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Increasing Safety: A Survey of Open Greenspace Usage during and after the Pandemic in Belgrade, Serbia

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Abstract: COVID-19 has severely affected almost every aspect of our everyday lives, especially the use of open greenspace (OGS) in urban settings, which has proven to have a significant role in increasing overall public health and well-being. Hence, the restricted usage of these spaces should be reconsidered. This research aims to analyze the sensitive nature of OGS usage (1) during the pandemic from the perspective of users' perceived safety and (2) after the pandemic to assess the possible long-term effects. Additionally, this research proposed that location-tracking mobile applications could lead to an increased frequency of OGS visits. The methodology contains detailed background research and two surveys. One survey was conducted during the pandemic in 2020 (sample size n = 412) and was repeated post-pandemic in 2024 (sample n = 451). The 2020 questionnaire A includes questions about the duration, frequency, and activities of OGS usage while focusing on the perceived safety and possibilities of monitoring OGS visits using mobile apps. The 2024 survey represents the continuation of the 2020 survey, focusing on the post-pandemic state of OGS. The statistical analysis is separated into a descriptive data analysis, various χ^2 independence tests and a machine learning safety prediction. The results indicate how COVID-19 could affect OGS usage and how app-related physical safety enhancements during the pandemic cannot be statistically distinguished from those in the post-pandemic period. Although the interest in location-tracking mobile applications has statistically decreased in 2024, the majority of the total 863 participants stated that applications could increase their feeling of perceived safety. The added value of this research is that it considers age and gender roles in analyzing OGS usage in the context of a pandemic.

Keywords: pandemic; COVID-19; health and well-being; perceived safety; open greenspace (OGS); monitoring; mobile application; Belgrade

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1. Introduction

The COVID-19 pandemic significantly impacted our everyday activities and the usage of open public spaces in cities [1]. Different measures worldwide included regulations on the maximum number of people in a public space, the maximum time spent outdoors, and social distancing measures. These regulations varied regionally, but they all had one thing in common—controlling the way and means of using open public spaces. The pandemic was declared in Serbia in March 2020, followed by regulations based on WHO suggestions and the country's overall healthcare status. Between March and July 2020, the Serbian government implemented various social measures, such as restrictions and lockdowns, thus seriously transforming everyday life that could affect citizens' physical and mental health [1,2].

Regardless of the pandemic context, spending time in open spaces, especially OGS, can benefit public health for multiple reasons. Natural open space elements have a rather important role in improving public health, focusing on characteristics that influence our sensory systems [3]. More precisely, greenery and landscape vistas, sunlight, and even natural sounds and smells can lower stress levels, affecting physical health and enhancing the physiological processes in the body, resulting in overall better health outcomes and well-being [4–7]. Frederick Law Olmsted underlines that parks are the lungs of a city [8]. However, in the state of a pandemic, the usage of these spaces is regulated and limited, primarily due to the concern for personal safety. At the same time, people are afraid to use OGS freely. In this research, the focus is on the users' perception regarding their perceived safety and satisfaction. The main research questions are: Does the pandemic state influence the usage of OGS in cities, and how? What could be the possible solution for spending more time in OGS during and after the pandemic?

Based on the overall topic of this paper, the available literature, research problems, and the identified research gap, the goal of this paper is to (1) analyze the usage of OGS during and after the pandemic, mainly from the perspective of perceived safety and (2) to explore the possible role of ICT—Information and communication Technology (usage of mobile applications by OGS users)—in increasing personal and perceived safety, therefore increasing the overall usage of OGS under conditions such as pandemics and after pandemic periods. Regarding the post-COVID-19 period, the additional aim of this research is to (3) assess the possible long-term effects that COVID-19 had on the usage of OGS, as well as (4) provide a comparison of OGS usage during and after the pandemic. Additionally, the essential goal is to bridge the research gap by considering age or gender variations, i.e., the possible effect on questions regarding perceived safety in OGS and willingness to use aforementioned mobile applications.

2. Background Research

The term open green space (with variations: OGS, green space, urban green space, open space, and others) is well known and commonly used. Nevertheless, there are numerous definitions, so Taylor and Hochuli D.F. emphasize the importance of the research context, discipline, culture, and regional specificities [9]. Of those mentioned in Taylor and Hochuli's article, the definition that open greenspace is urban vegetation and nature in the urban context is closer to the context of this research. On the other hand, Vilcins, Sly, Scarth and Mavoa state that open green space includes forested land, public parks, land within private institutions, golf courses, and natural land around waterways, all in private and public land [10]. Similarly, other authors include the following open green spaces: urban green parks, square spaces, and waterfront spaces. Aiming to use the term open greenspace(s) correctly in the research context, this research includes the following urban open greenspaces (OGS): urban parks, squares, open greenspaces along waterfronts, and urban forested lands [11]. In this paper, the following understanding of the term "park" has been implied (unless the authors of references given in the paper used a different meaning): (Urban) park is a public greenspace located in any part of the city which with its position, size, equipment, capacity, quality and accessibility, can attract and serve residents of a part of the city or several city municipalities [12]. Likewise, the following definition of an (urban) square has also been implied: "Square is a landscaped green area, intended for public use, with an area of less than 1 ha, maintained to provide conditions for a short-term relaxation of residents and improvement of the visual quality of the environment" [12].

2.1. *The Importance of OGS for Health and Well-Being*

The understanding of health has shifted from a medical term to the well-being of the body, soul and mind [5,7], while care for public health and a healthy lifestyle has become a new imperative, thus creating a need for designing healthier environments. Spending time in OGS is one of the crucial elements that can influence overall public health and well-being [13].

Just like pandemics have repeatedly reshaped city environments throughout history [14], the COVID-19 pandemic has influenced everyday life in urban areas and how people work, travel and socialize [15]. It imposed staying indoors for a great deal of time and altered OGS visit patterns, which is not sustainable in the long run as it can lead to mental and physical health issues [16,17]. In parallel, virtual space threatened to replace the real space, thus decreasing the overall usage of OGS. During the pandemic and with the help of mobile applications, people attended virtual social events in a virtual environment, making a virtual alternative for public life and socialization [18]. In the post-pandemic times, when there are no space-related restrictions, it is necessary to encourage the use of OGS from a public health point of view.

According to environmental psychology, the use of natural green environments and OGS significantly lowers stress levels and anxiety, resulting in better health outcomes [6,19,20]. Ulrich states that even a passive form of spending time in OGS, such as a view towards the green landscape, is salutogenic and can help reduce stress [21]. Further, the psycho-evolutionary theory argues that people have an inherited ability to respond positively to various elements of nature [6,21]. Natural characteristics such as greenery, landscape, sunlight, fresh air and natural sounds can influence overall health by reducing stress levels [22–24]. In the 1980s, Kaplan and Kaplan established the Attention Restoration Theory [25], which explains how spending time in the natural environment can lead to mental resting and regaining psychological strength. Also, exposure to natural conditions strengthens the immune system and reduces the risk of chronic diseases. Natural elements of OGS induce positive behavioral and psychological changes, emotions, and cognitive activities, which reduce the risk of mental illness, psychosis, depression, and anxiety [7,21,23–28]. The usage of OGS, especially during the pandemic, is gaining even more importance [29].

2.2. Monitoring the Usage of OGS during the Pandemics

Following the WHO's recommendations during the pandemic, OGS were closed in many countries worldwide [30,31] to prevent the spread of COVID-19. Later, one of the main restrictions worldwide, other than the WHO's recommendations regarding the 2 m social distancing rule [32,33], considered the number of users in specific spaces based on the presumptions regarding the possible spreading of the virus. Distancing rules had to consider multiple factors, including viral load, ventilation, type of activity, indoor and outdoor settings, and masking [33]. After OGS reopened, a maximum of five people were allowed to stay close to each other, provided they wore masks, and a distance of 2 m between people was recommended. The COVID-19 pandemic, which initially prompted widespread lockdowns, subsequently inspired people around the globe to seek out OGS near their homes.

During the two-year pandemic, significant research was conducted on using and controlling OGS through surveys about the frequency, duration, and types of activities, but with different research aims [31,34]. Research from Hungary presented how people had used public OGS before and after the first wave of the pandemic and their expectations of OGS use in the post-pandemic period [35]. The paper also emphasized the significance of OGS use in maintaining the livability of Hungarian settlements [35]. Research in Krakow (Poland) aimed to demonstrate the impact of the COVID-19 pandemic on the significance of urban green areas, specifically regarding the mental and physical health of the population, which had become a significant challenge [31,34]. Their results empirically demonstrated the importance of OGS for residents and how they can influence urban spatial policy and the management of these areas [31].

On the other hand, Curtis, D. et al., in a study titled: "Policy and Environmental Predictors of Park Visits During the First Months of the COVID-19 Pandemic: Getting Out While Staying in", used 620 weekly cell phone location data from the US countries during the pandemic in 2020 [36], aiming to identify the factors influencing park visitation patterns in the early stages of the pandemic. This study's significance lies in analyzing the relationship between policy measures, environmental factors, and individuals' decisions to visit parks. By examining these predictors, the study provides valuable insights into how public health policies and environmental characteristics shape people's behaviors and choices concerning park visits during a pandemic [36]. Similarly, a study of various OGS in New Jersey analyzed geotagged social media data to investigate whether OGS's visitation increased during the onset of the COVID-19 pandemic and whether shutdown orders effectively deterred OGS usage [17]. They examined OGS usage during four specific stages in spring 2020: (1) before the pandemic, (2) during the initial phase of the pandemic, (3) during a state-wide OGS shutdown order, and (4) after the lifting of the shutdown. Their findings indicate that OGS visitation experienced a significant increase when the pandemic began. The subsequent OGS shutdown order resulted in a severe decline in visitation, while OGS that remained open continued to have high visitation levels. Visitation returned to the elevated levels seen before the shutdown once closed, and OGS were allowed to reopen. Volenec Z. et al. emphasized the ongoing significance of OGS as valuable community resources and their vital role in promoting public health and psychological well-being [17], especially in limited recreational opportunities.

2.3. Monitoring the Usage of OGS after Pandemics

This part of this research considers the post-COVID-19 period from 2023, as the pandemic's end was proclaimed in May 2023 [37]. Research on the post-COVID-19 consequences of OGS usage is numerous, but it has different outcomes, examines different demographic groups, and uses quite different methods, thus making it rather tricky to summarize "the common ground" for further research and leaving a research gap.

The research on green space and the health of older adults during and after the pandemic in Tehran showed that older people visited smaller, neighboring OGS during the pandemic, as opposed to the period after the pandemic when they mostly visited the larger OGS [38]. In their study on changes in visits to OGS during and after the pandemic in Japan, Hyerin Kim et al. (2023), using Mobile phone GPS data and census data, concluded that the number of visitors to urban OGS has decreased after the pandemic, while at the same time, the number of visits has increased on most nature trails in the backcountry [39]. In the case of Madrid, the data given by Talavera-Garcia, Perez-Campaña & Cara-Santana unveiled the pandemic's impact on visits to Madrid's parks during and after the pandemic [40]. Their insights from mobile phone data analysis using Big Data imply a general decrease in trips to urban parks post-COVID-19. In contrast, smaller, local, community-led parks suffered a smaller decline in visitors and even an increase in the number of visits. Recent research in monitoring OGS use, specifically the spatiotemporal patterns of recreational activities in three urban parks in Moscow, Russia, before, during, and after the COVID-19 pandemic, indicates a decrease in activities and subsequent reactivation [41].

A study regarding planning for Egyptian cities in the post-COVID-19 era suggests different and more networked urban green places in green infrastructure, thus connecting all kinds of OGS (even green roofs) so that residents can move more easily and connect to nature [42]. Qualitative and quantitative studies on Wuhan citizens using OGS after the pandemic indicate changes in visitations to such places regarding the preferred areas, duration, purpose, frequency, and other aspects [43]. Positive trends are manifested through an increased number of residents choosing to use OGS for relaxation and physical exercise, more considerable frequency and duration, and increased general citizens' willingness to visit green spaces.

2.4. ICT Mobile Applications in Controlling the Usage of OGS

In his paper, Kummitha investigated the contrasting approaches of China and Western democracies in utilizing smart technologies to combat perceived safety and space usage during the COVID-19 pandemic [1]. The author emphasized the difference between the

Chinese top-down, technology-driven approach with active national government coordination (possibly related to control and censorship) and the Western, human-driven approach, which mainly relies on technology to inform, persuade, and achieve consensus among citizens. There is concern that some governments might exploit the pandemic to extend technological surveillance over citizens beyond the scope of pandemic control [1].

Cui, Malleson, Houlden and Comber discuss using social media data—Twitter—to examine spatiotemporal changes in OGS use in London, comparing georeferenced Tweets during three-month periods from 2019 to 2023 [44]. This method can help in informing policy makers to plan and manage OGS during a crisis. The previous study by the same authors, through extensive literature research, examined using volunteered geographical information and social media data to understand OGS usage [45]. Their research on more than 170 research papers summarizes the characteristics and usage of data from different platforms: Twitter and Weibo (providing text-based data), Instagram and Flickr (providing image-based data), and OpenStreetMap (providing map-based data) for gathering information. This directs future research on using existing social media to generate information about safety in OGS. Park S, Kim S, Lee J, and Heo B. analyzed social media data on OGS perception changes before and after the COVID-19 pandemic using a machine-learning approach for New York, New Jersey, and Connecticut [46]. In contrast to the other studies, this study focused on human perception changes and people's emotional experiences.

Finally, it is helpful to mention the systematic overview by Zabelskyte, G., Kabisch, N., and Stasiskiene, Z. on social media data applications concerning visitations to urban OGS [47]. The study's findings managed to identify the patterns of OGS use and analyze visitors' needs and demands, as well as the advantages and limitations of using social media data regarding potentially biased information and data security issues.

All the studies emphasized the significance of OGS for mental and physical health and the necessity of controlling them during a pandemic due to the fear of COVID-19 infections. Increasing the availability of natural green areas and integrating them into urban green infrastructure may be the most relevant policy to acknowledge the crucial role of urban nature as a source of resilience in turbulent times [41].

From the previous literature overview, it can be concluded that the use of different ICT tools by researchers was and still is widespread, intending to establish patterns of behavior of OGS users during and after the pandemic. It is fair to say that it was conducted based on available means and not a standard methodology; furthermore, the application of ICT tools in monitoring the use of OGS comes mostly from researchers or (local, national) government and not so much from the users of these areas themselves. This represents the research gap aimed to be resolved by involving the survey questions about the usage of ICT tools by OGS users to monitor and, to some extent, control the safety of these urban green areas.

3. Methodology

The paper's methodology encompasses qualitative and quantitative methods, including (1) theoretical background research and focused content analysis, (2) an exploratory case study with expert observation and a focus on conducting two survey questionnaires among the users and data analysis.

(1) The content analysis research included an extensive literature review of current studies and primary research topics in the domain of OGS and health, COVID-19 regulations, with a particular focus on the usage of OGS during the pandemics and the possible use of ICT for crowd monitoring. Further, the research results regarding OGS usage before and during the pandemics were compared.

(2) The case study was developed by analyzing the OGS areas in Belgrade, Serbia. Since the main focus of this research is on the usage of these spaces, 42 OGS from all over the city of Belgrade were selected as the research polygon. Participants were the users of OGS in Belgrade. They were asked several questions regarding the usage

of approximately 30 public OGS in 10 different Belgrade municipalities. Two similar surveys were conducted in the same location but during different periods: the first survey was done in 2020 to gather data about the users of OGS during the pandemic, and the second in 2024, after the pandemic, to determine the possible long-term effects of the COVID-19 pandemic on OGS usage and enable comparison of the results from the two surveys.

The first survey was conducted during the lockdown period in April and May 2020. A total of n = 412 people participated in the survey. The questionnaire contained precoded questions divided into two parts—A and B. At the beginning of the questionnaire, general data about the users, such as age, gender, and location (municipality) where they use open greenspace most often, were gathered. Part A included questions about OGS usage during a pandemic, such as the duration, frequency, and activity of OGS visits before and during the pandemic. Also, the participants were asked if they behaved according to social distancing regulations and perceived safety.

Part B of the questionnaire was oriented towards analyzing the possible interest of users in OGS crowd tracking via customized mobile applications. These questions focused on perceived safety in the context of monitoring the OGS. Therefore, users were asked whether they would be interested in ICT, such as mobile applications, that would allow them to know the frequency of users in a specific OGS and if they would be willing to provide their phone's location to use such applications.

Survey data analysis included several statistical methods. Regarding the 2020 research survey, the statistical process of the gathered results was divided into three parts. In the preliminary stage, the descriptive structure of the data, with tables and graphical plots, was analyzed. This analysis aimed to obtain a comprehensive overview of the survey results.

In the second stage, χ^2 independence tests were conducted to investigate the dependence structure among selected features. The results allowed us to identify relationships between features or to rule out links between them. The independence hypothesis is rejected if its *p*-value is below a chosen significance level. If that is the case, we reject that the two features are statistically independent. Otherwise, we cannot deny their independence.

The third and final step involved a machine learning prediction to forecast perceived safety enhancements from possible monitoring via mobile apps. The machine learning model used is the state-of-the-art Random Forest Classifier with ten features. The predictions with those from the Xgboost model are compared. [48].

The second survey presented the continuation of the 2020 survey and was conducted in January and February 2024. It consisted of nine post-COVID-19-related questions (Q1–Q9) that 451 survey participants answered. The questions were similar but not identical to the 2020 survey. They focused on the possible pandemic influence on OGS usage today, almost four years after the first COVID-19 outbreak in Serbia.

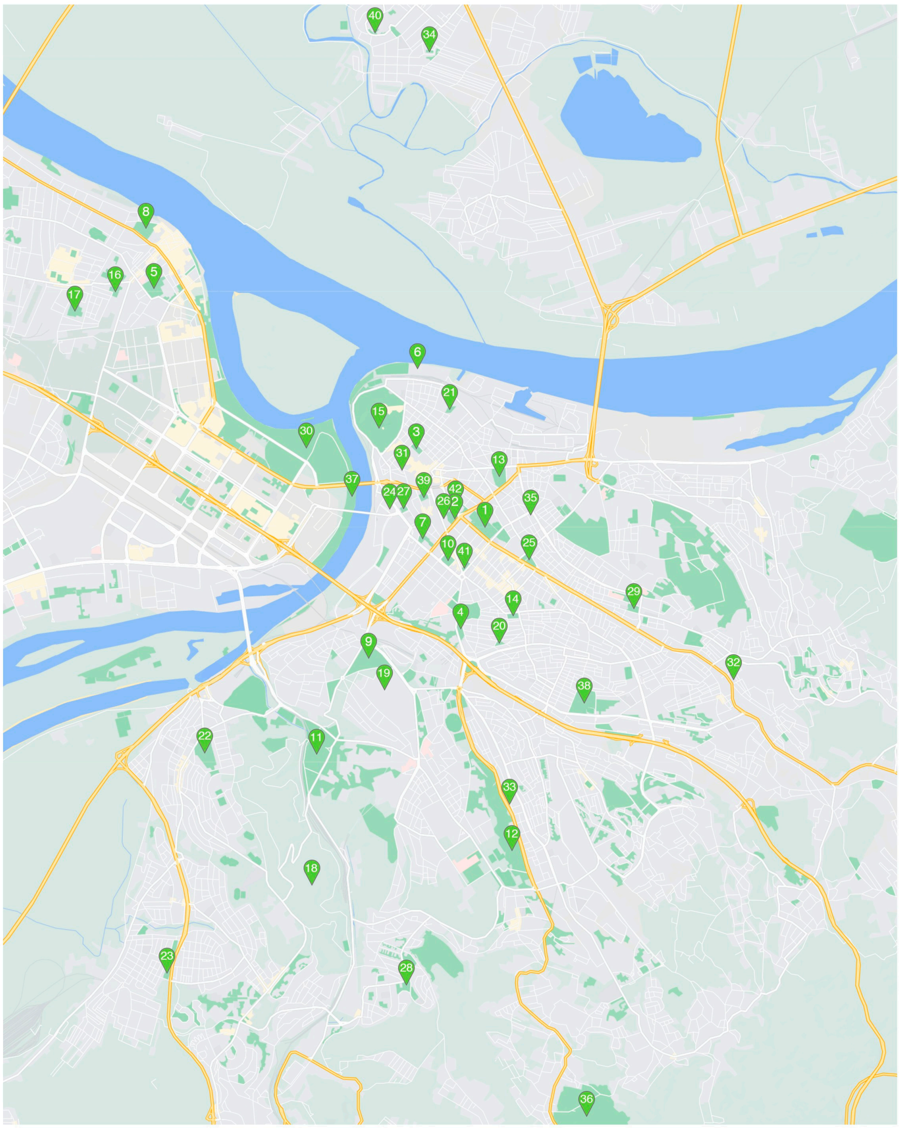
The outcomes of the 2024 survey in multiple χ^2 Independence Tests were analyzed. The dependence between demographic features, perceived safety-related features and interest in the mobile apps was tested. Finally, COVID-19 and post-COVID-19-related differences were compared with two-sample proportion tests to check the differences in mobile app interest and perceived safety enhancements with data and knowledge of the pre- and post-pandemic survey.

All the questions from the 2020 and 2024 surveys are listed in Table A1 in the Appendix A.

4. Results

This research monitored the usage of OGS—specifically urban locations in Belgrade, Serbia—during and after the COVID-19 pandemic. OGS, as defined in Section 2, represented the survey site conducted in 2020 and 2024. Belgrade is home to more than 40 OGS spread across ten municipal areas, with a concentration in Savski Venac and Zemun municipalities, while the OGS of the municipality of Novi Beograd occupy the largest expanse. OGS cover over 385 hectares and presents significant land usage in the city [49–53]. The development of OGS in Belgrade commenced during the reign of Prince Miloš, with most OGS dating back to the latter half of the 19th and the early 20th century. In the 1840s, the first rows of trees were planted in Belgrade, and the oldest city park, Financial Park, was established in 1860 [54].

All major OGS in Belgrade municipalities were taken into consideration. Municipalities such as "Stari grad" and "Savski Venac" were among the most frequently used OGS, alongside other OGS in municipalities shown in Figure 1. A total of 42 OGS in Belgrade were used as the research polygon, and their distribution in Belgrade municipalities is shown in Figure 1 below.



1. Tašmajdan
2. Pionirski park
3. Univerzitetski park Studentski park)
4. Karađorđev park
5. Gradski park u Zemunu
6. Dunavski kej
7. Finansijski park
8. Gardoš
9. Hajd park
10. Park Manjež
11. Topčiderski park
12. Banjička šuma
13. Botanička bašta Jevremovac
14. Čuburski park
15. Kalemegdan
16. Kalvarija
17. Jelovac
18. Košutnjak
19. Muzej 25. maj
20. Neimarski park
21. Pančićev park
22. Park Banovo Brdo
23. Park Bele Vode
24. Park Bristol
25. Park Ćirila i Metodija
26. Andrićev venac
27. Park Luke Ćelovića (park kod ekonomskog fakulteta)
28. Miljakovački izvori (kod MZ Miljakovac)
29. Park Slavujev potok (kod VI beogradske gimnazije)
30. Park prijateljstva
31. Park proleće
32. Park stara okretnica
33. Park u ulici Jove Ilića
34. Park u ulici Sonje Marinković
35. Park u ulici Starine Novaka
36. Spomen park Jajinci
37. Staro sajmište
38. Šumice
39. Terazijska terasa
40. Trg JNA
41. Mitićeva rupa
42. Park kod narodne skupštine Srbije

Figure 1. Map with specific locations of greenspaces in Belgrade municipalities used in this research (source: Open Street Map: https://openstreetmap.rs/ (accessed on 30 March 2024) (author: Darinka Matić).

4.1. Data Analysis of User Perception on OGS Usage during the Pandemic in 2020

This survey includes a questionnaire comprising the questions in the two-part questionnaire (List of questions, see Table A1 in Appendix A). In the first step, the descriptive nature of the data for each question is analyzed. The majority of participants are female (67.5%, and male 32.5%). Most attendants are between 15 and 24 years old (39.8%), and the average respondent is around 35. Older participants, aged 41 years or more, form 29.2% of the population. The remaining 31.0% of the population are participants between 25 and 40 (see Table A2 in Appendix B).

Firstly, the participants were asked about their OGS-visiting habits. The questions target their pre- and during-pandemic OGS visiting routine. Data showed that most participants are frequent OGS visitors, which speaks to the representativeness of this questionnaire. Key observations are: half of the participants (49.5%) were frequent OGS visitors with at least a few times per week visits before the pandemic, and only 2.3% of all users stated they did not visit the OGS before the pandemic. For the majority, this did not change during the pandemic. A total of 64.7% of the participants report visiting OGS at least as frequently as before the pandemic. A portion of 40.5% even increased their visits. The preferred time for more than half of users (68.3%) extends to 1 h spent in the OGS (see Tables A3 and A4 in Appendix B).

The most popular OGS visited by users are located in Novi Beograd (17.3%), Vračar (14.9%), Stari grad (14.4%), Palilula (12.7%) and Zemun (11.6%). A detailed overview of the remaining municipalities is provided in Table A5 in Appendix B.

Participants could select from multiple choices regarding the social aspects of OGS visits. The majority (73.5%) prefer to spend their visit to OGS with others, either with a partner or a friend (35.6%), groups of friends (31.1%) or with children (6.8%). The remaining (26.5%) prefer to visit the OGS alone or with a pet. Meetings in larger groups are unpopular (5.4%) (see Table A6 in Appendix B).

One of the principal COVID-19-related regulations in Serbia targeted the reduced number of visitors in specific OGS. Participants were asked about their interest in using a possible mobile application that could track their location and inform them about the frequency of users in the selected OGS and whether usage of these applications would enhance their subjective physical and COVID-19-related safety. Interestingly, the majority of participants (64.2%) were interested in using this kind of application and many (57.0%) would anonymously share their location to use the app (see Tables A7 and A8 in Appendix B). Data further show that OGS monitoring through the apps would provide an increased feeling of physical safety to more than half of all users—the 54.2% of all the participants. Moreover, 56.2% of the participants would feel more safe from possible COVID-19 infections while using the app (see Tables A9 and A10 in Appendix B).

In the second stage of this research, the dependency structure between features, is analyzed by testing independence between selected features of interest. The independence hypothesis is rejected if its p-value is below a chosen significance level. If that was the case, the two statistically independent features were rejected. Otherwise, their independence cannot be denied.

Given the 5% confidence level, analyzing and considering OGS visit preferences among demographic groups began. The consideration of age group implies categorical variables equivalent to a child, young, middle-aged or old. Specifically, independence between demographics (age, gender) and OGS visit preferences, app interest, and subjective safety is tested.

First, three χ^2 independence tests are performed to test the independence between the gender and any OGS visit-related features. The test results are presented in Tables 1–8 below. Pre-pandemic OGS visits by gender are shown in Contingency Table 1. Given a p-value of 62.39%, the hypothesis that gender is independent of any OGS visit-related features cannot be rejected. Tables 3 and 4 are contingency tables demonstrating how the visiting frequency increased during the pandemic by gender and age, respectively. Table 5 summarises pre-pandemic OGS visits by age. With strong significance (p-value = 0.01%), the independence test indicates dependence between age and pre-pandemic OGS visits.. The resulting independence tests lead to the *p*-values p = 16.02% and p = 7%. Thus, the hypothesis that changes in the frequency of visits are independent of demographic characteristics cannot be rejected. Contingency Tables 2 and 6 summarise time spent in an OGS during the pandemic by gender and age, respectively. The test results provide the *p*-values p = 6.94% and p = 12%, respectively. Hence, the hypothesis that time spent in an OGS during the pandemic is independent of demographics (*p*-value > 5%) cannot be rejected. Contingency Table 7 presents results of pandemic-related visiting habit changes by age. Table 8 presents Chi-square test result that relates to Contingency Tables 5–7, respectively.

Table 1. Contingency Table: Pre-pandemic park visits (Q1) by gender.

	Female	**Male**	**All**	**Female (%)**	**Male (%)**	**All (%)**
Always, almost every day	64	24	88	16	6	22
Not at all	6	3	9	1.5	0.75	2.25
Often, a couple of times per week	75	35	110	18.75	8.75	27.5
Rarely, a couple of times per year	26	18	44	6.5	4.5	11
Sometimes, a couple of times per month	99	50	149	24.75	12.5	37.25
All	270	130	**400**	67.5	32.5	**100**

Table 2. Contingency Table: Time spent in the park during the pandemic (Q3) by gender.

	Female	**Male**	**All**	**Female (%)**	**Male (%)**	**All (%)**
From 15 to 30 min	42	27	69	10.5	6.75	17.25
From 30 min to one hour	90	28	118	22.5	7	29.5
More than one hour	49	32	81	12.25	8	20.25
Not at all	34	12	46	8.5	3	11.5
Up to 15 min	55	31	86	13.75	7.75	21.5
All	270	130	**400**	67.5	32.5	**100**

Table 3. Contingency Table: Pandemic-related visiting habits changes Q2 by gender.

	Female	**Male**	**All**	**Female (%)**	**Male (%)**	**All (%)**
As frequently	70	27	97	17.5	6.75	24.25
Less frequently	81	33	114	20.25	8.25	28.5
More frequently	105	57	162	26.25	14.25	40.5
Not at all	14	13	27	3.5	3.25	6.75
All	270	130	**400**	67.5	32.5	**100**

Table 4. Chi-square test result table that relates to Contingency Tables 1–3, respectively.

Question and Gender	**Value**	**DoF**	***p*-Value**
Visits 2019	2.62	4	0.6239
Time spent during the Pandemic	8.69	4	0.0694
Frequency to pre-COVID	5.1643	3	0.1602

Table 5. Contingency Table: Pre-pandemic park visits (Q1) by age.

Age	Always, Almost Every Day	Not at All	Often, a Couple of Times per Week	Rarely, a Couple of Times Per Year	Sometimes, a Couple of Times per Month	All	Always, Almost Every Day (%)	Not at All (%)	Often, a Couple of Times per Week (%)	Rarely, a Couple of Times per Year (%)	Sometimes, a Couple of Times per Month (%)	All (%)
15–24	18	2	47	10	42	119	4.41	0.49	11.52	2.45	10.29	29.17
25–40	44	4	39	14	60	161	10.78	0.98	9.56	3.43	14.71	39.46
41–64	29	3	24	23	48	127	7.11	0.74	5.88	5.64	11.76	31.13
7–14	1	0	0	0	0	1	0.25	0	0	0	0	0.25
All	92	9	110	47	150	**408**	22.55	2.21	26.96	11.52	36.76	**100**

Table 6. Contingency Table: Time spent in parks during the pandemic (Q3) by age.

Age	From 15 to 30 min	From 30 min to One Hour	More than One Hour	Not at All	Up to 15 min	All	From 15 to 30 min (%)	From 30 min to One Hour (%)	More than One Hour (%)	Not at All (%)	Up to 15 min (%)	All (%)
15–24	27	32	20	20	20	119	6.62	7.84	4.9	4.9	4.9	29.17
25–40	24	51	38	16	32	161	5.88	12.5	9.31	3.92	7.84	39.46
41–64	21	38	23	10	35	127	5.15	9.31	5.64	2.45	8.58	31.13
7–14	1	0	0	0	0	1	0.25	0	0	0	0	0.25
All	73	121	81	46	87	**408**	17.89	29.66	19.85	11.27	21.32	**100**

Table 7. Contingency Table: Pandemic-related visiting habit changes (Q2) by age.

Age	As Frequently	Less Frequently	More Frequently	Not at All	All	As Frequently (%)	Less Frequently (%)	More Frequently (%)	Not at All (%)	All (%)
15–24	28	36	46	8	118	6.88	8.85	11.3	1.97	28.99
25–40	35	49	72	5	161	8.6	12.04	17.69	1.23	39.56
41–64	35	29	46	17	127	8.6	7.13	11.3	4.18	31.2
7–14	0	0	1	0	1	0	0	0.25	0	0.25
All	98	114	165	30	**407**	24.08	28.01	40.54	7.37	**100**

Table 8. Chi-square test result table that relates to Contingency Tables 5–7, respectively.

Question and Gender	Value	DoF	*p*-Value
Visits 2019	25.67	12	0.01
Time spent during the Pandemic	17.87	12	0.12
Frequency to pre-COVID	15.91	9	0.07

Second, the independence between demographics (age, gender) and the interest in the app were analyzed. The interest in the app by gender and age, respectively, is presented in Tables A11 and A12 in Appendix B. The test results are found in Tables 9–12 below. Contigency Table 9 presents the Location sharing by gender. Table 10 presents Chi-square test results that relates to Contigency Table A11 (in Appendix B) and Table 9, respectively. On the one hand, the hypothesis that gender is independent of the interest in app technology (p-value = 57.38%) cannot be rejected. On the other hand, the independence between the age and the interest in the app (p-value < 5%) was rejected. Location-sharing willingness by demographics is presented in Tables 9 and 11. According to the test results in Table 12, both tests cannot be rejected (p-value = 0.57; p-value = 0.69).

Table 9. Contingency Table: Location sharing (Q11) by gender.

Gender	No, Not at All	Yes, at All Time	Yes, While Using the App	All	No, Not at All (%)	Yes, at All Times (%)	Yes, While Using the App (%)	All (%)
Female	120	63	87	270	30	15.75	21.75	67.5
Male	52	32	46	130	13	8	11.5	32.5
All	172	95	133	**400**	43	23.75	33.25	**100**

Table 10. Chi-square test result table that relates to Contingency Tables 9 and A11, respectively.

Question and Gender	Value	DoF	*p*-Value
Interest	0.3163	1	0.57
Location	0.73	2	0.69

Table 11. Contingency Table: Location sharing (Q11) by age.

Age	No, Not at All	Yes, at All Time	Yes, While Using the App	All	No, Not at All (%)	Yes, At all Times (%)	Yes, While Using the App (%)	All (%)
15–24	61	19	37	117	15.25	4.75	9.25	29.25
25–40	72	39	48	159	18	9.75	12	39.75
41–64	39	37	48	124	9.75	9.25	12	31
All	172	95	133	**400**	43	23.75	33.25	**100**

Table 12. Chi-square test result table that relates to Contingency Tables 11 and A12, respectively.

Question and Gender	Value	DoF	*p*-Value
Interest	0.3163	1	0.57
Location	0.73	2	0.69

The independence of safety-related features and demographics was questioned. The gender-related test results are listed in Tables 13–16, and the age-related results are in Tables 17–20. Subjective physical safety is compared by gender and age in Table 13 and Table 17, respectively. The independence between enhanced physical safety through the app and gender (p-value = 4%) was rejected. With strong significance, the independence of physical safety enhancement and age (p < 0.01%) was rejected. In Contingency Tables 14 and 18, COVID-19-related safety by gender and age, respectively, was compared. While the independence of COVID-19-related safety and gender (p-value = 56%) cannot be rejected, with strong significance, the independence between age and COVID-19-related safety enhancements by monitoring (p < 0.01%) is rejected.

Table 13. Contingency Table: Physical safety enhancements from monitoring (Q8) by gender.

Gender	No	Yes	All	No (%)	Yes (%)	All (%)
Female	133	137	270	33.25	34.25	67.5
Male	50	80	130	12.5	20	32.5
All	183	217	**400**	45.75	54.25	**100**

Table 14. Contingency Table: COVID-19 safety enhancements from monitoring (Q9) by gender.

Gender	No	Yes	All	No (%)	Yes (%)	All (%)
Female	127	143	270	31.75	35.75	67.5
Male	48	82	130	12	20.5	32.5
All	175	225	**400**	43.75	56.25	**100**

Table 15. Contingency Table: Social distancing (Q6) by gender.

Gender	No	Yes	All	No (%)	Yes (%)	All (%)
Female	65	205	270	16.25	51.25	67.5
Male	38	92	130	9.5	23	32.5
All	103	297	**400**	25.75	74.25	**100**

Table 16. Chi-square test result table that relates to Contingency Tables 13–15, respectively.

Question and Gender	Value	DoF	p-Value
Physical safety	4.12	1	0.04
App-related safety	3.65	1	0.56
Social distancing	1.22	1	0.27

Table 17. Contingency Table: Physical safety enhancements from monitoring (Q8) by age.

Age	No	Yes	All	No (%)	Yes (%)	All (%)
15–24	72	45	117	18	11.25	29.25
25–40	69	90	159	17.25	22.5	39.75
41–64	42	82	124	10.5	20.5	31
All	183	217	**400**	45.75	54.25	**100**

Table 18. Contingency Table: COVID-19-related safety enhancements through monitoring (Q9) by age.

Age	No	Yes	All	No (%)	Yes (%)	All (%)
15–24	68	49	117	17	12.25	29.25
25–40	69	90	159	17.25	22.5	39.75
41–64	38	86	124	9.5	21.5	31
All	175	225	**400**	43.75	56.25	**100**

Table 19. Contingency Table: Social distancing (Q6) by age.

Age	No	Yes	All	No (%)	Yes (%)	All (%)
15–24	34	83	117	8.5	20.75	29.25
25–40	45	114	159	11.25	28.5	39.75
41–64	24	100	124	6	25	31
All	103	297	**400**	25.75	74.25	**100**

Table 20. Chi-square test result table that relates to Contingency Tables 17–19, respectively.

Question and Age	Value	DoF	*p*-Value
Physical safety	19.17	2	0.0001
App-related safety	18.48	2	0.0001
Social distancing	3.86	2	0.14

A third pair of contingency tables compare social distancing practices by gender in Table 15 and age in Table 19. According to the test results, the independence of demographic features from social distancing practices (p-value = 0.27; p-value = 0.14) cannot be rejected.

It is interesting to analyze the dependence between the interest in the app and features relating to OGS visits. Contingency Table 21 compares the interest in the app to pre-pandemic OGS visit habits. The test results are listed in Contingency Table 22. With strong significance ($p < 0.01\%$), dependence between pre-pandemic OGS visit habits and interest in the app was tested. The test result rejects the independence of time spent in the OGS and interest in the app with strong significance ($p < 0.01\%$). Interest in the app could be evaluated by increased visit frequency during the pandemic, and the independence of these two features cannot be rejected ($p = 10.56\%$).

Lastly, the dependence structure between interest in app technology (personal location sharing) and perceived safety enhancement (physical, COVID-19-related) was analyzed. Table 23 shows interest in the app through its physical safety enhancements. Table 24 illustrates the interest in the app by perceived COVID-19-related safety enhancements. According to the test results provided in Table 25, the interest in the app is not independent of perceived safety enhancements with strong significance (p-value < 0.01% in both cases). This result is expected since all safety-related questions are related to interest in monitoring technology.

Table 21. Contingency Table: Interest in the app (Q10) by pre-pandemic park visits (Q1).

Would You Be Interested in Technology That Would Allow You to Know How Many People Are in a Place You Would like to Go?	Always, Almost Every Day	Not at All	Often, a Couple of Times per Week	Rarely, a Couple of Times per Year	Sometimes, a Couple of Times per Month	All	Always, Almost Every Day (%)	Not at All (%)	Often, a Couple of Times per Week (%)	Rarely, a Couple of Times per Year (%)	Sometimes, a Couple of Times per Month (%)	All (%)
No	19	6	50	21	47	143	4.75	1.5	12.5	5.25	11.75	35.75
Yes	69	3	60	23	102	257	17.25	0.75	15	5.75	25.5	64.25
All	88	9	110	44	149	**400**	22	2.25	27.5	11	37.25	**100**

Table 22. Chi-square test result table that relates to Contingency Tables 21, A13 and A14, respectively.

Questions and Interest in the App	Value	DoF	*p*-Value
Time spent pre-pandemic	19.832	4	0.0005
Time spent during the pandemic	21.631	4	0.0002s
Frequency increase during the pandemic	6.13	3	0.1056

Table 23. Contingency Table: Interest in tech (Q10) and physical safety enhancements by the app.

	No	Yes	All	No (%)	Yes (%)	All (%)
No	107	36	143	26.75	9	35.75
Yes	76	181	257	19	45.25	64.25
All	183	217	**400**	45.75	54.25	**100**

Table 24. Contingency Table: Interest in tech (Q10) and COVID-19-related perceived safety enhancement.

	No	Yes	All	No (%)	Yes (%)	All
No	117	26	143	29.25	6.5	35.75
Yes	58	199	257	14.5	49.75	64.25
All	175	225	**400**	43.75	56.25	**100**

Table 25. Chi-square test result table that relates to Contingency Tables 23 and 24, respectively.

Questions and Interest in the App	Value	DoF	*p*-Value
Physical safety	75.80	1	0
Enhanced safety	131.07	1	0

Machine Learning

Considering the overall aim of this research and the survey, the prediction of perceived safety enhancements through monitoring was analyzed. Specifically, the goal was to determine safety prediction based on the survey results. The target variable 'safety' is defined as an intersection of the variables 'physical perceived safety' (Q8) and 'COVID-19-related safety' (Q9). On the conservative approach, the individual perception was labelled as safe if 'physical perceived safety' (Q8) and 'COVID-19-related safety' (Q9) were satisfied (For a list of questions, see Table A1 in Appendix A). The Random Forest and Xgboost models are classification models used to estimate the probability of perceived safety. Broadly, these models are tree-based models that generate a multitude of decision trees and output decision tree averages. One decision tree is illustrated in Figure 2. The input of these models includes ten features such as age, gender, municipality visited, location, duration, frequency, and activities of OGS visits. Given some threshold probability, these estimated models help us to predict whether someone feels safe in OGS.

The model's performance is evaluated by the generalization accuracy on a test set that contains 25% of the initial data set. According to the accuracy metrics in Table 26, the Xgboost model performs slightly better than the Random Forest model. A test set performance of 73% means that 73% of the cases are correctly classified whether someone feels safe. The above metric classifies safety if the estimated probability is above a threshold of 50%. If the aim is to ensure perceived safety at any threshold, a suggestion is to look at the Receiver operating characteristic (ROC) illustrated in Figure 3. They are under this curve (AUC), which determines the quality of the prediction. As the quality of both estimators is approximately 76% of the entire area, the estimation quality is satisfactory.

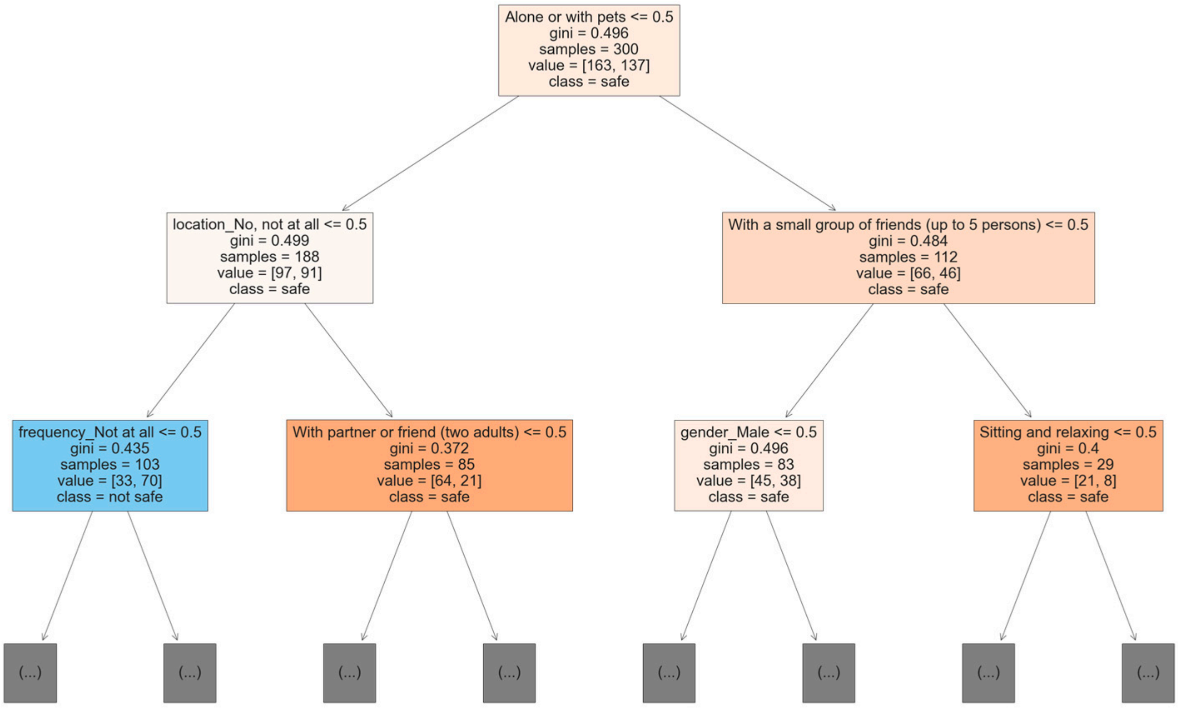


Figure 2. Example of one resulting decision tree (author: Jovanka Lili Matić).

Table 26. Regression model accuracy metrics.

		Training (%)	Test (%)	AUC (%)
Accuracy	Random Forest	87.00	70.00	76.07
	Xgboost	57.67	47.00	y

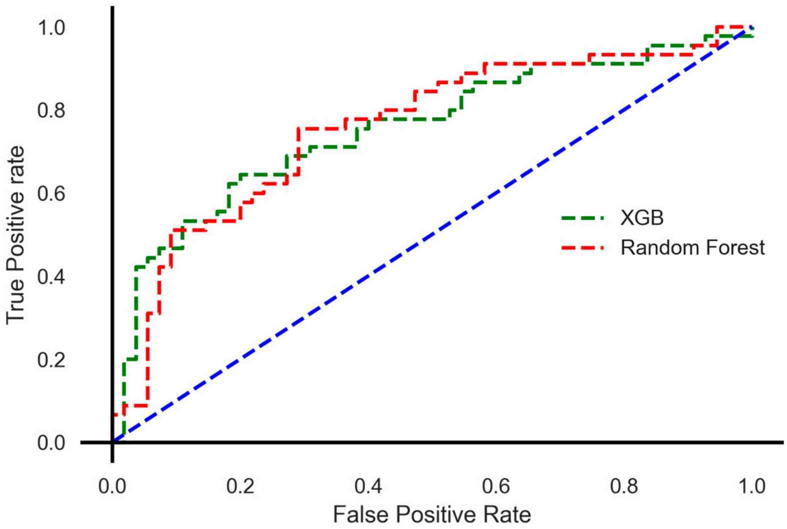


Figure 3. ROC curve (author: Jovanka Lili Matić).

It is interesting to have an insight into which features are relevant to the prediction mentioned above. The contribution is evaluated by impurity-based feature importance. The results are illustrated in Figures 4 and 5 and Table 27. The most contributing variable in both models is the pandemic-related frequency change in OGS visits. Additional contributing features are the willingness to share one's location and the activities done in OGS.

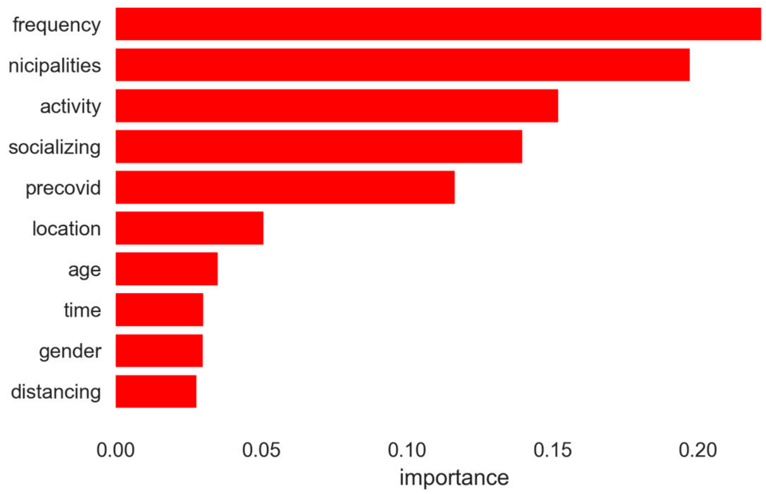


Figure 4. Variable importance of Random Forest estimator (author: Jovanka Lili Matić).

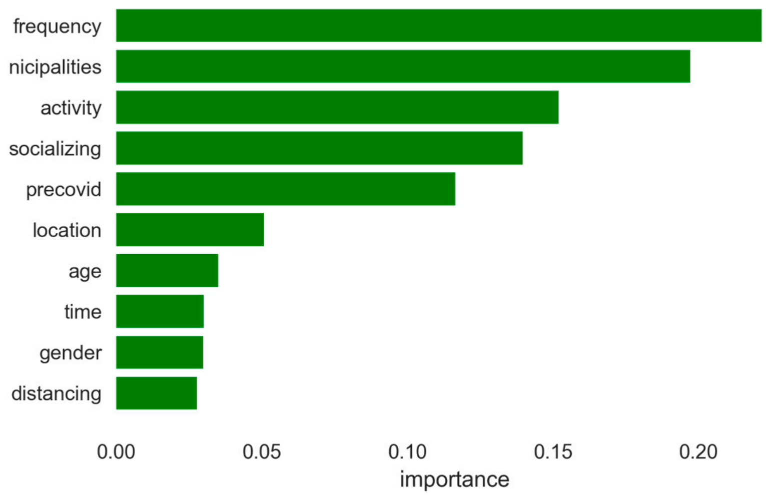


Figure 5. Variable importance of the Xgboost model (author: Jovanka Lili Matić).

Table 27. Variable importance of Random Forest and Xgboost.

	Importance	
Feature	**Random Forest**	**Xgboost**
distancing	0.03	0.00
gender	0.05	0.04
time	0.05	0.03
socializing	0.08	0.05
age	0.09	0.06
pre-COVID	0.09	0.07
activity	0.12	0.05
municipalities	0.13	0.09
location	0.13	0.05
frequency change	0.23	0.56

4.2. Data Analysis of User Perception on OGS Usage after the Pandemic 2024

The second survey was conducted from 8 January 2024 to 1 February 2024 and consisted of nine post-COVID-19-related questions, while the total number of participants was 451 (List of questions, see Table A1 in Appendix A). Regarding the demographic structure, most participants (57%) are female. The average participant is 38 years old, with a median of 37 years and a standard deviation of 12.43. The youngest is 18 years old, and the oldest is 83 years old (see Table A15 in the Appendix C).

The most popular OGS that the participants visited in 2024 are located in Novi Beograd (31.5%), Stari Grad (26.4%) and Vracar (26.2%) (see Table A16 in Appendix C). The majority of users (89.8%) feel safe while visiting OGS. However, if feeling unsafe, the dominant safety concerns are OGS visits at night (40.4%), OGS visits in deprived areas (21.1%) and unsafe playgrounds (20.4%) (see Tables A17 and A18 in Appendix C).

Approximately one-third of the participants reported increased post-pandemic OGS visits (30.8%), while one-tenth (10.6%) started going to parks less often after the pandemic (see Table A19 in Appendix C). Nearly one-quarter of the participants (23.9%) feel post-pandemic safer in open green spaces, and only a small proportion (10.6%) feel less safe (see Table A20 in Appendix C).

Many survey participants (53%) expressed their interest in using the ICT mobile applications (Q8), and a large proportion (58.5%) believed that this app would provide physical safety enhancements for them (see Tables A21 and A22 in the Appendix C).

χ^2 Independence Tests

Links between the selected variables are analyzed in multiple χ^2 Independence tests. In the first analysis, the general safety perception (Q5) was researched to determine whether it was independent of the interest in the app (Q7). A contingency table is provided in Table 28. According to the test results in Table 29, the independence between app monitoring and general physical safety is rejected.

Table 28. Contingency Table: Interest in the app (Q8) and general physical safety perception (Q5).

	No	Yes	All	No (%)	Yes (%)	All (%)
No	11	35	46	2.44	7.76	10.2
Yes	201	204	405	44.57	45.23	89.8
All	212	239	**451**	47.01	52.99	**100**

Table 29. Chi-square test result table that relates to Contingency Table 28.

Topic and Interest in App	Value	DoF	*p*-Value
General safety	9.96	1	0.0016

Second, a test for independence between safety concerns (Q9) and gender (Q1), interest in the app (Q8) and physical safety enhancements through the app (Q7), respectively, was done. The corresponding contingency tables are illustrated in Tables 30–32. According to the test results in Table 33, the null hypothesis is rejected in all three tests. Precisely, the independence between safety concerns and gender ($p < 0.01\%$), interest in the app ($p < 0.1\%$) and physical safety enhancements through the app ($p < 5\%$) is rejected (Tables 28 and 29, respectively).

Table 30. Safety concern (Q9) by interest in the app (Q8).

	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All
No	79	45	58	30	212	17.52	9.98	12.86	6.65	47.01
Yes	103	50	34	52	239	22.84	11.09	7.54	11.53	52.99
All	182	95	92	82	**451**	40.35	21.06	20.4	18.18	**100**

Table 31. Safety concern (Q9) by gender (Q1).

	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All
Female	127	44	45	41	257	28.16	9.76	9.98	9.09	56.98
Male	54	51	45	41	191	11.97	11.31	9.98	9.09	42.35
Other	1	0	2	0	3	0.22	0	0.44	0	0.67
All	182	95	92	82	**451**	40.35	21.06	20.4	18.18	**100**

Table 32. Safety concern (Q9) by physical safety enhancements through the app (Q7).

	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All	Park Visits at Night	Park Visits in Deprived Areas	Unsafe Playgrounds	Visits of Overcrowded Greenspaces	All
No	69	40	51	27	187	15.3	8.87	11.31	5.99	41.46
Yes	113	55	41	55	264	25.06	12.2	9.09	12.2	58.54
All	182	95	92	82	**451**	40.35	21.06	20.4	18.18	**100**

Table 33. Multiple contingency tables.

	Female	Male	Other	All	Female	Male	Other	All
Post-COVID-19 greenspace usage								
My visits have become less frequently	24	23	1	48	5.32	5.1	0.22	10.64
No, not at all	86	80	0	166	19.07	17.74	0	36.81
The usage remained unchanged	52	46	0	98	11.53	10.2	0	21.73
I visit greenspaces more frequently and actively than before the pandemic	95	42	2	139	21.06	9.31	0.44	30.82
All	257	191	3	**451**	56.98	42.35	0.67	**100**
General safety perception								
No	27	16	3	46	5.99	3.55	0.67	10.2
Yes	230	175	0	405	51	38.8	0	89.8
All	257	191	3	**451**	56.98	42.35	0.67	**100**
Post-COVID-19 safety perception change								
I feel less safe	25	22	1	48	5.54	4.88	0.22	10.64
I feel safer in open spaces	57	49	2	108	12.64	10.86	0.44	23.95
safety unchanged	175	120	0	295	38.8	26.61	0	65.41
All	257	191	3	**451**	56.98	42.35	0.67	**100**
Physical safety enhancements								
No	101	86	0	187	22.39	19.07	0	41.46
Yes	156	105	3	264	34.59	23.28	0.67	58.54
All	257	191	3	**451**	56.98	42.35	0.67	**100**

Table 33. *Cont.*

	Female	Male	Other	All	Female	Male	Other	All
Monitoring								
No	123	89	0	212	27.27	19.73	0	47.01
Yes	134	102	3	239	29.71	22.62	0.67	52.99
All	257	191	3	**451**	56.98	42.35	0.67	**100**

Additional χ^2 independence tests look at the independence between gender (Q1) and post-COVID-19 greenspace usage (Q4), the general safety perception (Q5), post-COVID-19 safety perception changes (Q6), physical safety enhancements through the app (Q7) and interest in the app (Q8), respectively. The corresponding contingency tables are consolidated into Table 33. Given the test results in Table 34. the independence between gender and post-COVID-19 greenspace usage ($p < 5\%$) and the general perception of safety ($p < 0.01\%$) is rejected. In all remaining cases, the hypothesis that the named variables are independent of gender cannot be rejected (Table 30).

Table 34. χ^2-Test result table that relates to Contingency Table 33.

Topic and Gender	Value	DoF	*p*-Value
Post-COVID-19 greenspace usage	16.07	6	0.0134
General safety perception	27.13	2	0.0000
Post-COVID-19 safety perception changes	7.09	4	0.1314
Physical safety enhancements	3.62	2	0.1637
Interest in the app	2.75	2	0.253

4.3. Two-Sample t-Tests (Comparison of the Data Gathered through Surveys in 2020 and 2024)

Two two-sample proportion tests were performed to investigate whether there are differences in the interest in the mobile app usage and differences in physical safety enhancements from the app, respectively. Each test is one sided and tests against the alternative, that the differences in a proportion have increased.

The first test tested whether the proportions of people interested in the app differ during and post-pandemic. The test results are summarised in Table 35. Given a 95% confidence level, a change in the proportion of people interested in the app was tested. The second test is performed to question differences in the safety enhancements through the app. The respective test results are given in Table 36. Given a 95% confidence level, the hypothesis that physical safety enhancement perceptions are identical in pre-during and post-pandemic samples cannot be rejected.

Table 35. Interest in the app monitoring by survey.

		COVID	Post-COVID
Interest in app one-sided two-sample proportion test	size	257	239
	mean	0.64	0.53
	standard deviation	0.024	0.0235
Test results	Standard error	0.0339	
	Value	3.32	
	p-value	0.0004	

Table 36. Physical safety enhancements by survey.

		COVID	Post-COVID
Interest in app one-sided two-sample proportion test	size	217	264
	mean	0.54	0.59
	standard deviation	0.0249	0.0232
Test results	Standard error	0.034	
	Value	−1.26	
	p-value	0.8959	

This section presents the results from the two surveys and data from the questionnaires. All additional results are presented in tables in the appendixes. All of the aforementioned results are transparent and reproducible. The code is available at https://github.com/lilimatic/greenspace/tree/master (accessed on 30 March 2024).

5. Discussion and Conclusions

We live in a time when health has become one of the crucial resources, challenged by the impact of global warming, stress-induced lifestyles, and, most recently, the consequences of the COVID-19 pandemic. Therefore, it is imperative to improve public health, particularly in urban areas with more exposure to risk factors. Spending time in OGS in cities is essential as this improves the overall physical and mental health benefits. During the pandemic, OGS usage was regulated, either entirely restricted or limited to a specified number of visitors or a limited amount of time per day.

The research survey focuses on a thorough analysis of the pandemic-related usage of OGS and its aftermath after the pandemic. The main research questions concentrated on analyzing the influence of the pandemic on OGS usage, as shown in the example of Belgrade. The survey was done at the pandemic's peak in 2020 and almost four years later in 2024.

The 2020 survey targeted frequent OGS visitors who prefer multiple visits per week. Research showed that many participants reported even increased OGS visits during the pandemic. Similarly, the studies above showed increased public OGS visits at the beginning of pandemics. However, this study showed users mostly visited OGS near their residences due to the time and space pandemic-related restrictions, while large public OGS remained relatively empty, which is actually in contrast with some of the findings from presented studies.

Through the data gathered in the survey, the exploratory statistical analysis presents that OGS visits are independent of demographics and how the level of perceived safety influences most OGS usage during the pandemics. In contrast, previous research studies showed how public health policies and environmental characteristics mainly influenced the OGS visits during the pandemic.

Additionally, this study tests the possibility of spending more time in OGS by introducing mobile apps that could provide information regarding the frequency of users in OGS. The survey showed that most respondents expressed interest in the proposed mobile apps and stated that this form of OGS monitoring would improve their physical perceived safety while visiting OGS during the pandemic. The results of the hypothesis tests indicate that the interest in the app is independent of gender but dependent on the age group. Further analysis suggests that possible physical safety enhancement through monitoring is linked to gender. Apart from demographics, this study points out that the interest in possible mobile app usage depends on pre-pandemic- and pandemic-related OGS-visiting habits.

As a central part of the methodology, the descriptive structure of the data was studied, and the results were analyzed using explorative data analysis. The predictive power of data in a machine learning prediction task was challenged. A machine learning classification task challenges the predictive power of features extracted in the 2020 survey to classify perceived safety enhancements with a Random Forest model. The predictive performance is satisfactory, and the most relevant features for this type of classification are the frequency change in OGS visits during the pandemic, the willingness to share one's location, the specific location where the survey took place, and the activities done in the OGS. Apart from that, it can be concluded that mobile app usage can increase perceived safety and influence the frequency, duration, and activities in OGS during the pandemic.

The second survey in 2024 aimed to detect the possible long-term effects of the pandemic and evaluate and compare the features of OGS usage during (2020) and after the pandemic (2024). The post-pandemic survey reveals that COVID-19 may have had a positive influence on the frequency of OGS visits since almost one-third of all 2024 survey participants reported increased OGS visits since the pandemic, and more than 20% of all users stated they feel safer in OGS after the pandemic.

Since the 2024 data analysis revealed a statistical dependence between the interest in the aforementioned mobile app and safety concerns or perceived safety, the important question of the 2024 survey was whether the users were still interested in mobile apps since the safety concerns of virus infections were significantly lower than in 2020. Despite a statistically significant decrease in interest in the apps, most 2024 survey participants still stated they would use them while visiting OGS. In addition, changes in possible physical safety enhancements from the app usage are statistically insignificant.

Concerning the survey results presented above, it can be concluded that developing the suggested mobile apps for OGS user tracking could provide more frequent usage of OGS due to increased levels of perceived safety among the majority of users. Previous research conducted on the usage of OGS during and post-pandemic focuses on safety concerns through the geotracking of residents. This research focuses on analyzing the management of OGS usage with mobile apps, which allows for improving safety efficiently and with limited resources. Furthermore, the proposed approach is data-privacy friendly, as users voluntarily provided data for this specific purpose; the data was not gathered from social media, as in some similar OGS monitoring proposes. Further research might deal with the issues regarding the regulation of OGS from the perspective of safety and in the context of the use of mobile applications, as this field is yet to be researched and defined worldwide and in Serbia.

One of the study limitations was connected with the sensitive time of this research. The first survey was conducted during a pandemic-related lockdown period in Belgrade. At that time, most people feared socializing and were unwilling to participate in the survey or use the OGS. Also, research focuses on perceived safety concerns, which may lead to data that are subjective to the personal perception of users and could be influenced by unlimited reasons unrelated to the study. However, in addition to the limitations, this research successfully met all the predefined research goals: (1) research analyzed the specific usage of OGS during the pandemic, especially from the perspective of perceived safety; (2) explored the possible role of location-tracking mobile apps in increasing personal and perceived safety; (3) analyzed the possible long-term effects that COVID-19 had on the increased frequency of OGS usage; and (4) provided the comparison of aforementioned OGS usage and willingness of participants to use mobile apps during and after the pandemic.

There are two main scientific contributions of this research: (a) a better understanding of OGS usage in the context of users' perceived safety during and after the pandemic, and (b) analyzing the possible solution to the safety issue that could improve the overall OGS usage in urban areas. Its additional scientific value and significance is that it considers age and gender variations that may have a role in determining the perceived safety among the users of OGS since this aspect is not reflected in previous similar research studies.

Possible future research based on this study's data analysis and results should consider analyzing OGS usage in unexpected scenarios other than pandemics, which could involve risk management and assessment. Also, possible research topics of interest are potential urban regulations and urban design transformations regarding the spatial characteristics of OGS in the form of guidelines for adapting future urban design to better usage in the pandemic. This paper can influence policy makers, urban planners, and public health officials to develop effective strategies to manage OGS usage and promote public health during similar crises. Finally, this paper offers valuable insights to guide future pandemic response planning and can inform OGS management strategies.

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Data Availability Statement: All of the research results are transparent and reproducible. The code is available at https://github.com/lilimatic/greenspace/tree/master (accessed on 30 March 2024).

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Appendix A

Table A1. Questions from the 2020 and 2024 surveys.

The 2020 survey	*- List of questions from Part A*	
	Qa,b	Gender and Age
	Q1	How often have you visited parks or squares in 2019 during the day?
	Q2	Regarding the parks or squares you visited in 2019, did you visit parks or squares more frequently during the day before the coronavirus outbreak?
	Q3	How much time have you usually spent in parks or squares since the coronavirus outbreak in Serbia?
	Q4	When you are in parks or squares, what do you typically do?
	Q5	When visiting parks or squares, who are you often in company with?
	Q6	While using parks or squares, do you behave according to social distancing regulations, standing at least 2.0 m apart from others?
	Q7	Do you feel safe visiting parks or squares, regardless of the coronavirus?
	- List of questions from Part B	
	Q8	Would you feel physically safe if there was a park or square usage monitoring that you could access through your phone?
	Q9	Would you feel secure regarding the coronavirus if there was monitoring of park or square usage that you could access through your phone?
	Q10	Would you be interested in technology that would allow you to know how many people are there in a specific place (e.g., shopping mall, clubs. . .) you would like to go?
	Q11	If your identity was not revealed, would you want to provide your phone's location (see question 10)?
	Q12	Circle the municipality in which you visit the parks or squares.

Table A1. *Cont.*

The 2024 survey	Q1.2	Gender and Age
	Q3	Municipality in which you visit parks or squares after the pandemic?
	Q4	Has the COVID-19 pandemic modified your usage of open greenspaces?
	Q5	Do you generally feel safe when you visit parks or squares?
	Q6	Did the COVID-19 pandemic influence your safety perception in parks or squares?
	Q7	Would you feel physically secure knowing that park or square usage is monitored and accessible through your phone?
	Q8	Would you be interested in technology that enables you to track how many people are in specific open greenspace at any time?
	Q9	What particular safety concerns bother you?

Appendix B

The below tables present the additional results within the 2020 survey.

Table A2. Gender and age of the participants presented as the total number and percentage.

		Absolute	Percentage (%)
Gender	Male	270	67.5
	Female	130	32.5
Age	15–24	159	39.8
	25–40	124	31.0
	41–64	117	29.2

Table A3. Time spent in parks during the pandemic (Q3).

	Absolute	Relative (%)
Not at all (1)	46	11.5
Up to 15 min (3)	86	21.5
From 15 to 30 min (2)	69	17.3
From 30 min to one hour (5)	118	29.5
More than one hour (4)	81	20.2

Table A4. Pre-pandemic park visits (Q1).

	Absolute	Relative (%)
Not at all	9	2.3
Rarely, a couple of times per year	44	11.0
Sometimes, a couple of times per month	149	37.2
Often, a couple of times per week	110	27.5
Always, almost every day	88	22.0

Table A5. Parks or squares/green spaces in Belgrade municipalities most visited by the participants (multiple entries permitted).

Municipality Visits	Absolute	Relative (%)
Novi Beograd	137	17.3
Vračar	118	14.9
Stari grad	114	14.4
Palilula	101	12.7

Table A5. *Cont.*

Municipality Visits	Absolute	Relative (%)
Zemun	92	11.6
Zvezdara	65	8.2
Čukarica	48	6.1
Voždovac	44	5.5
Savski Venac	32	4.0
Rakovica	23	2.9
Others	19	2.4

Table A6. Social aspects of a park visit (Q5).

	Absolute	Relative (%)
With a partner or a friend (two adults)	195	35.6
Alone or with pets	145	26.5
With a small group of friends (up to 5 persons)	141	25.7
With children	37	6.8
With a large group of friends (More than 5 people)	30	5.5

Table A7. Interest in the app (Q10).

	Count	Relative (%)
Yes	257	64.2
No	143	35.8

Table A8. Location sharing (Q11).

	Count	Relative (%)
Yes, at all times	95	23.8
Yes, while using the app	133	33.2
No, not at all	172	43.0

Table A9. SARS COVID-19 2 safety enhancements from monitoring (Q9).

	Count	Relative (%)
Yes	225	56.2
No	175	43.8

Table A10. Physical safety enhancements from monitoring (Q8).

	Count	Relative (%)
Yes	217	54.2
No	183	45.8

Table A11. Contingency Table: Interest in the app (Q10) by gender.

Gender	No	Yes	All	No (%)	Yes (%)	All (%)
Female	94	176	270	23.5	44	67.5
Male	49	81	130	12.25	20.25	32.5
All	143	257	**400**	35.75	64.25	**100**

Table A12. Contingency Table: Interest in the app (Q10) by age.

Age	No	Yes	All	No (%)	Yes (%)	All (%)
15–24	51	66	117	12.75	16.5	29.25
25–40	57	102	159	14.25	25.5	39.75
41–64	35	89	124	8.75	22.25	31
All	143	257	**400**	35.75	64.25	**100**

Table A13. Contingency Table: Interest in the app (Q10) by time spent in parks during the pandemic (Q3).

Would You Be Interested in Technology That Would Allow You to Know How Many People Are in a Place You Would Like to Go?	From 15 to 30 min	From 30 min to One Hour	More than One Hour	Not at All	Up to 15 min	All	From 15 to 30 min (%)	From 30 min to One Hour (%)	More than One Hour (%)	Not at All (%)	Up to 15 min (%)	All (%)
No	15	42	41	23	22	143	3.75	10.5	10.25	5.75	5.5	35.75
Yes	54	76	40	23	64	257	13.5	19	10	5.75	16	64.25
All	69	118	81	46	86	**400**	17.25	29.5	20.25	11.5	21.5	**100**

Table A14. Contingency Table: Interest in the app (Q10) by pandemic-related visiting habits changes (Q2).

	As Frequently	Less Frequently	More Frequently	Not at All	All	As Frequently (%)	Less Frequently (%)	More Frequently (%)	Not at All (%)	All (%)
No	42	35	53	13	143	10.5	8.75	13.25	3.25	35.75
Yes	55	79	109	14	257	13.75	19.75	27.25	3.5	64.25
All	97	114	162	27	**400**	24.25	28.5	40.5	6.75	**100**

Appendix C

The below tables present additional results within the 2024 survey.

Table A15. The gender and age of the participants are presented as the total number and percentage.

		Absolute	Percentage (%)
Gender (Q1)	Male	191	42.3
	Female	257	57
	Other	3	0.7

Table A16. Municipalities in which participants visited the open greenspaces (multiple entries permitted) (Q3).

Municipality Visits	Absolute	Relative (%)
Novi Beograd	142	14.9
Vracar	118	12.4
Stari Grad	119	12.5
Zemun	91	9.5
Zvezdara	90	9.4
Vozdovac	75	7.9
Palilula	70	7.3
Savski venac	70	7.3

Table A16. *Cont.*

Municipality Visits	Absolute	Relative (%)
Cukarica	59	6.2
Rakovica	32	3.4
Mladenovac	19	2
Surcin	16	1.7
Grocka	15	1.6
Obrenovac	15	1.6
Sopot	10	1
Barajevo	7	0.7
Lazarevac	6	0.6

Table A17. General safety perception (Q5).

	Count	Relative (%)
Yes	405	89.8%
No	46	10.2%

Table A18. Safety concerns (Q9).

	Count	Relative (%)
Park visits at night	182	40.4
Park visits in deprived areas	95	21.1
Unsafe playgrounds	92	20.4
Visits of overcrowded greenspaces	82	18.1

Table A19. Post-COVID-19 greenspace usage (Q4).

	Count	Relative (%)
Usage unchanged	264	58.6
I visit greenspaces more frequently and actively than before the pandemic	139	30.8
My visits have become less frequently	48	10.6

Table A20. Post-COVID-19 safety perception changes (Q6).

	Count	Relative (%)
My perception of safety remained unchanged	295	65.4%
I feel safer in open spaces	108	24.0%
I feel less safe	48	10.6

Table A21. Interest in the app (Q8).

	Count	Relative (%)
Yes	239	53.0%
No	212	47.0%

Table A22. Physical safety enhancements from monitoring (Q7).

	Count	Relative (%)
Yes	264	58.5%
No	187	41.5%

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