a steady increase in PT users up until the COVID-19 pandemic (IMT, 2020).

Next, we divided our sample in the three groups of users previously mentioned (former users, new users and respondents who were

[3] When analysing Likert-scales (constituted by more than a single Likert item, like our case in which we are comparing factors) using parametric tests like ANOVA is typically accepted (Carifio and Perla, 2008; Norman, 2010).

**Table 3**
Modal share of the main modes of transport for commuting (trips from home to work or school) before (N = 259) and during COVID-19 (N = 171). Note: 24 of respondents that use *GIRA* in the current situation declared to no longer commute.

| Main mode of transport for commuting trips | Before | Now |
|---|---|---|
| *GIRA shared bicycle* | 23.0% | 28.3% |
| *Public Transport* | 33.4% | 23.6% |
| *Walking* | 19.6% | 22.8% |
| *Private car* | 10.2% | 11.9% |
| *Personal bicycle* | 8.2% | 7.7% |
| *Taxi or equivalent* | 2.6% | 3.2% |
| *Motorcycle* | 1.7% | 1.7% |
| *Other* | 1.2% | 0.7% |

users before COVID-19 and continue to use the system), with their main demographic and socioeconomic characteristics represented in Table 2. Although the small number of respondents in each group, particularly regarding the group of new users, restricts possible generalizations, we can observe that the former users tend to have higher car (84% versus 79% of users before and during COVID-19 and 60% of new users) and bicycle availability (68% versus 58% of users before and during COVID-19 and 37% of new users). Furthermore, the majority of new users in our sample are women (60% versus 39% of users before and during COVID-19 and 32% of former users) and tend to be younger (74% are under 35 years old comparatively to only 40% of users before and during COVID-19 and 43% of former users).

According to our previous classification of the periods of analysis to be considered (Section 4.1.), in the period before COVID-19 we obtained 259 valid answers (retrospective questions from groups A and C), while in the period during COVID-19 we have 195 valid answers (current answers from groups A and B).

## 5. Results

### 5.1. Descriptive statistics

#### 5.1.1. Main mode of transport

To better contextualize the motivations for using *GIRA* before and during COVID-19, we start our analysis by observing the main modes of transport used by our respondents in their commuting trips between the two periods (Table 3). The respondents could select one or multiple modes in their commute, with walking trips only considered if there were made exclusively or were longer than 5 consecutive minutes in a combined trip. Furthermore, respondents had the option to declare to no longer commute during COVID-19.

Although the modal share of most modes of transport remains fairly stable between the two periods, we can observe two significant differences: a decrease in the modal share of PT and an increase in the modal share of *GIRA*. While before the pandemic, PT was the most frequently chosen mode (33.4%) followed by *GIRA* (23.0%), now *GIRA* has surpassed PT (28.3% versus 23.6%) as the most used mode by our respondents.

#### 5.1.2. Motivations for using GIRA

We now turn our attention to the motivations for using *GIRA* before and during COVID-19. Fig. 5 shows the motivations for using *GIRA* between the two periods, ranked according to the respondents highest scores.

The motivation with the highest scores in both periods was the existence of *GIRA* stations near the respondents' destinations, closely followed by the availability of shared e-bikes as well as the pleasure of cycling. Environmental concerns, the existence of *GIRA* stations near the respondents' home, as well as the availability of cycling lanes serving the trip and the easiness of using the system were also considered important motivations for using *GIRA* in both time periods. The relative higher importance given to the existence of *GIRA* stations near the respondents' destinations comparatively to the stations near home may be explained by *GIRA* stations being predominantly located in the city centre near major business districts and universities, with a scarcity of stations near residential areas. On the opposite spectrum, marketing was the least influential motivation with only 12% and 13% of respondents considering it to be an important or very important reason for using *GIRA* in each period. Similarly, motivations related to the social environment, such as the influence of family/friends/colleagues or seeing other people using the system had also some of the lowest scores. Using *GIRA* to access PT was likewise considered of little importance, being even less important during COVID-19.

The importance of most motivations remained stable between the periods before and during COVID-19, with the major exceptions being the motivations of maintaining a social distance during the trip and avoiding the use of PT, which are now much more relevant. While using *GIRA* to avoid PT was already important to some users before COVID-19 (with a score similar to the motivations of travel costs reductions as well as health concerns and fitness improvement), the percentage of users considering it an important or very

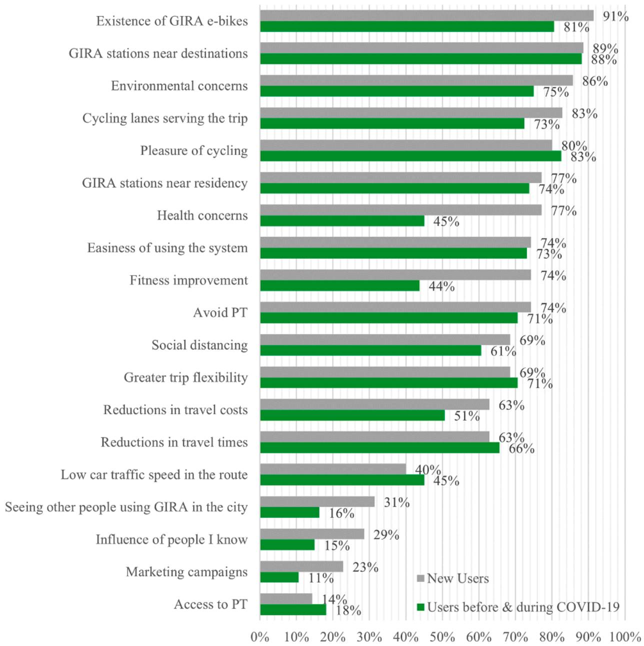


**Fig. 6.** Comparison of the motivations for using *GIRA* during COVID-19 between New Users (N = 35) and Users Before and During COVID-19 (N = 160) (for easier reading only the combined percentage of the two highest ratings - important and very important - is displayed).

important motivation is now close to the importance given to the motivations of greater trip flexibility and easiness of using the system. Likewise, the percentage of respondents considering that maintaining a social distance during the trip is an important or very important reason for using *GIRA* has skyrocketed, moving from being one of least important motivations to being almost as important as the motivation of reducing travel times.

### *5.1.3. Motivations of new users versus users before and during COVID-19*

We have also explored possible differences in the motivations between the users who have joined *GIRA* during the pandemic and the respondents who were already users before and continue to currently use *GIRA* (Fig. 6). Although most motivations have the same importance for both user groups, the comparison reveals some substantial differences. Firstly, new users give considerably more importance to seeing other people using the system and to the influence of their social circle comparatively to the older users (a 15% and 14% difference, respectively). Likewise, marketing campaigns are more valued by new users (12% difference). More remarkably, the new users consider the motivations of health concerns and fitness improvement as much more important than the older users, with a difference of>30%, being to them as important as using *GIRA* to avoid PT.

### *5.1.4. Reasons for quitting GIRA*

Lastly, we asked the respondents who have quitted *GIRA* to justify their choice. Of the 99 respondents who have quitted the system, only 30 justified their decision on the consequences of the pandemic, while 69 stopped using *GIRA* due to reasons not directly related to COVID-19. For the respondents who quitted *GIRA* due to the pandemic, most justified their decision on the trip purpose no longer existing (49%), with only a minority avoiding using the system due to infection fears (38%).

Regarding the users who quitted *GIRA* due to reasons not related to COVID-19, their answers are presented in Fig. 7, with most of their chosen reasons being linked to the coverage and quality of the system. The shortage of shared bikes (26%), particularly e-bikes (20%), was the most chosen reason for quitting the system, followed by the lack of *GIRA* stations near their destinations or home (17%), poor condition of the bikes (11%) as well as a lack of available docking points to return the *GIRA* bicycles (10%). Changing home or work/study location (10%) and shifting to their personal bicycle (8%) were the most frequently chosen reasons not directly connected to the systems' coverage and quality.

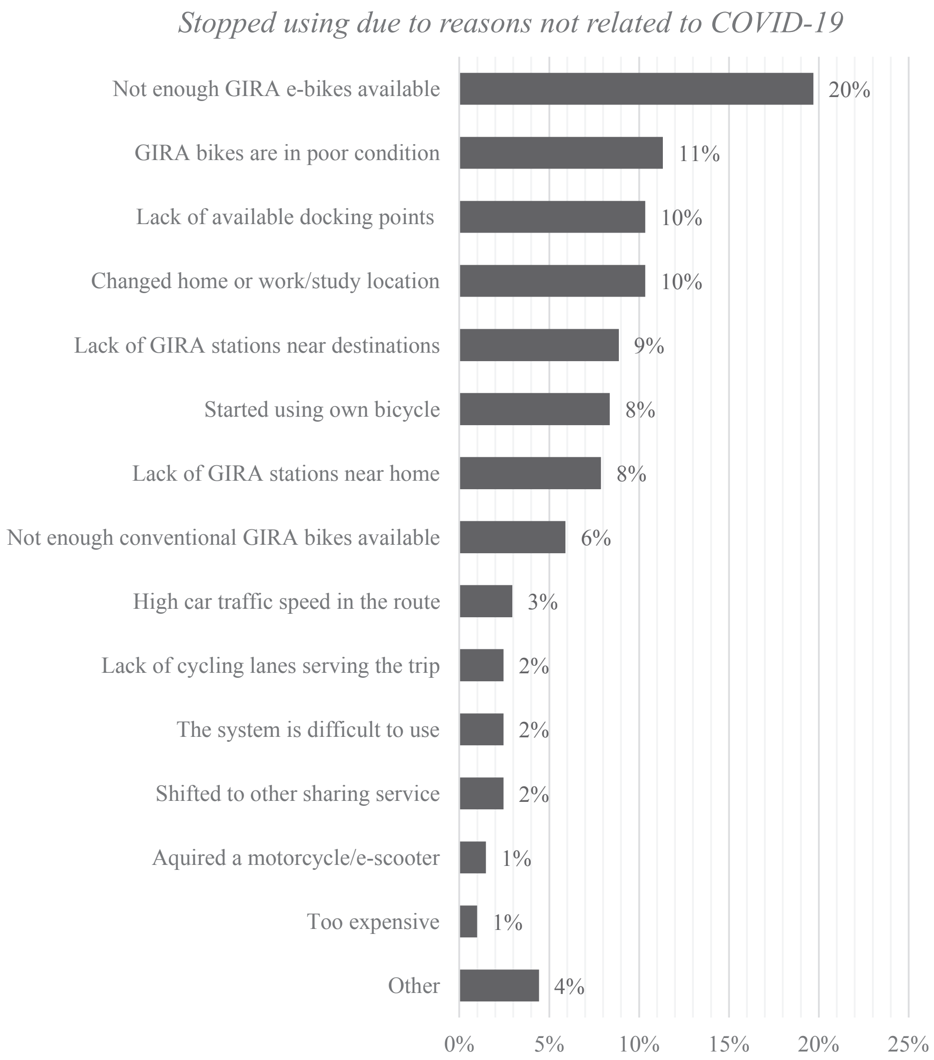


**Fig. 7.** Reasons for stopping using *GIRA* not related to the COVID-19 pandemic (N = 69) (multiple choice) (responses to the question "*Having replied that you stopped using GIRA for other reasons unrelated to the pandemic, what were the reasons for that decision?*").

### *5.2. Analysis of motivations before and during COVID-19*

#### *5.2.1. Factor analysis*

Factor analysis was conducted to aggregate the motivations presented in Fig. 5 into a smaller and more manageable number of latent factors. We removed the motivation *access to PT* from the analysis due to a lack of meaningful correlations with the other variables (all correlations were bellow 0.3). Furthermore, as the variables *health concerns* and *fitness improvement* were highly correlated ($r > 0.8$), we decided to exclude the latter[4] from the analysis to avoid multicollinearity issues (Hair et al., 2014). Finally, the motivation *low car traffic speeds in the route* was also removed due to significant cross-loadings. Each time a variable was removed, the EFA was repeated. The three variables had the same problems in both samples and, therefore, were removed from both.

In the end, 16 different motivations were retained, obtaining the same 5 distinct factors in both time periods. Both samples had acceptable Kaiser-Meyer-Olkin (KMO) Measures of Sampling Adequacy (KMO = 0.77 before COVID-19 and KMO = 0.68 during COVID-19), and all KMO values for the individual items were 0.6 or greater (well above the 0.5 minimum threshold) (Field, 2013b). Likewise, the Bartlett's Test of Sphericity was significant ($p < .001$) in the two samples. Table 4 and Table 5 represent, respectively, the factor analyses conducted in the periods before and during COVID-19. Cross-loadings lower than 0.4 were omitted from the tables for easier reading.

[4] We also conducted the analysis removing *health concerns* instead and obtained the same result. Ultimately, we opted for excluding *fitness improvement* due to a lower *Cronbach's α* score obtained in the corresponding factor.

**Table 4**
EFA before COVID-19 (Total variance explained = 60.4%, N = 259).

| | Service Coverage & Quality | Social Influence | Utility & Competitiveness | Personal Interests & Well-being | Social Discomfort |
|---|---|---|---|---|---|
| *GIRA stations near home* | **0.735** | | | | |
| *GIRA stations near destinations* | **0.735** | | | | |
| *Existence of GIRA e-bikes* | **0.728** | | | | |
| *Cycling lanes serving the trip* | **0.584** | | | | |
| *Easiness of using the system* | **0.539** | | | | |
| *Seeing other people using GIRA in the city* | | **0.812** | | | |
| *Influence of people I know* | | **0.745** | | | |
| *Marketing campaigns* | | **0.700** | | | |
| *Reductions in travel times* | | | **0.771** | | |
| *Greater trip flexibility* | | | **0.757** | | |
| *Reductions in travel costs* | | | **0.692** | | |
| *Health concerns* | | | | **0.792** | |
| *Pleasure of cycling* | | | | **0.756** | |
| *Environmental concerns* | | | | **0.653** | |
| *Avoid PT* | | | | | **0.769** |
| *Social distancing* | | 0.467 | | | **0.616** |
| Eigenvalues | 3.84 | 1.98 | 1.47 | 1.39 | 0.99 |
| % of variance explained | 14.9% | 12.9% | 12.2% | 12.1% | 8.5% |
| *Cronbach's Alpha (α)* | 0.71 | 0.68 | 0.68 | 0.68 | 0.55 |

**Table 5**
EFA during COVID-19 (Total variance explained = 57.3%, N = 195).

| | Service Coverage & Quality | Utility & Competitiveness | Personal Interests & Well-being | Social Influence | Social Discomfort |
|---|---|---|---|---|---|
| *GIRA stations near home* | **0.752** | | | | |
| *Existence of GIRA e-bikes* | **0.740** | | | | |
| *GIRA stations near destinations* | **0.626** | | | | |
| *Easiness of using the system* | **0.492** | | | | |
| *Cycling lanes serving the trip* | **0.395** | | | | |
| *Reductions in travel times* | | **0.710** | | | |
| *Greater trip flexibility* | | **0.651** | | | |
| *Reductions in travel costs* | | **0.596** | | | |
| *Health concerns* | | | **0.778** | | |
| *Pleasure of cycling* | | | **0.726** | | |
| *Environmental concerns* | | | **0.678** | | |
| *Seeing other people using GIRA in the city* | | | | **0.806** | |
| *Influence of people I know* | | | | **0.725** | |
| *Marketing campaigns* | | | | **0.654** | |
| *Social distancing* | | | | | **0.850** |
| *Avoid PT* | | | | | **0.740** |
| Eigenvalues | 3.35 | 1.76 | 1.50 | 1.36 | 1.20 |
| % of variance explained | 12.6% | 12.0% | 11.4% | 11.3% | 10.0% |
| *Cronbach's Alpha (α)* | 0.62 | 0.60 | 0.65 | 0.63 | 0.70 |

The motivations for using BSS can be represented by five distinct factors, with 60.4%, and 57.3% of the total variance explained, respectively, before and during COVID-19:

- *Service Coverage & Quality* – characterized by the convenient location of BSS stations, the easiness of using the system, as well as amenities valued by users like the availability of shared e-bikes and the existence of cycling lanes serving their routes
- *Personal Interests & Well-being* – defined by the perceived environmental and health benefits of using bike sharing, as well as the pleasure and enjoyment of cycling
- *Utility & Competitiveness* – represented by the transport advantages of bike sharing, such as reductions in travel times and costs as well as the flexibility provided by shared bikes
- *Social Influence* – constituted by the influence of the social circles as well as the perceived social acceptance of using bike sharing in the city

**Table 6**
Estimated marginal means of the motivations for using *GIRA* before COVID-19 (N = 258).

| Motivations | Mean | Std. Deviation | Std. Error | 95% CI |
|---|---|---|---|---|
| *Service Coverage & Quality* | 4.035 | 0.789 | 0.049 | [3.938; 4.132] |
| *Personal Interests & Well-being* | 3.882 | 0.902 | 0.056 | [3.772; 3.993] |
| *Utility & Competitiveness* | 3.602 | 1.019 | 0.063 | [3.477; 3.727] |
| *Social Influence* | 2.059 | 0.953 | 0.059 | [1.943; 2.176] |
| *Social Discomfort* | 2.738 | 1.220 | 0.076 | [2.589; 2.888] |

**Table 7**
Estimated marginal means of the motivations for using *GIRA* during COVID-19 (N = 193).

| Motivations | Mean | Std. Deviation | Std. Error | 95% CI |
|---|---|---|---|---|
| *Service Coverage & Quality* | 4.152 | 0.703 | 0.051 | [4.053; 4.252] |
| *Personal Interests & Well-being* | 3.969 | 0.865 | 0.062 | [3.846; 4.092] |
| *Utility & Competitiveness* | 3.689 | 0.960 | 0.069 | [3.553; 3.825] |
| *Social Influence* | 2.085 | 0.950 | 0.068 | [1.950; 2.219] |
| *Social Discomfort* | 3.785 | 1.320 | 0.095 | [3.598; 3.972] |

**Table 8**
Pairwise comparisons of the motivations for using *GIRA* before COVID-19 (N = 258).

| Motivations | | Mean Difference | Std. Error | 95% CI for Difference[b] |
|---|---|---|---|---|
| *Service Coverage & Quality* | Personal Interests & Well-being | 0.152 | 0.065 | [−0.031; 0.336] |
| | Utility & Competitiveness | $0.433^{*b}$ | 0.067 | [0.242; 0.624] |
| | Social Influence | $1.975^{*b}$ | 0.070 | [1.776; 2.175] |
| | Social Discomfort | $1.297^{*b}$ | 0.084 | [1.058; 1.535] |
| *Personal Interests & Well-being* | Service Coverage & Quality | −0.152 | 0.065 | [−0.336; 0.031] |
| | Utility & Competitiveness | $0.280^{*b}$ | 0.072 | [0.077; 0.484] |
| | Social Influence | $1.823^{*b}$ | 0.072 | [1.620; 2.026] |
| | Social Discomfort | $1.144^{*b}$ | 0.077 | [0.927; 1.361] |
| *Utility & Competitiveness* | Service Coverage & Quality | $-0.433^{*b}$ | 0.067 | [−0.624; −0.242] |
| | Personal Interests & Well-being | $-0.280^{*b}$ | 0.072 | [−0.484; −0.077] |
| | Social Influence | $1.543^{*b}$ | 0.077 | [1.324; 1.761] |
| | Social Discomfort | $0.864^{*b}$ | 0.086 | [0.620; 1.107] |
| *Social Influence* | Service Coverage & Quality | $-1.975^{*b}$ | 0.070 | [−2.175; −1.776] |
| | Personal Interests & Well-being | $-1.823^{*b}$ | 0.072 | [−2.026; −1.620] |
| | Utility & Competitiveness | $-1.543^{*b}$ | 0.077 | [−1.761; −1.324] |
| | Social Discomfort | $-0.679^{*b}$ | 0.075 | [−0.891; −0.467] |
| *Social Discomfort* | Service Coverage & Quality | $-1.297^{*b}$ | 0.084 | [−1.535; −1.058] |
| | Personal Interests & Well-being | $-1.144^{*b}$ | 0.077 | [−1.361; −0.927] |
| | Utility & Competitiveness | $-0.864^{*b}$ | 0.086 | [−1.107; −0.620] |
| | Social Influence | $0.679^{*b}$ | 0.075 | [0.467; 0.891] |

*The mean difference is significant at the 0.05 level.
[b]Adjustment for multiple comparisons: Bonferroni.

- *Social Discomfort* – constituted by the motivations more affected by COVID-19, specifically using *GIRA* to maintain a social distance during the trip and as an alternative to PT

*Cronbach's α* presented accepted values for an exploratory study (Hair et al., 2014) in all factors except on *Social Discomfort* in the period before COVID-19 (below the minimum threshold of 0.60), however in the current period the *Cronbach's α* of this factor has substantially increased to 0.70. The low *Cronbach's α* score can be attributed to the motivation of maintaining a social distance, which also presents a significant cross-loading with the factor *Social Influence* in the period before COVID-19. Such problems can be explained by the nature of this motivation, which before COVID-19 had a different context, more associated with avoiding interacting with other people or with the discomfort of being in crowded places that, for instance, characterize PT (Haywood, Koning, & Monchambert, 2017; Thomas, 2009). During COVID-19, maintaining a social distance has gained a new meaning, and much more relevance, as it is now connected to the fear of infection.

**Table 9**
Pairwise comparisons of the motivations for using *GIRA* during COVID-19 (N = 193).

| Motivations | Mean Difference | Std. Error | 95% CI for Difference[b] | |
|---|---|---|---|---|
| *Service Coverage & Quality* | Personal Interests & Well-being | 0.183 | 0.074 | [−0.025; 0.392] |
| | Utility & Competitiveness | 0.463[*b] | 0.075 | [0.250; 0.676] |
| | Social Influence | 2.068[*b] | 0.077 | [1.850; 2.285] |
| | Social Discomfort | 0.367[*b] | 0.101 | [0.081; 0.653] |
| *Personal Interests & Well-being* | Service Coverage & Quality | −0.183 | 0.074 | [−0.392; 0.025] |
| | Utility & Competitiveness | 0.280[*b] | 0.079 | [0.055; 0.505] |
| | Social Influence | 1.884[*b] | 0.079 | [1.659; 2.110] |
| | Social Discomfort | 0.184 | 0.104 | [−0.111; 0.479] |
| *Utility & Competitiveness* | Service Coverage & Quality | −0.463[*b] | 0.075 | [−0.676; −0.250] |
| | Personal Interests & Well-being | −0.280[*b] | 0.079 | [−0.505; −0.055] |
| | Social Influence | 1.604[*b] | 0.086 | [1.361; 1.848] |
| | Social Discomfort | −0.096 | 0.100 | [−0.381; 0.189] |
| *Social Influence* | Service Coverage & Quality | −2.068[*b] | 0.077 | [−2.285; −1.850] |
| | Personal Interests & Well-being | −1.884[*b] | 0.079 | [−2.110; −1.659] |
| | Utility & Competitiveness | −1.604[*b] | 0.086 | [−1.848; −1.361] |
| | Social Discomfort | −1.700[*b] | 0.104 | [−1.996; −1.404] |
| *Social Discomfort* | Service Coverage & Quality | −0.367[*b] | 0.101 | [−0.653; −0.081] |
| | Personal Interests & Well-being | −0.184 | 0.104 | [−0.479; 0.111] |
| | Utility & Competitiveness | 0.096 | 0.100 | [−0.189; 0.381] |
| | Social Influence | 1.700[*b] | 0.104 | [1.404; 1.996] |

*The mean difference is significant at the 0.05 level.
[b]Adjustment for multiple comparisons: Bonferroni.

**Table 10**
Comparison of the motivations for using *GIRA* between the New Users (N = 35) and Users Before and During COVID-19 (N = 158), as well as the *t-tests* (two-tailed) results and associated significance.

| Motivations | User type | Mean | Std. Deviation | Std. Error | *t-test* | Differences significant at p < .05 (test) |
|---|---|---|---|---|---|---|
| *Service Coverage & Quality* | New users | 4.240 | 0.542 | 0.092 | 0.815 | No |
| | Users before and during COVID-19 | 4.133 | 0.734 | 0.058 | | |
| *Personal Interests & Well-being* | New users | 4.190 | 0.789 | 0.133 | 1.683 | No |
| | Users before and during COVID-19 | 3.920 | 0.875 | 0.070 | | |
| *Utility & Competitiveness* | New users | 3.743 | 0.754 | 0.128 | 0.436[b] | No |
| | Users before and during COVID-19 | 3.677 | 1.002 | 0.080 | | |
| *Social Influence* | New users | 2.410 | 1.039 | 0.176 | 2.261 | **Yes** |
| | Users before and during COVID-19 | 2.013 | 0.917 | 0.073 | | |
| *Social Discomfort* | New users | 3.971 | 1.124 | 0.190 | 1.042[b] | No |
| | Users before and during COVID-19 | 3.744 | 1.359 | 0.108 | | |

[b]Equal variances not assumed.

### *5.2.2. Repeated measures ANOVA*

The resulting five factors from the previous factorial analyses were submitted to a one-way repeated measures ANOVA[5] to determine the importance of each factor. The procedure was conducted separately for each time period (i.e., before COVID-19 and now). As Mauchly's test indicated that the assumption of sphericity was violated in both samples ($\chi^2$ (9) = 41.12; $p < .001$ for the sample before COVID-19 and $\chi^2$ (9) = 53.00; $p < .001$ for the sample during COVID-19), we considered the corrections when this assumption is violated (Field, 2013d), which are provided in Appendix B.

As the repeated measures ANOVA was statistically significant (even when considering the corrections for the violation of sphericity), we can accept that there are significant differences between the factors and analyse the post-hoc estimated marginal means and pairwise comparisons. The estimated mean scores as well as the pairwise comparisons of each factor in the period before COVID-19 are, respectively, represented in Table 6 and Table 8, while the corresponding results for the period during COVID-19 are displayed in Table 7 and Table 9.

The pairwise comparisons revealed that before the pandemic the motivations more influential on the decision to use bike sharing

[5] Before conducting the repeated measures ANOVA, possible outliers of the summated scales derived from the EFA (and calculated through simple means) were detected and removed based on z-scores > 3.29 (Field, 2013e), resulting in one outlier being removed from the sample before COVID-19 and two outliers being removed from the sample during COVID-19.

were those related to the *Service Coverage & Quality* as well as to the users' *Personal Interests & Well-being*, followed by the motivations connected to *Utility & Competitiveness*. Conversely, the least influential motivations when comparing with each of the other motivational factors were linked to *Social Influence*.

During COVID-19 the relationship between most motivations remains the same, except for the motivations connected to *Social Discomfort*. While before COVID-19, *Social Discomfort* was the second least important motivation (only more significant than *Social Influence*), during the pandemic the prominence of *Social Discomfort* has increased substantially, being now as important as the motivations related to *Personal Interests & Well-being* and *Utility & Competitiveness* (the mean differences are no longer statistically significant). Only the motivations connected to the *Service Coverage & Quality* remain more important than *Social Discomfort* (statistically significant), but the mean difference is now much less pronounced.

#### *5.2.3. Independent samples t-test*

Lastly, we employed *t-tests*[6] to analyse possible differences on the importance of the motivational factors between the users who have joined *GIRA* during COVID-19 and the respondents who were users before and during COVID-19 (Table 10). The importance of each motivational factor is mostly the same for both user groups during the pandemic. The only exception is the *Social Influence* factor, with new users considering the motivations linked to this factor to be statistically more important than the older users.

## 6. Discussion, limitations and conclusions

The analysis has revealed that the most influential motivations regarding BSS usage, overall, are those related to the *Service Coverage & Quality*, particularly the proximity of BSS stations to the users' destinations and the availability of shared e-bikes. The suitable location of BSS stations as a major motivation is in line with previous findings (Fishman et al., 2014), and were an expected outcome as they greatly determine the ability to reach their desirable destinations. The existence of shared e-bikes revealed to be highly regarded by users. The availability of e-bikes can be a potential trigger for inducing cycling as it helps to overcome some of the main perceived barriers for bicycle use, such as physical effort and long trip distances (Félix, Moura, & Clifton, 2019). However, the current price of buying an e-bike is still a barrier particularly for lower income groups. In that sense, the provision of shared bikes at an affordable usage cost could encourage new users to take up bike sharing.

The motivations connected to *Personal Interests & Well-being* were also deemed highly influential on the decision to use bike sharing. Moreover, the pleasure of cycling was found to have a similar level of importance as the motivations with the highest scores from *Service Coverage & Quality*. Notably, the importance given to these motivations also illustrates how BSS can help to minimize some of the negative effects on general well-being caused by the coronavirus pandemic (De Vos, 2020), through providing its users with an activity associated with positive emotions as well as a mean for performing physical activity when most of the usual exercise facilities are not available.

Inversely, the influence of the social environment on BSS usage was mostly disregard by its users. The marketing campaigns in particular had amongst the lowest scores. Nevertheless, the *Social Influence* factor was found to be more valued by the new users who have joined *GIRA* during COVID-19. This could indicate that the coronavirus has led to an increase in the social acceptability of cycling, as evidenced by the significant rise on cycling levels during the pandemic in several countries (Buehler & Pucher, 2021), inducing new users to take up bike sharing. Likewise, the observed increase in the marketing campaigns' importance among new users may be related to the *GIRA's* current communication campaigns focused on the safety measures implemented to decrease the infection risk of using the system.

Finally, the impact of coronavirus on the motivations for using BSS is clearly represented by the rise on the importance of the motivational factor *Social Discomfort*. Before the pandemic, this factor was amongst the least prominent, only more important than *Social Influence*, being mostly represented by the motivation of using *GIRA* to avoid PT. Avoiding using PT was already a fairly important motivation prior to the pandemic and was related to the fact that Lisbon's PT network was facing a quality decline, namely by suffering from overcrowded services. With the emergence of COVID-19, *Social Discomfort* has gained a new relevance and meaning, becoming as important as the motivational factors of *Personal Interests & Well-being* and *Utility & Competitiveness*. If before the pandemic, there were already some respondents that considered *GIRA* as an attractive alternative to PT, now that number has drastically increase. Likewise, there is now a significant percentage of respondents that consider the maintenance of a social distance during the trip an important motivation for using *GIRA*, with this motivation acquiring a new significance connected to the fear of infection.

With the emergence of the coronavirus pandemic, BSS have gained a new role as a significant portion of their users now consider using bike sharing to avoid PT and to maintain a social distance in their trips as import or very important motivations. Therefore, BSS could increase the resilience of urban transport systems by potentially providing an alternative mode to PT, where physical distancing can be kept. Systems that provide e-bikes (found to be amongst the most valued motivations by users) could be especially capable of acting as an alternative to PT due to the increased range of e-bikes. As countries prepare (again) to gradually reopen and ease travel restrictions, policymakers should consider BSS in their reopening strategies, taking advantage of the bike sharing's capability to act as an alternative to PT namely by deploying additional BSS stations near major trip generators to reduce the pressure from PT services.

[6] Before conducting the *t-tests*, possible outliers of the summated scales derived from the EFA were detected and removed based on z-scores $> 3.29$ (Field, 2013e), resulting in two outliers being removed from the sample during COVID-19.

Likewise, policymakers could also explore possible synergies between bike sharing and *open streets* experiments or other similar initiatives (Glaser & Krizek, 2021), as BSS have the potential to reinforce the human scale of cities and counteract the lack of liveliness in the public space (while keeping a safe distance from others) exacerbated by the present pandemic.

Additionally, the identification of the motivators for bike sharing usage provides some insights on how BSS operators may tailor their promotional efforts. First, the implementation of new BSS stations or the deployment of shared e-bikes (and the associated advantages of e-bikes) should be widely publicised. Equally, marketing campaigns should focus on advertising the pleasure of cycling or the associated environmental and health benefits, as all these motivations were highly regarded by BSS users both before and during COVID-19. During disruptive public health pandemics such as the coronavirus, the usual marketing strategies could be complemented by promoting bike sharing as a mode of transport where a safe social distance can be maintained during the trip.

However, strategies promoting BSS need to be accompanied by measures aimed at increasing the safety of using bike sharing, which now encompasses two different dimensions. Firstly, traffic safety, where the risk posed by motor traffic needs to be minimized through the construction of segregated cycling lanes or the implementation of traffic calming measures within the catchment areas of BSS stations. Secondly, the risk of infection posed by coronavirus (and similar infectious respiratory diseases), where the transmission risk from contaminated surfaces or from gatherings near the BSS stations should be reduced through enhancing cleaning procedures and restricting contact between users (e.g., enforcing social distancing at the BSS stations or installing a larger number of smaller BSS stations covering the same area instead of a few high-capacity stations).

This study has some limitations. First, we resorted to a convenience sampling method, which can lead to an overrepresentation of respondents more easily accessible and more willing to participate. We have addressed this shortcoming by disseminating the survey in several online channels, obtaining a sample similar to the representative survey conducted by the system's operator. Furthermore, the comparison between the periods before and during COVID-19 relied on retrospective questions, which are susceptible to recall biases. However, the severity and disruptive nature of COVID-19, makes it realistic to assume that people still remember their behaviour before the pandemic.

Future studies could build upon and improve this research by performing similar assessments in additional BSS to validate these results. Follow-up research could further explore the behaviour and attitudes of respondents who have decided to join bike sharing during the pandemic. This can be achieved by collecting bigger samples of such users in similar surveys or through qualitative research designs such as semi-structured interviews. Comparing the perceptions and behaviour of users with non-users might also deliver valuable additional insights. The potential preference for bike sharing instead of PT could be further investigated through actual data on the modal shift dynamics between the two modes, replicating the methodologies of studies conducted prior to the coronavirus pandemic. It would be especially useful to perform longitudinal studies at different points of the pandemic (e.g., comparing the behaviour of BSS users during the lockdowns versus during the different reopening phases) to have a better understanding of possible structural changes that the coronavirus may induce on BSS usage and on its relationship with the broad transport system.

### CRediT authorship contribution statement

**João Filipe Teixeira:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Cecília Silva:** Supervision, Writing – review & editing. **Frederico Moura e Sá:** Supervision, Writing – review & editing.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix A. Alternative non-parametric procedures

Tables A.1–A.4

**Table A1**
Friedman test results for each period.

| | Before COVID-19 | During COVID-19 |
|---|---|---|
| *N* | 258 | 193 |
| *Chi-Square* | 477.685 | 308.710 |
| *df* | 4 | 4 |
| *Sig.* | $p<.001$ | $p<.001$ |

**Table A2**
Post-hoc pairwise comparisons of the motivations for using *GIRA* and associated Wilcoxon Signed Rank tests before COVID-19 (N = 258).

| Pairwise comparisons | Number of Ranks | Z | |
|---|---|---|---|
| *Personal Interests & Well-being vs Service Coverage & Quality* | | | |
| | Negative Ranks | 134 | −2.341[b] |
| | Positive Ranks | 110 | |
| | Ties | 14 | |
| *Utility & Competitiveness vs Service Coverage & Quality* | Negative Ranks | 160 | −5.945*[b] |
| | Positive Ranks | 81 | |
| | Ties | 1 | |
| *Social Influence vs Service Coverage & Quality* | | | |
| | Negative Ranks | 248 | −13.590*[b] |
| | Positive Ranks | 6 | |
| | Ties | 4 | |
| *Social Discomfort vs Service Coverage & Quality* | | | |
| | Negative Ranks | 203 | −11.255*[b] |
| | Positive Ranks | 42 | |
| | Ties | 13 | |
| *Utility & Competitiveness vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 130 | −3.592*[b] |
| | Positive Ranks | 89 | |
| | Ties | 39 | |
| *Social Influence vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 239 | −13.421*[b] |
| | Positive Ranks | 6 | |
| | Ties | 13 | |
| *Social Discomfort vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 200 | −11.175*[b] |
| | Positive Ranks | 39 | |
| | Ties | 19 | |
| *Social Influence vs Utility & Competitiveness* | | | |
| | Negative Ranks | 218 | −12.506*[b] |
| | Positive Ranks | 25 | |
| | Ties | 15 | |
| *Social Discomfort vs Utility & Competitiveness* | | | |
| | Negative Ranks | 184 | −8.577*[b] |
| | Positive Ranks | 58 | |
| | Ties | 16 | |
| *Social Discomfort vs Social Influence* | | | |
| | Negative Ranks | 61 | −8.093*[c] |
| | Positive Ranks | 167 | |
| | Ties | 30 | |

*Significant at the 0.05 level (Bonferroni correction for multiple comparisons).
[b]Based on positive ranks.
[c]Based on negative ranks.

**Table A3**
Post-hoc pairwise comparisons of the motivations for using *GIRA* and associated Wilcoxon Signed Rank tests during COVID-19 (N = 193).

| Pairwise comparisons | Number of Ranks | Z | |
|---|---|---|---|
| *Personal Interests & Well-being Service Coverage & Quality* | Negative Ranks | 97 | −2.363[b] |
| | Positive Ranks | 80 | |
| | Ties | 16 | |
| *Utility & Competitiveness vs Service Coverage & Quality* | Negative Ranks | 116 | −5.672[*b] |
| | Positive Ranks | 58 | |
| | Ties | 19 | |
| *Social Influence vs Service Coverage & Quality* | Negative Ranks | 186 | −11.821[*b] |
| | Positive Ranks | 4 | |
| | Ties | 3 | |
| *Social Discomfort vs Service Coverage & Quality* | Negative Ranks | 89 | −2.806[*b] |
| | Positive Ranks | 83 | |
| | Ties | 21 | |
| *Utility & Competitiveness vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 93 | −3.370[*b] |
| | Positive Ranks | 64 | |
| | Ties | 36 | |
| *Social Influence vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 181 | −11.675[*b] |
| | Positive Ranks | 3 | |
| | Ties | 9 | |
| *Social Discomfort vs Personal Interests & Well-being* | | | |
| | Negative Ranks | 90 | −1.334[b] |
| | Positive Ranks | 75 | |
| | Ties | 28 | |
| *Social Influence vs Utility & Competitiveness* | | | |
| | Negative Ranks | 168 | −11.072[*b] |
| | Positive Ranks | 13 | |
| | Ties | 12 | |
| *Social Discomfort vs Utility & Competitiveness* | | | |
| | Negative Ranks | 71 | −1.229[c] |
| | Positive Ranks | 94 | |
| | Ties | 28 | |
| *Social Discomfort vs Social Influence* | | | |
| | Negative Ranks | 22 | −10.614[*c] |
| | Positive Ranks | 160 | |
| | Ties | 11 | |

*Significant at the 0.05 level (Bonferroni correction for multiple comparisons).
[b]Based on positive ranks.
[c]Based on negative ranks.

**Table A4**
Comparison of the motivations for using *GIRA* between the New Users (N = 35) and Users Before and During COVID-19 (N = 158), as well as the results of the Mann-Whitney U tests and associated significance.

| Motivations | User type | Mean Rank | Mann-Whitney *U* test | | Differences significant at p < .05 (test) |
|---|---|---|---|---|---|
| | | | U | Z | |
| *Service Coverage & Quality* | New users | 99.586 | 2674.5 | −0.305 | No |
| | Users before and during COVID-19 | 96.427 | | | |
| *Personal Interests & Well-being* | New users | 111.329 | 2263.5 | −1.695 | No |
| | Users before and during COVID-19 | 93.826 | | | |
| *Utility & Competitiveness* | New users | 98.914 | 2698.0 | −0.226 | No |
| | Users before and during COVID-19 | 96.576 | | | |
| *Social Influence* | New users | 114.543 | 2151.0 | −2.081 | **Yes** |
| | Users before and during COVID-19 | 93.114 | | | |
| *Social Discomfort* | New users | 101.086 | 2622.0 | −0.493 | No |
| | Users before and during COVID-19 | 96.095 | | | |

## Appendix B. Corrections for the violation of sphericity on repeated measures ANOVA

Table B.1

**Table B1**
Repeated measures ANOVA (tests of within-subjects effects) considering the corrections for the violation of sphericity in each period.

| Sample | Corrections | ε | df | F | Sig. | $\omega^2$ |
|---|---|---|---|---|---|---|
| *Before COVID-19* | Greenhouse-Geisser | 0.92 | 3.68 | 251.95 | <.001 | 0.49 |
| | Huynh-Feldt | 0.93 | 3.74 | 251.95 | <.001 | 0.49 |
| | Lower-bound | 0.25 | 1.00 | 251.95 | <.001 | 0.49 |
| *During COVID-19* | Greenhouse-Geisser | 0.86 | 3.45 | 175.35 | <.001 | 0.48 |
| | Huynh-Feldt | 0.88 | 3.52 | 175.35 | <.001 | 0.48 |
| | Lower-bound | 0.25 | 1.00 | 175.35 | <.001 | 0.48 |

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