Students' Perceptions of Air Quality – an Opportunity for More Sustainable Urban Transport in the Medium-sized University City in the Balkans

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The way citizens perceive air quality has a huge impact on the public's willingness to contribute agendas that promote a sustainable future. Consequently, the scientific community wonders do the sudden and short-term shifts in air quality (such as one caused by the COVID-19 pandemic) have the potential to induce long-term changes in community behavior.

This study is based on the interpretation and analysis of a facultative survey administered to the student population of a medium-sized university city in the Balkans. The study's goal is to identify the types and strengths of factors that influence students' perceptions of air quality. In this regard, six classification algorithms were compared in order to select the one with the best fit between students' demographics, traveling habits, and air quality perception.

Individual variable influence revealed that Weekly lectures attendance and Distances students travel determine the perception of air quality more than Gender and Permanent place of residence. According to the study, potential commuting reorganization should target those living 2–4 km from the faculty building. Students who regularly attend lectures are likely to be willing to rely on better-organized public transport. Those who do not, will generally contribute the initiative once the positive effects are evident.

Key Words: *air quality, COVID-19, permanent changes, inner-city travel, students, university*

1. INTRODUCTION

Air pollution represents one of the most severe environmental problems facing modern-day urban communities. Besides inducing various diseases [1, 2] increased concentrations of air pollutants cause approximately 6.7 million deaths annually [3] and reduce overall life quality. Air pollution, on the other hand, is primarily caused by anthropogenic activities. Consequently, national governments face a delicate task in creating strategies to empower the continuous development of sustainable societies while balancing between the states of citizens' life standard and citizens' life quality.

As a result, the strength and effectiveness of air quality control measures often depict the scale of national priorities [4]. For example, the developing world[1] has the most severe environmental problems in

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[1]According to IMF classification, developing world refers to the countries whose standard of living, income, economic and industrial development remain below average [35].

terms of air quality [5], and as material living standards improve, so does the demand for environmental quality [6].

Aside from the state of the economy, air quality is significantly influenced by the settlement size and prime commercial activity of the community. Given their size, large cities are subjected to a significant influence from immense anthropogenic activities (industry, transportation, services, etc.), causing air quality to deteriorate [7]. On the other hand, in relatively small urban areas, the primary commercial activity of the community (tourism, mining, energy production, education, etc.) determines the state of the air quality [8].

Upon the COVID-19 pandemic, national governments imposed measures[2] to curtail the spread of the disease and sustain the virus death toll. Imposed measures influenced global carbon emission to reduce by 7% [9], road transport emission (NO_x) by 10% [9], and particulate matter (PM2.5) by 12% [10] compared to the pre-pandemic period. However, air quality has not improved equally across all world regions and city sizes. For example, the average decrease in concentrations of particular matter in Europe (5%) was significantly lower than in Asia (16%) [10] and Africa [11]. Similarly, developed world megacities[3] observed a smaller decrease in road transport emission (London, UK – up to 40% [12], Berlin, Germany – up to 40% [13]) compared to megacities of the developing world (Delhi, India – up to 50% [14], Istanbul, Turkey 47% [15]). On the example of medium-sized cities in Italy (Florence, Pisa, Lucca) no evidence of a direct relationship between the lockdown measures and the improvement of air quality was observed, except in areas characterized by heavy vehicular traffic [14]. Relatively small urban communities where tourism is the prime economic activity, on the other hand, experienced a „general" reduction in air pollution – specifically, road transport emissions [16]. In parallel, air quality in some cities has deteriorated due to increased concentrations of particular matter [17]. The worsening of air quality in those areas was caused by the increased reliability on freight trucks[4] [18] and intensified use of households' HVAC systems [19].

Besides the monitored indicators of air quality, citizens' perceptions play an important role in guiding local governments to organize environmental agendas [20]. In the cases where the improvement is noticeable, the positive effects may encourage citizens to change their usual commuting behavior. As a result, local governments could exploit the wiliness of people to contribute sustainable societies by reorganizing existing traffic routes, promoting carpooling [21] and non-motorized modes of transport [22].

On the other side, those who do not perceive the improvements could potentially resist actions aimed at creating a more sustainable future. In this regard, perception of improved air quality can contribute to a positive societal response even if it is not based on reality, as the improvement of air quality that goes unnoticed cant.

Thus, some researchers believe that citizens' perception of air quality should be considered as one of the features determining air quality indicators (as good air quality that remains unnoticded) [23]. Besides this, society's response can be influenced by cultural factors and country's level of development [24]. This is especially important given that the post-COVID-19 revitalization presents an opportunity to reshape societies [25] so they strive for more sustainable development [26].

Because air quality during the pandemic of COVID-19 disease has changed, one might wonder could the perception of change cause permanent shift in citizens' commuting behavior in one geographical region.

To examine these assumptions, the following questions should be answered:

- How do citizens perceive the state of air quality in their communities?
- Is there a gap between public perceptions and monitoring indicators of air quality i.e., is citizens' perception based on measured improvements in air quality or on other factors? Understanding the underlying causes of perception change can enable a more effective public response to motivate people to contribute to a more sustainable future.
- What are the factors influencing community members to perceive air quality differently?

This study aims to analyze the perception of air quality among the student population in a medium-sized university city in a developing country. The outcomes of the study could contribute distinguishing demographic and behavioral details that cause students to perceive air quality in the university city differently.

To be more specific, to identify details that influence readiness to embrace changes toward a more sustainable future. Presented results enlarge the international catalog of knowledge by focusing on a specific urban community (the medium-sized city in the Balkans) and a specific group of community members (students).

[2] Movement control orders, homeschooling, restriction of public events, border lock-ups, etc.

[3] A city with more than 5 million inhabitants [36].

[4] Freight trucks account for a relatively small portion of the vehicle miles traveled (VMT), however, they make up around 25% of the PM2.5 [18]

2. MATERIALS

In order to examine students' perception of air quality, an online survey was conducted at the Faculty in Serbia. A voluntary survey was conducted using the Google Form platform, during which students provided basic demographic information[5] as well as opinions on air quality [27]. According to the poll (which had 214 participants), roughly half of the respondents (49%) lived in the university city permanently.

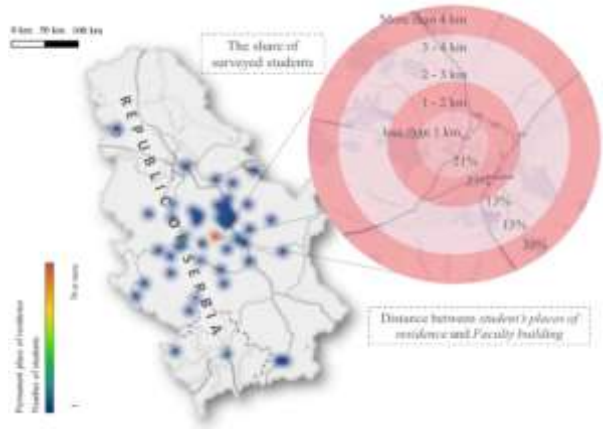

Figure 1 - The representation of permanent places of residence for all the students, and share of distances from the main Faculty building to the students' permanent or temporary residences in the university city

The other half came from other cities and was temporarily residing in dorms or private housing near the University. Figure 1 depicts the permanent residences of students in the Republic of Serbia, as well as the portion of distances between the main Faculty building (FB) and the permanent or temporary residences of students in the University city. As shown in Figure 1, the majority of students (45%) live up to two kilometers from the main FB. The percentage of student houses per kilometer remains constant between 2 and 4 kilometers, at 13%. Approximately one-third of all respondents live more than 4 km away from the main FB.

Figure 3 shows the share of students' permanent places of residence (From UC/From out UC), as well be noticed that the majority of students attend lectures 5 times a week, whereby students from other cities are more regular than those with permanent residence in the UC (45% and 27%, respectively). Approximately, 60% of all the students attend lectures more than three times a week. Considering the students' answers regarding the perception of air quality, 62% of the respondents did not notice a change, 24% considered air quality as improved, while 14% believe air quality *deteriorated* compared to the pre-pandemic period. The majority of students' responses (86%) did not correspond to the official report [28] describing ambient air as more polluted than the previous year's [29].

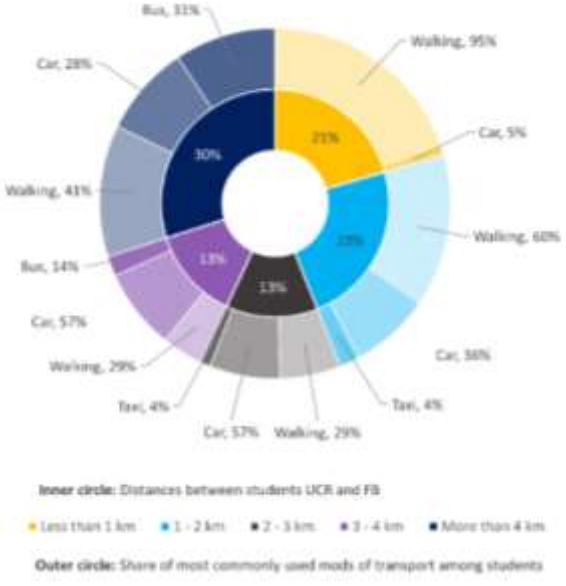

Figure 2 - Share of distances between students UCR and FB, and most commonly used modes of inner-city transport

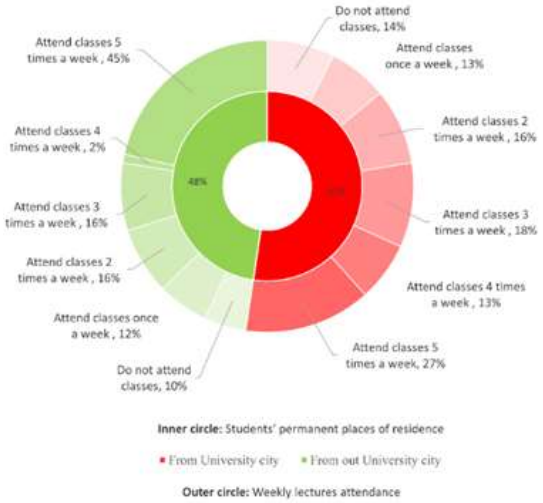

Figure 3 - Share of students permanent residences (cathegories: From UC/From out UC) and Weekly lectures attendance per category

The report conclusions were based on air quality indexes determined by average daily concentrations[6]

[5]The demographic data collected was limited to details that could be considered university statistics.

[6] Ambient air pollution in the UC has been measured throughout a national network of automatic monitoring stations. The rules concerning reference methods, data validation, and the location of sampling points for the assessment of ambient air quality are in accordance with the Law on Air Protection ("Official Gazette *of the Republic of Serbia",* No.*38/09, 10/2013, 26/2021*).

of the air pollutants, such are nitric oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM_{10}). Table 1 presents mean annual concentrations of the pollutants determining air quality in the UC. Besides that, the table presents the number of days exceeding daily limit values for two consecutive years – the survey year (during the COVID-19 period) and the year before (pre-pandemic period).

Table 1. Sampling details that determine the air quality index in the UC [28,29]

Year	SO_2		NO_x		PM_{10}		Air Quality Category[7]
	M.A.V. [µg/m^3]	N.D.E.L.V. [-]	M.A.V. [µg/m^3]	N.D.E.L.V. [-]	M.A.V. [µg/m^3]	N.D.E.L.V. [-]	
Pre-pandemic period	6.5	0	21.4	0	32	51	II
Pandemic period	9	0	18	0	42	68	III

M.A.V. – mean annual value
N.D.E.L.V. – number of days exceeding limit values

The data (table 1.) show that the mean annual concentration of nitric oxides in the survey year has decreased by 16% compared to the year before. Even though this share was not insignificant, NO_x concentrations were below the threshold value [30] even before the pandemic, without a single day exceeding the daily threshold. For the same reason, the increased concentration of sulfur dioxide in the ambient air did not significantly influence the index of air quality.

Thus, air quality in the UC is mainly determined by the concentration of particular matter (PM_{10}), as confirmed by government agencies [31] and previous research [32]. In the survey year, the mean annual concentration of PM_{10} increased by 24% compared to the previous, while the number of days with exceeded threshold values (68) increased by 25% compared to the year before (51).

The cause for an increase was the relatively high heating load of the residential sector [19] which was caused by citizens spending more time at home than usual (lock downs, home offices). Heat is provided by burining solid fuels (primarily coal) [33].

2.2. Sample

The data used for the analysis (inputs and outputs) consists of classes of students' answers amassed by the google questionnaire (table 2).

Table 2. Characteristics of the training and testing set (balanced data)

Characteristics	Training set (n=150)					Testing set (n=64)					*p*-value
Gender [M/F - 0/1] n (%)	101 (67.3)					37 (57.8)					0.085
From UC/From out UC [0/1] n (%)	72 (48)					32 (50)					0.912
Distances between students UCR and FB * [1-5] n (%)	26	40	12	20	52	15	15	4	9	21	0.478
	17.3	26.7	8	13.3	34.7	23.4	23.4	6.3	14.1	32.8	
Weekly lectures attendance ** [1-5] n (%)	17	27	23	9	52	22	7	7	11	2	26	11	0.451
	11.3	18	15.3	6	34.7	14.7	10.9	11	17	3.1	40.6	17.2	
Commonly used mode of transport in the UC *** [1-4] n (%)	91	40	16	3		36	18	10	1		0.629
	60.7	26.7	10.7	2		56.3	28.1	15.6	1.6		
Perception of air quality *(deteriorated / not changed / improved)* [1/2/3] n (%)	50	50	50			21	21	22			1.000
	33.3	33.3	33.3			32.8	32.8	34.4			

** Distances between students UCR and FB consist of 5 classes, whereby every class represent 1 km of distance, except the last class that represents 5 km or more of distance*
*** Weekly lectures attendance consists of 5 classes, whereby every class represent the number of weekly lectures attendances*
**** Commonly used mode of transport in the UC consists of 4 classes, whereby every class represent a different transport mode (walking, (car) driving, bus, taxi)*

To cure the problem of output multinominal classification in the presence of imbalanced data[8], balancing the data was performed by simple oversampling with

[7] In accordance with measurement results and the Law on Air Protection, the Serbian Environmental Protection Agency determines three categories of air quality: I – clean, II – moderately polluted, and III – excessively polluted

[8] Imbalanced data characterize the classification with unequal distribution of classes in the training dataset.

replacement from the minority class. The study sample, after resampling, was randomly split into training (70%) and testing (30%) sets. Characteristics of the data sets and data sets' classes are presented in table 2.

3. METHODS

Following data stratification, the study used R software to create six machine learning models, including a logistic regression model, an artificial neural network, a decision tree, and three ensembled tree-based ML algorithms: random forest (RF), gradient boosted trees, and extreme gradient boosted model. The models' training results were calculated using tenfold cross-validation. After selecting the best performing model, its default parameters[9] were optimized[10] to fit the data as closely as possible. For model optimization, the open-source H2O platform [34] was used.

4. RESULTS

The resulting algorithms demonstrate various levels of performance, with accuracies and error rates for forecasting perception of air quality shown in figure 4. The best-performing model, as shown in figure 4, was RF. For the final model test set, the common multi-category classification accuracy evaluation measures (namely: Correct Classification Percentage (CCP) ,and Coefficient of Determination (R2)) are presented in table 3.

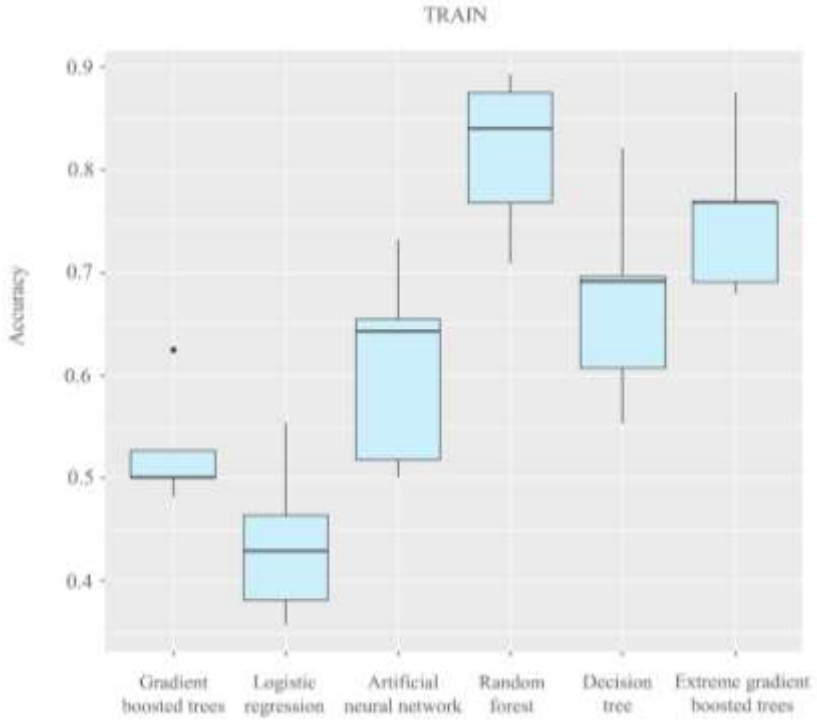

Figure 4 - Comparison of classification accuracies

Table 3. Predictive performance of default and final model based on training and test datasets

ACCURACY MEASURES	FINAL RF MODEL (mean (± STD))
CCP (95% CI)	0.786 ± 0.085
CCP *Air quality has deteriorated*	0.897
CCP *Air quality has not changed*	0.795
CCP *Air quality has improved*	0.667
R^2 (95% CI)	0.602 ± 0.335

The CCP is computed to be 0.786 for the final model, indicating that roughly four-fifths of the subjects in the sample are correctly classified using the final model in the dataset. The coefficient of determination indicates that a relatively large fraction of the total variation could be explained by the model. Referring to the outcome classes, the model

[9]Default parameters of the RF model were: number of the tree [ntree=50], maximum depth of each tree [max_depth=20].

[10]In order to optimize the model, a „cartesian" grid search was applied. The parameters specific to the RF algorithm were tuned as following: the ntree 50 – 200 in increments of 50, the number of variables to be sampled as split criteria at each node (mtry) 2 – 5 in increments of 1, the max_depth 20 – 60 in increments of 20, the minimum number of observations for a leaf (min_rows) 1 – 2 in increments of 1, and the row sampling rate (sample_rate) 0.55, 0.632, 0.75 (that is a total of 288 model combinations)

provided the highest accuracy for predicting/explaining the perception: air quality deteriorated (90%). Although lower, the model's accuracies for the other two outcomes were also relatively acceptable: air quality improved (67%), air quality did not change (79%). As shown in figure 5, Weekly lecture attendance and Distances between students UCR and FB, have the greatest impact on model performance, i.e. student perception of air quality. Variables From UC/From out UC and Gender, on the other hand, have a minor impact on model performance. In addition to variable importance[11], this study aims to determine the directions of variable influences, i.e. the functional relationship between the classes of students' answers and the output classes of the model responses.

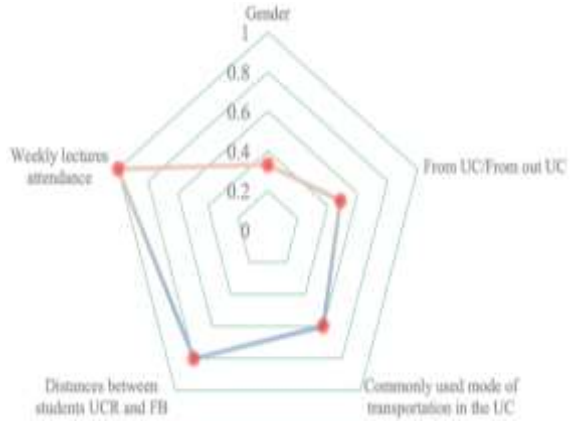

Figure 5 - Variable importance for the optimized RF model

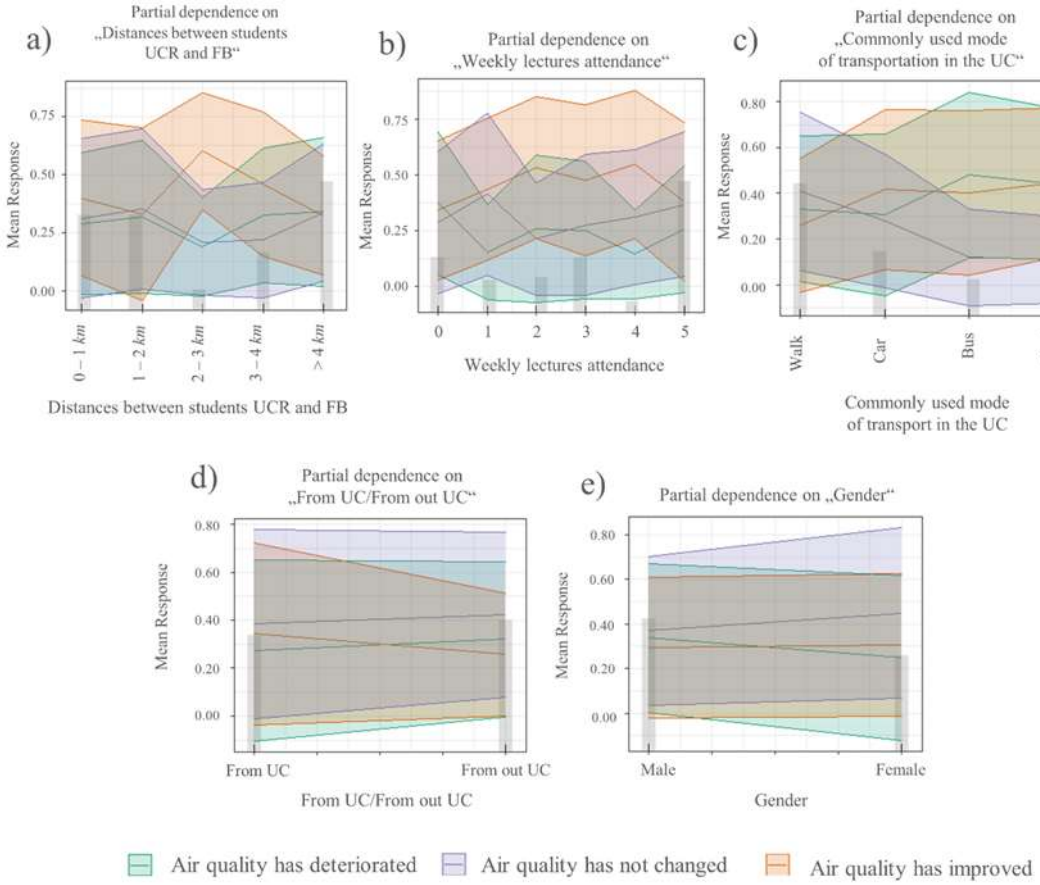

Figure 6 - Partial dependence plot for the optimized RF model

A partial dependence plot of the proposed RF model was performed in this regard (figure 6). Figure 6 is made up of six separate plots, each of which depicts the direction of individual variable influences. The x-axis shows classes of students' res ponses per variable, whereas the y–axis shows the model's mean response per unmarginalized class. Output partial reliance per variable class is presented with lines in the centers of the colored fields representing 95% of the output confidence interval.

Figure 6. a) shows that the RF model considers students seated 1 – 2 km from the main FB, as well as those seated 4 km or more, as the most suitable to perceive the change of air quality as it is – deteriorated, or not changed. The responses of students seated less than 1 km from the FB, as well as those seated 2–3 km

[11] A variable importance value is used to express (in a scalar quantity) the degree to which a variable affects the response value through the chosen model [37]

away, influence the general model's prediction of the outcome – Air quality improved.

Considering the influence of the next two parameters presented in Figures 6. b) and 6. c), respondents who travel by bus 2 or 3 times a week, are predisposed to perceive the actual state of air quality – deteriorated. Those who travel more (attend lectures 2 – 4 times a week) and commute by Cars, Buses, or Taxi Cabs, on the other hand, are less likely to notice the difference, and will generally perceive the air quality as improved.

According to the model, students who walk to their lectures once a week mostly are unlikely to notice a change in air quality. The last two plots (6. d) and 6. e)) represent the factors that have a minor influence on predicting results. Fig. 6. d) demonstrates that students from out UC are more able to perceive changes in air quality in the UC than their colleagues permanently residing the UC.

Referring to gender, the model indicates that males are slightly more subjected to observing the actual change of air quality than females, as well they were more willing to change before established comuting behaviour [32].

5. CONCLUSION

This study analyzed the influence of demographics and travling habits on students' perception of air quality. The study was based on interpretation and analysis of data from a facultative survey conducted among the student population of a medium-sized university city in the Balkans.

Referring to data interpretation, the study presents sample details based on multiple criteria: Gender, From UC/From out UC, Distances between students UCR and FB, Weekly lectures attendance, and Commonly used modes of transport in the UC. In general, the study discovered that the majority of students were unable to observe the change of air quality as measured, resulting the gap between the measured index of air quality and perception of air quality in the UC. In detail, during the COVID-19 pandemic, according to the installed air quality measuring stations, the air quality in the UC deteriorated due to increased emission of the particular matter in the air. This change was noticed just by 14% of the respondents, while the rest perceived air quality as not changed (62%) or improved (24%) compared to the pre-pandemic period.

To determine the factors influencing the students' perception of air quality, six classification methods were employed to find the one with the best fit between students' demographics, travling habits, and students' perceptions. The best performing model (RF), after additional optimization, was able to correctly classify 79% of the subjects in the sample.

The comparative influence of individual variables on the model outcome was determined by the variable importance. The influence of individual classes of answers (variables) on the model outcome was determined by partial dependence plots. Using both methods, the study concludes that Weekly lectures attendance and Distances between students UCR and FB are the variables with the greatest influence on students' perception of air quality. In particular, students who rarely attend lectures and walk to the University are unlikely to notice a change in air quality. Those who attend the lectures regularly and commute by car, bus, or taxi cab will be more compliant to perceive the air quality as better than it is. As a result, this group of students may be the most committed to advancing agendas that promote more sustainable cities. In this regard, future agendas should specifically encourage regular lecture attendees to rely more on public transport instead of personal vehicles. Because this applies specifically to those traveling between 2 and 4 km to attend lectures, public transport within this circle could be rearranged by creating more bus stops, increasing the number of bus lines, and/or decreasing bus waiting time. Students who are residing 1–2 km or more than 4 km from the FB and attend lectures on an irregular basis, will be the best candidates to observe the actual state of air quality. Assumably, they will support the sustainable initiatives once the positive effects become evident. That way, relatively small actions that are timely supported at the outset could potentially provoke positive changes toward more societies.

6. ABBREVIATIONS

CCP- Correct Classification Percentage
CI - Confidence interval
ML - Machine learning
PDP - Partial Dependence Plot
RF - Random Forest
FB - Faculty building
UC - University city
UCR - University city residence

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REZIME

PERCEPCIJA STUDENATA O KVALITETU VAZDUHA – PRILIKA ZA ODRŽIVI GRADSKI PREVOZ U UNIVERZITETSKOM GRADU SREDNJE VELIČINE NA BALKANU

Način na koji građani vide kvalitet vazduha ima ogroman uticaj na spremnost javnosti da doprinese programima koji promovišu održivu budućnost. Shodno tome, naučna zajednica se pita da li iznenadne i kratkoročne promene kvaliteta vazduha (kao što je ona izazvana pandemijom COVID-19) imaju potencijal da izazovu dugoročne promene u ponašanju zajednice. Ova studija je zasnovana na tumačenju i analizi fakultativne ankete sprovedene među studentskom populacijom srednjeg univerzitetskog grada na Balkanu. Cilj studije je da identifikuje vrste i snage faktora koji utiču na percepciju kvaliteta vazduha učenika. S tim u vezi, upoređeno je šest klasifikacionih algoritama kako bi se izabrao onaj koji najbolje odgovara demografiji učenika, navikama putovanja i percepciji kvaliteta vazduha. Individualni varijabilni uticaj je otkrio da sedmična posećenost predavanjima i razdaljine koje studenti putuju više određuju percepciju kvaliteta vazduha nego pol i mesto prebivališta. Prema studiji, potencijalna reorganizacija putovanja na posao trebalo bi da bude usmerena na one koji žive 2–4 km od zgrade fakulteta. Studenti koji redovno pohađaju predavanja verovatno će biti spremni da se oslone na bolje organizovan javni prevoz. Oni koji to ne čine, generalno će doprineti inicijativi kada pozitivni efekti budu evidentni.

Ključne reči: *kvalitet vazduha, COVID-19, trajne promene, putovanja u grad, studenti, univerzitet*