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Research Article

Temporal and Spatial Analysis of Noise at the Sakarya University Esentepe Campus

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Abstract: This study primarily focuses on the spatial distribution of noise pollution at Sakarya University Esentepe Campus, utilizing the Inverse Distance Weighted (IDW) interpolation method within a Geographic Information Systems (GIS) framework. Noise pollution is a critical environmental issue that disrupts educational activities and reduces the well-being of students and staff. According to WHO and ISO standards, noise levels exceeding 55 dB(A) are classified as annoying, while those above 65 dB(A) pose significant health risks. The main objective of this research is to map and analyze these noise levels across 18 strategic locations representing various campus land uses during morning and afternoon periods. The methodology integrated field measurements via ArcGIS Field Maps with advanced spatial analysis. IDW interpolation was employed to generate continuous noise surfaces from point data, allowing for a comprehensive visualization of noise intensity across the entire campus. Statistical evaluations, including one-way ANOVA and one-sample t-test, were performed to evaluate the significance of spatial differences among measurement points and compare campus noise averages against the 55 dB(A) threshold. Furthermore, the study integrated these IDW-based maps into a web-based Interactive Noise Information Environment using ArcGIS StoryMaps and Survey123. This digital setup enables users to visualize spatial noise data and contribute to the database through geo-tagged photo submissions, providing a participatory decision-support tool for campus management. The findings derived from IDW mapping highlight critical noise hotspots, particularly along major transport routes and social hubs. These results serve as a scientific basis for implementing mitigation strategies, such as biological barriers and traffic regulations. By combining IDW spatial modeling with Web GIS technologies, this research contributes a sustainable and technology-driven model for creating quieter educational environments in Türkiye.

Keywords: Noise Pollution, Geographic Information Systems, Sustainable Solutions, Noise, Web GIS

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1. Introduction

Noise is generally defined as disturbing and unwanted sounds; with the increasing urbanization and industrialization of today, it has become one of the major environmental problems with far-reaching social impacts. Transportation modes such as road, rail, air, and waterways; industrial facilities, construction sites, entertainment venues, workshops, and various equipment used in open areas constitute the primary sources of environmental noise (Ministry of Environment, Urbanization and Climate Change, 2023).

Indoor noise generated by mechanical systems within buildings is also included in this scope. Noise pollution can lead to various physical and psychological consequences, such as sleep disorders, stress, anxiety, cardiovascular diseases, and reduced cognitive performance (WHO, 2011). The World Health Organization (WHO) and the International Organization for Standardization (ISO) have established certain limit values to prevent these effects. According to the WHO, noise levels exceeding 40 dB(A) at night can cause sleep disturbances (WHO, 2009), while the ISO (2003) classifies levels above 55 dB(A) as annoying and those above 65 dB(A) as posing a health risk (Morova et al., 2010). In this context, the reduction and control of environmental noise have become an important component of modern urban planning and public health policies. Especially in city centers, noise from motor vehicles, combined with factors such as traffic congestion and unplanned urbanization, can reach high decibel

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levels in residential areas (Kayan, 2018; Onay et al., 2024). This constant exposure not only triggers physiological and psychological distress but can also negatively impact individuals' productivity and well-being (Onay et al., 2024).

Today, environmental noise has emerged as a major issue that directly affects quality of life, particularly in large cities. In Türkiye, rapid urbanization and transportation planning that lacks environmental sustainability have led to the intertwining of living and working spaces, which has exacerbated noise pollution (Öner & Sesli, 2018). Studies in the literature indicate that the majority of environmental noise stems from road traffic and that noise levels frequently exceed threshold values. For example, in Afyonkarahisar, 58.5% of traffic-related noise levels were found to exceed 80 dB(A) (Erdoğan et al., 2007), while in Avanos, noise levels on major arteries ranged between 79–85 dB(A), exceeding international limits (Kalıpçı, 2017). Similarly, in the case of Erzurum Aziziye Park (Özer, 2014), it has been reported that traffic and operational intensity have elevated noise pollution to critical levels. This situation demonstrates that noise levels between 55–60 dB(A) increase discomfort, show a significant rise in the 60–65 dB(A) range, and values above 65 dB(A) can lead to serious health problems (Kalıpçı, 2017).

University campuses are among the most sensitive areas affected by this pollution, as they require a quiet and productive working environment. However, research on campus noise in Türkiye remains limited compared to that in developed countries. In international examples, the average Leq value at a campus in Nigeria was found to be 70.94 dB(A), exceeding legal limits (Egbenta et al., 2024). Similar findings exist in studies conducted on campuses in Türkiye; while noise levels reached 76 dB(A) at Süleyman Demirel University (Morova et al., 2010), it was determined that the 55 dB(A) limit was exceeded at Atatürk University, with an average of 62.70 dB(A) (Özer et al., 2014). In the case of Ordu University, it was noted that the campus's location along the main transportation route negatively impacts the quality of education (Yeşil & Güzel, 2023). This situation highlights the potential negative effects of noise pollution on academic performance and student health within university campuses, underscoring the need for more comprehensive studies in these sensitive areas (Özer et al., 2014; Yeşil & Güzel, 2023). In this context, detailed analyses to determine noise levels on university campuses and ensure acoustic comfort are of great importance (Onay et al., 2024).

According to the WHO, noise levels in the immediate vicinity of educational facilities should not exceed 55 dB(A), whereas Turkish regulations set the legal limit at 65 dB(A). In this context, it is necessary to regularly monitor environmental noise on university campuses and analyze its spatial distribution. The current study aims to map the spatial distribution of noise pollution through measurements conducted at different times of the day at Sakarya University's Esentepe Campus and to develop comprehensive solution proposals based on the data obtained. As part of the study, equivalent noise levels (Leq) will be determined at various strategic points across the campus during morning and afternoon periods; these data will be processed using interpolation methods within a Geographic Information System (GIS) environment to create digital noise maps. The prepared data will be presented interactively on a web-based GIS platform. The use of GIS in this context is essential for detailing and visually presenting the spatial distribution of noise levels across the campus (Maguire, 1991). Additionally, a digital workflow has been established within the platform, allowing students to report noise pollution issues using visual evidence (photos). This ensures that noise-related issues are directly communicated to the administration, aiming to enhance the project's broader impact and sustainably improve the quality of campus life. The up-to-date noise data obtained from this study aims to improve the health and productivity of students and academic staff by providing a scientific foundation for future campus planning and acoustic improvements to the existing building stock (Dönmez et al., 2023; Onay & Şahin, 2022).

2. Data and Methodology

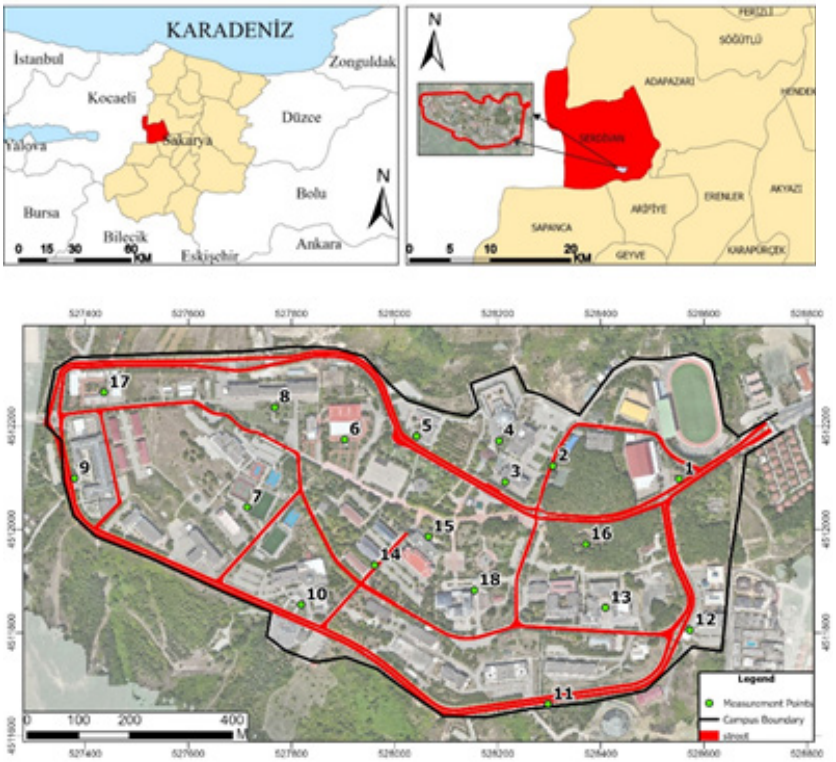
2.1. Data

The study area is the Sakarya University Esentepe Campus, located north of Lake Sapanca within the boundaries of Serdivan District, Sakarya Province (Figure 1). Covering an area of approximately 1,749,000 m^2, the campus is strategically located between 40° 44' latitude and 30° 19'–30° 20' longitude. The campus is bordered by the D-100 highway to the south, the KYK campus to the east, and dormitory areas along the northwest boundary (Büke, 2016).

The campus is home to 14 faculties, 5 institutes, and numerous research centers (such as BAUM and SARGEM), as well as innovation hubs like Teknokent. This integrated campus, comprising 62 separate buildings, accommodates not only academic units but also social facilities, a commercial area, sports complexes, and residential units, resulting in heavy foot and vehicle traffic. This functional diversity and extensive area make the campus a highly representative study site for environmental noise pollution and user perception analyses.

Figure 1

Map of the Study Area



Noise measurement points were obtained in vector data format. The coordinates of these points were recorded directly in the field using the ArcGIS Field Maps mobile app. Thanks to the app, the locations of the measurement points were determined with high accuracy, and the data entries were transferred to the GIS environment in real time. Orthophoto images of Sakarya University's Esentepe Campus were used as the spatial reference. These images are in raster data format and were obtained through drone flights conducted across the campus. The spatial layers containing building polygons and functional attributes were sourced from the "AllRoofs_campus_join_union" dataset, which was produced as part of previous solar energy potential assessment studies conducted across the campus. Noise levels were measured using the mobile-based Decibel X application, and acoustic parameters such as Leq, Lmin, and Lmax were collected for each measurement point. Comprehensive tests conducted in the literature on the reliability of smartphone applications demonstrate that these software tools operate in accordance with professional Type-2 sound level meters (SLMs) within an acceptable margin of error of ±2 dB(A). As emphasized by Murphy and King (2016), although there is a certain margin of error in smartphone data, it has been determined that this margin is no greater than the uncertainties in traditional calculation models based on estimated data such as traffic flow, vehicle composition, and speed. While input data in traditional models often relies on assumptions, which can lead to significant errors, this smartphone-based approach eliminates the need for external data for the "source model" by measuring directly at the source and has the potential to reflect the actual state of the acoustic environment. In light of these scientific references, the methodology followed in this study is assessed as sufficient and reliable at the academic level for generating spatial planning decisions at the campus scale.

The data obtained were preprocessed in Microsoft Excel and then imported into the ArcGIS Pro (Esri, 2024a) environment for spatial analysis. SPSS (Statistical Package for the Social Sciences) software was used for statistical analyses. To determine the significance levels of the data, parametric tests—

specifically the one-sample t-test and one-way ANOVA—were applied. A one-sample t-test was utilized to determine whether the measured noise levels significantly differed from the 55 dB(A) regulatory threshold, while ANOVA (Analysis of Variance) was used to compare the mean noise levels among the different measurement locations. These tests were preferred when the data exhibited a normal distribution and homogeneity of variance was ensured.

In spatial analysis, the IDW (Inverse Distance Weighted) interpolation method was used to create noise distribution maps across the campus. This method estimates new values by weighting known values based on their distances to unknown points. The reason for choosing IDW is that it provides a computational framework where measurements at nearby points carry greater weight for data exhibiting physical dispersion, such as noise, thereby enabling the spatial distribution of noise levels to be estimated with high accuracy.

This technique, which has proven successful in noise pollution analyses in the literature (Morova et al., 2010), is one of the most suitable tools for visualizing noise levels, particularly when working with irregularly distributed measurement points. The use of this method in the study enabled the data collected from various points across the campus to be transformed into a continuous surface, thereby allowing for the scientific prediction of noise risk in intermediate areas where no measurements were taken.

Cloud-based Web GIS technologies were utilized to provide an interactive presentation of the data obtained within the scope of the study and to facilitate user interaction. In this regard, the ArcGIS StoryMaps (Esri, 2024b) platform was selected to integrate the prepared noise maps into the Sakarya University campus information system and make them accessible. The digital workflow allowing students to submit location-based and photo-based reports regarding noise pollution was created using the ArcGIS Survey123 (Esri, 2024c) application. This web-based infrastructure establishes a direct communication channel between campus administration and students, providing the essential tools to enable rapid and effective responses to noise-related issues.

In order to conduct noise measurements within the Sakarya University campus, a total of 18 measurement points (Table 1) were identified with a homogeneous distribution covering different areas of the campus. In selecting these points, areas with heavy pedestrian and vehicle traffic, social spaces, and the locations of academic units were taken into account. This ensured a representative distribution of noise sources across the campus.

Table 1

Table of Noise Measurement Points and Measurement Values

		Minimum			Maximum			Leq		
LOCATION_NO	LOCATION_NAME	08.00-12.00	13.00-18.00	Mean	08.00-12.0	13.00-18.00	Mean	08.00-12.00	13.00-18.00	Mean
1	SPORT SCIENCES FACULTIES STOP	41,3	47,4	44,4	72,0	76,8	74,4	59,3	61,3	60,3
2	FACULTY OF HUMANITIES AND SOCIAL SCIENCES, BUILDING A	37,5	40,7	39,1	67,5	73,6	70,5	52,7	57,4	55,0
3	RING ROAD NO 1, STOP 2	41,3	42,5	41,9	72,4	71,2	71,8	58,0	56,5	57,2
4	CAMPUS MOSQUE	37,1	38,8	37,9	57,8	73,4	65,6	43,8	55,9	49,8
5	CAMPUS SQUARE	39,2	44,6	41,9	68,8	71,2	70,0	53,7	57,0	55,3
6	CENTRAL CAFETERIA	36,8	41,1	39,0	59,1	61,9	60,5	44,1	48,7	46,4
7	FACULTY OF CIVIL ENGINEERING AND SPORTS FIELDS AREA	35,3	36,3	35,8	62,7	68,9	65,8	44,6	48,5	46,6
8	FACULTY OF SCIENCE	36,2	36,2	36,2	58,2	59,9	59,0	43,2	45,1	44,2
9	FACULTY OF THEOLOGY	37,8	39,5	38,7	64,1	67,6	65,8	51,8	53,8	52,8
10	CULTURAL AND CONVENTION CENTER	41,3	41,9	41,6	65,4	66,8	66,1	52,0	52,5	52,3
11	RING ROAD NO 2	42,2	43,4	42,8	75,0	77,3	76,1	61,2	61,4	61,3
12	TEKNOKENT	39,3	40,7	40,0	68,4	75,9	72,2	55,5	60,6	58,1
13	LAW SCHOOL	39,7	39,7	39,7	59,9	62,5	61,2	47,6	48,5	48,1
14	FACULTY OF ENGINEERING (M2, M3, M4)	41,2	41,1	41,2	67,6	76,0	71,8	54,0	57,8	55,9
15	LIBRARY	38,4	42,7	40,5	63,3	76,1	69,7	47,9	56,8	52,4
16	FORESTED AREA	56,4	38,7	47,5	60,0	68,1	64,1	46,7	51,7	49,2
17	LABORATORIES	38,6	36,9	37,8	66,8	69,0	67,9	53,0	49,4	51,2
18	THE RECTORATE	43,2	46,5	44,8	59,6	76,1	67,8	47,6	58,8	53,2

2.2. Methodology

2.2.1. Data collection and measurement protocol

The ArcGIS Field Maps mobile app was used to coordinate and accurately locate the noise measurement points in the field. The 18 designated measurement points were entered into a web-based map using their geographic coordinates and imported into the app. This ensured quick and accurate access to the measurement points during fieldwork.

Noise measurements were conducted between April 25 and May 7 to cover the period of peak student activity on campus. The measurements were carried out during two main time periods to determine

changes in sound levels throughout the day: The first measurement period covered the morning hours and took place between 8:00 a.m. and 12:00 p.m. The second measurement interval covered the afternoon period and was conducted between 1:00 p.m. and 6:00 p.m.

To ensure temporal consistency of the data, care was taken to collect data at approximately the same time intervals for the designated locations on each measurement day. To ensure data consistency and comparability in line with these standards, a strict measurement protocol was followed using a Samsung smartphone equipped with the Decibel X application.

The application was calibrated against a professional Type-2 sound level meter before the fieldwork to ensure that measurements remained within an acceptable margin of error of ±2 dB(A). During the data collection process, the device was held at a height of approximately 1.25–1.50 meters above the ground, with the microphone oriented toward the primary noise source. Measurements were conducted under clear sky conditions, and care was taken to ensure that wind interference did not affect the accuracy of the acoustic data. At each measurement point, to minimize fluctuations in instantaneous sound levels and obtain more reliable average values, a protocol consisting of three repetitions with a 2-minute continuous measurement and a 1-minute interval was followed; for each measurement, the A-weighted equivalent noise level (Leq), maximum (Lmax), and minimum (Lmin) values were recorded.

2.2.2. Statistical analysis

All collected data were imported into SPSS software for statistical analysis. A One-Way Analysis of Variance (ANOVA) was conducted to determine whether there was a significant difference in the mean Leq values among the noise measurement points. Additionally, a one-sample t-test was used to compare noise levels across the campus with the 55 dB(A) threshold specified in the Regulation on the Assessment and Management of Environmental Noise (Ministry of Environment, Urbanization and Climate Change, 2022).

2.2.3. Spatial analysis and temporal variation

Geographic Information System (GIS) software was used to determine the spatial distribution of noise levels. The measurement data was imported into the ArcGIS environment and processed using the Inverse Distance Weighted (IDW) interpolation method. The IDW method estimates values based on the distance between measurement points and assigns greater weight to nearby points. Based on the geoprocessing history, the analysis was executed with an output cell size of 2, a power value of 2.5, and a variable search radius encompassing 18 nearest measurement points. The spatial analysis was conducted within the TUREF / EPSG: 5254 (TM30) coordinate system. The generated IDW surfaces are intended to represent the spatial trends and high-intensity noise hotspots across the campus. These maps serve as indicative models of the campus's acoustic environment, providing a scientific basis for identifying priority areas for noise mitigation.

A “Difference (Minus)” analysis was applied to determine the temporal variation of noise pollution on campus throughout the day. In this context, a difference map was obtained by subtracting the morning equivalent noise level (Morning Leq) layer from the afternoon equivalent noise level (Afternoon Leq) layer on a pixel-by-pixel basis. This analysis was used as a key indicator to identify priority areas where noise levels increase the most, aiding in the planning of landscape interventions and traffic restrictions.

2.2.4. Population exposure modeling

To model the population capacity affected by noise across the campus, the “AllRoofs_campus_join_union” dataset, which includes the physical and functional attributes of buildings, was used. The population exposure analysis was conducted using the approach defined in the literature as “Volumetric Dasymetric Mapping.” A population density model was developed based on the “PURPOSE_OF_USE” and “TOTAL_AREA” columns in this dataset, which define the intended uses of buildings and their total floor areas, respectively. In the ArcGIS Pro (Esri, 2024a) environment, the “EST_POP” (Estimated Population) parameter, representing the estimated population value for each building polygon, was calculated using the “Calculate Field” tool based on these attribute data. These numerical data were visualized using the “Graduated Symbols” method. This allowed for the creation of a spatial synthesis,

with potential human exposure in areas of highest noise levels represented in the legend by the classes "Low," "Medium," and "High Density."

2.2.5. Design of a web-based noise pollution platform

At this stage, a digital infrastructure has been established to present campus noise data and collect future complaints. IDW maps generated in ArcGIS Pro (Esri, 2024a) have been uploaded to the ArcGIS Online cloud server for web-based access. A form structure has been designed in ArcGIS Survey123 (Esri, 2024c) to allow students to report noise. This form is designed to include features such as location marking (GPS), noise type selection, and the ability to upload photos as evidence. All maps and the reporting form have been integrated into ArcGIS StoryMaps (Esri, 2024b), which offers a user-friendly interface, to create the "Noise Reporting and Monitoring Portal."

3. Results / Findings

In the study, Leq (dB(A)) noise level data collected during the morning (8:00 a.m.–12:00 p.m.) and afternoon (1:00 p.m.–6:00 p.m.) periods were analyzed by comparing them to the theoretical threshold value of 55 dB(A). For this purpose, a "one-sample t-test" was applied separately for each time period. This test was conducted to determine whether the measured noise levels showed a statistically significant difference from the regulatory limit of 55 dB(A). The analysis revealed that the average noise level during the morning period $(M = 50.94, SD = 5.53)$ was statistically significantly lower than the 55 dB(A) threshold $[t(17) = -3.119, p = .006]$. In contrast, no statistically significant difference was found between the average noise level obtained during the afternoon period and the 55 dB(A) threshold $[t(17) = -0.399, p = .695]$.

Table 2

Results of the One-Sample T-Test for Morning Hours

One-Sample Test

	Test Value = 55						
			Significance		Mean	95% Confidence Interval of the Difference	
	t	df	One-Sided p	Two-Sided p	Difference	Lower	Upper
GÜNDÜZ Leq (8-12)	-3,119	17	,003	,006	-4,0630	-6,811	-1,315

Table 3

Results of the One-Sample T-Test for Afternoon Hours

One-Sample Test

	Test Value = 55						
			Significance		Mean	95% Confidence Interval of the Difference	
	t	df	One-Sided p	Two-Sided p	Difference	Lower	Upper
AKŞAM Leq (13.00-18.00)	-,399	17	,347	,695	-,4650	-2,923	1,993

A one-way analysis of variance (one-way ANOVA) was conducted to determine whether there was a statistically significant difference in the mean Leq values among the noise measurement points.

A statistically significant difference was found in the Leq (dB(A)) noise levels measured in the morning ($F(17, 51) = 4.668$, $p < .001$).

Similarly, a statistically significant difference was also found between the Leq (dB(A)) noise levels measured in the afternoon ($F(17, 51) = 2.996$, $p = .001$).

When evaluated at the 5% significance level ($p < 0.05$), these p-values indicate that there is a statistically significant difference in average noise levels between at least one pair of groups.

According to the results of the post-hoc Waller-Duncan test following the ANOVA, the measurement points were grouped into distinct homogeneous subsets. During the morning period, measurement points L8, L4, L6, and L7 formed a homogeneous subset characterized by lower Leq values, and were not statistically significantly different from one another. In contrast, measurement points Location No.1 (Sport Sciences Faculties Stop) and Location No.11 (Ring Road No. 2) formed a distinct subset

with the highest noise levels, significantly differentiating them from the other groups. During the afternoon period, measurement points L8, L13, L7, L6, and L17 exhibited similar lower Leq values, while L1 and L11 once again emerged as a significantly different subset due to their elevated noise levels.

Table 4

Results of the One-Way Analysis of Variance (ANOVA) for Morning Hours

ANOVA

GÜNDÜZ Leq

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2019,752	17	118,809	4,668	<,001
Within Groups	1297,992	51	25,451		
Total	3317,744	68			

Table 5

Results of the One-Way Analysis of Variance (ANOVA) for Afternoon Hours

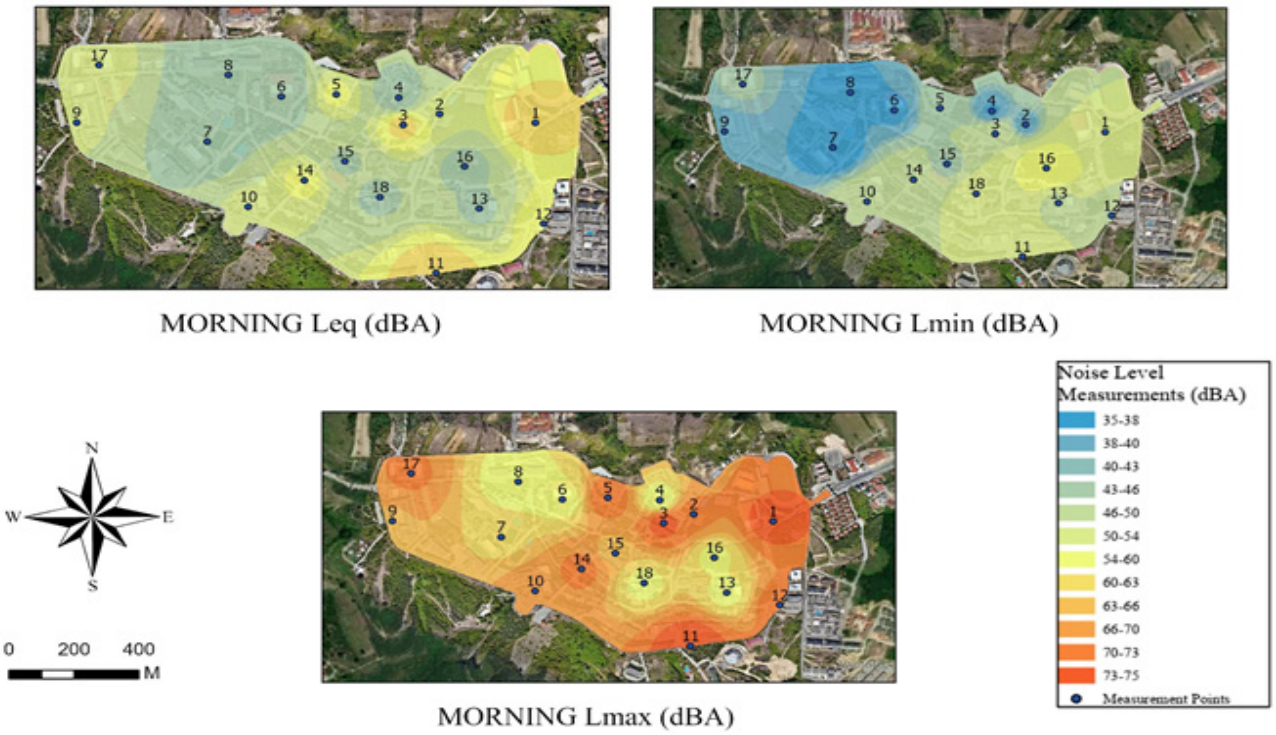
ANOVA

AKŞAM Leq

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1609,152	17	94,656	2,996	,001
Within Groups	1611,156	51	31,591		
Total	3220,309	68			

Figure 2

Noise Measurement Maps of Sakarya University's Esentepe Campus



The morning equivalent noise level map highlights areas with particularly heavy vehicle and pedestrian traffic. Measurements revealed that the area around Location No.1 (Sport Sciences Faculties Stop) and the campus entrances and exits had the highest Leq values due to heavy pedestrian and vehicle traffic. Similarly, the constant vehicle movement and minibus routes at Location No. 3 (Ring Road No. 1, Stop 2) contribute to an elevated average noise level. In Location No. 5 (Campus Square) within the campus (ATMs, cafes, photocopy services, etc.), constant conversation and machine noise resulting from commercial and social activities are increasing the average noise level. In the Location No.17 (Laboratories), construction work generates high noise levels in the morning, which is one of the factors raising the area's Leq value. Additionally, the proximity of Location No. 9 (Faculty of Theology) to public transportation stops, combined with the high concentration of students at the minibus stops, has contributed significantly to noise levels at these points. Heavy vehicle traffic and the increase in the number of motorcycles along Location No. 11 (Ring Road No. 2) are another factor contributing to high Leq values during the morning hours.

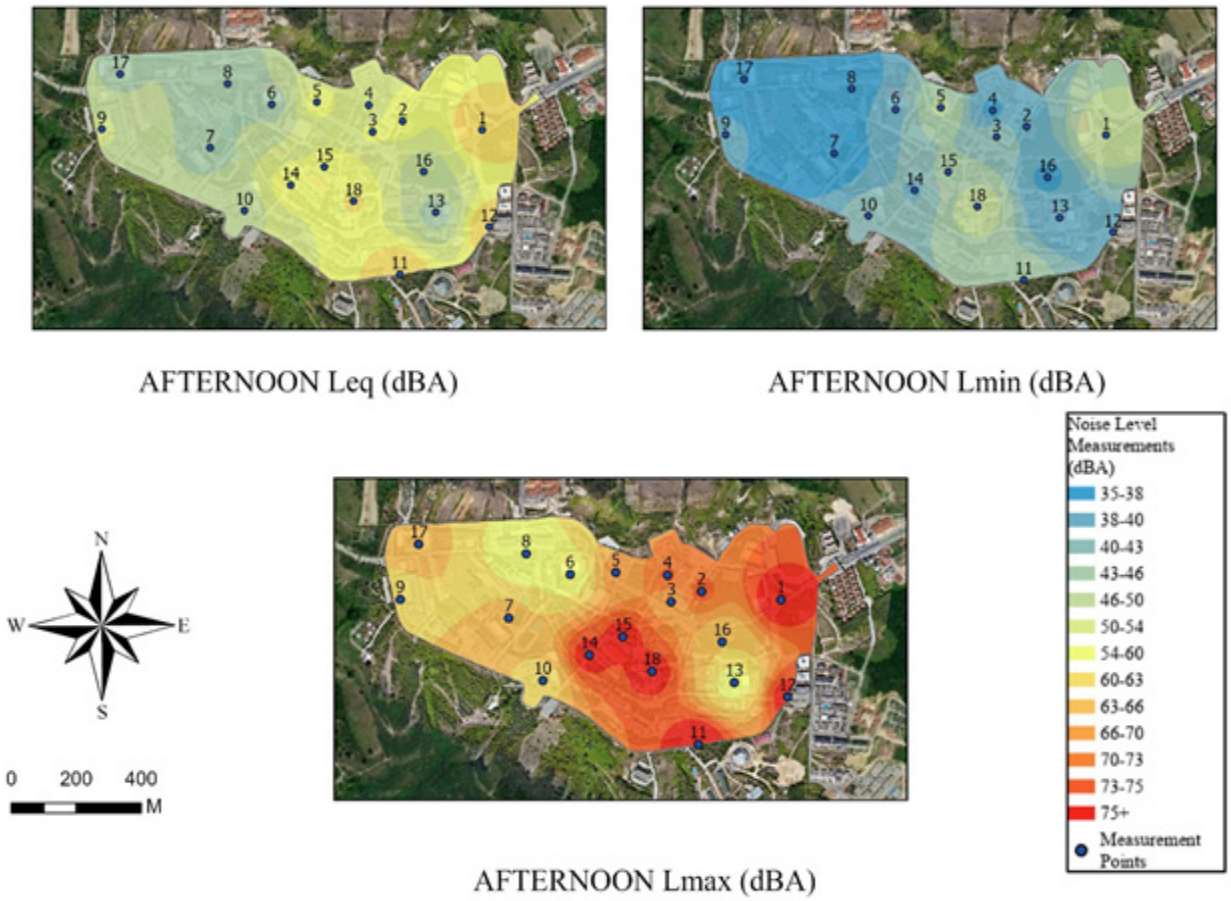
At the parking lot located on the uphill slope of Location No. 14 (Faculty of Engineering (M2, M3, M4)), significant noise was observed as a result of morning vehicle traffic. In summary, at these points where there is heavy vehicle traffic and human activity, Leq values during the morning period exceeded typical street noise levels.

The lowest sound levels on the morning minimum noise map were recorded in areas distant from vehicle traffic and large crowds. In particular, the vicinity of Location No. 8 (Faculty of Science), the area of Location No. 6 (Central Cafeteria), Location No. 7 (Faculty of Civil Engineering and Sports Fields Area), the vicinity of Location No. 4 (Campus Mosque), and Location No. 2 (Faculty of Humanities and Social Sciences, Building A) have shown the lowest Leq values. The noise levels measured in these areas consist largely of natural sounds (wind, bird, and animal sounds). In Location No. 17 (Laboratories), although ongoing work and machinery generate some noise, these levels are lower compared to other areas. In contrast, a relative noise level is observed even at the campus entrance and exit points and in the eastern sections of Location No. 3 (Ring Road No. 1, Stop 2), as vehicle traffic sounds from a distance can reach these areas. At Location No. 16 (Forested Area) and in green spaces, vehicle sounds are heard alongside bird and other natural sounds; however, without road noise, the natural background sound in these areas is generally much lower. For example, in such natural environments, daytime measurements can drop below 40 dB(A) during the quietest periods

The maximum noise map showed a distribution similar to that of the average map, but the peak levels highlighted the areas with the highest noise levels more clearly. The highest noise levels in the morning were again measured around campus entrances and exits, Location No. 3 (Ring Road No. 1, Stop 2), Location No. 5 (Campus Square) (near ATMs and cafes), and Location No. 17 (Laboratories). Additionally, continuous vehicle traffic along Location 11 (Ring Road No. 2) stood out in terms of maximum noise levels. Sudden, high-intensity noise spikes were observed during the morning hours when vehicle traffic was particularly heavy at these points. At these locations, identified as the noisiest points in the morning, both continuous vehicle noise and momentary high-intensity noise sources produced values significantly above average levels.

Figure 3

Maps of Afternoon Noise Measurements at Sakarya University's Esentepe Campus



According to measurements taken in the afternoon, the highest values on the average (Leq) noise map were again recorded at the campus entrances and exits. In addition, it was observed that Leq values increased along Location No. 11 (Ring Road No. 2) and around Location No. 18 (The Rectorate) compared to daytime levels. The open seating area next to Location No. 15 (Library) was particularly notable: the noise generated by students gathering after classes in the afternoon—resulting from conversation and movement—significantly raises Leq levels in this area. The combination of multiple people speaking and the movement of nearby vehicles contributes to an increase in the average sound level. Location No. 14 (Faculty of Engineering (M2, M3, M4)) also shows increased activity in the afternoon on the exit road: as students head toward the final stop and afternoon traffic intensifies, vehicles leaving the campus make this area noisier than in the morning. As a result, the afternoon Leq map reveals higher noise levels in the entrance/exit area, ring roads, and the campus center, where dense student populations and afternoon traffic converge.

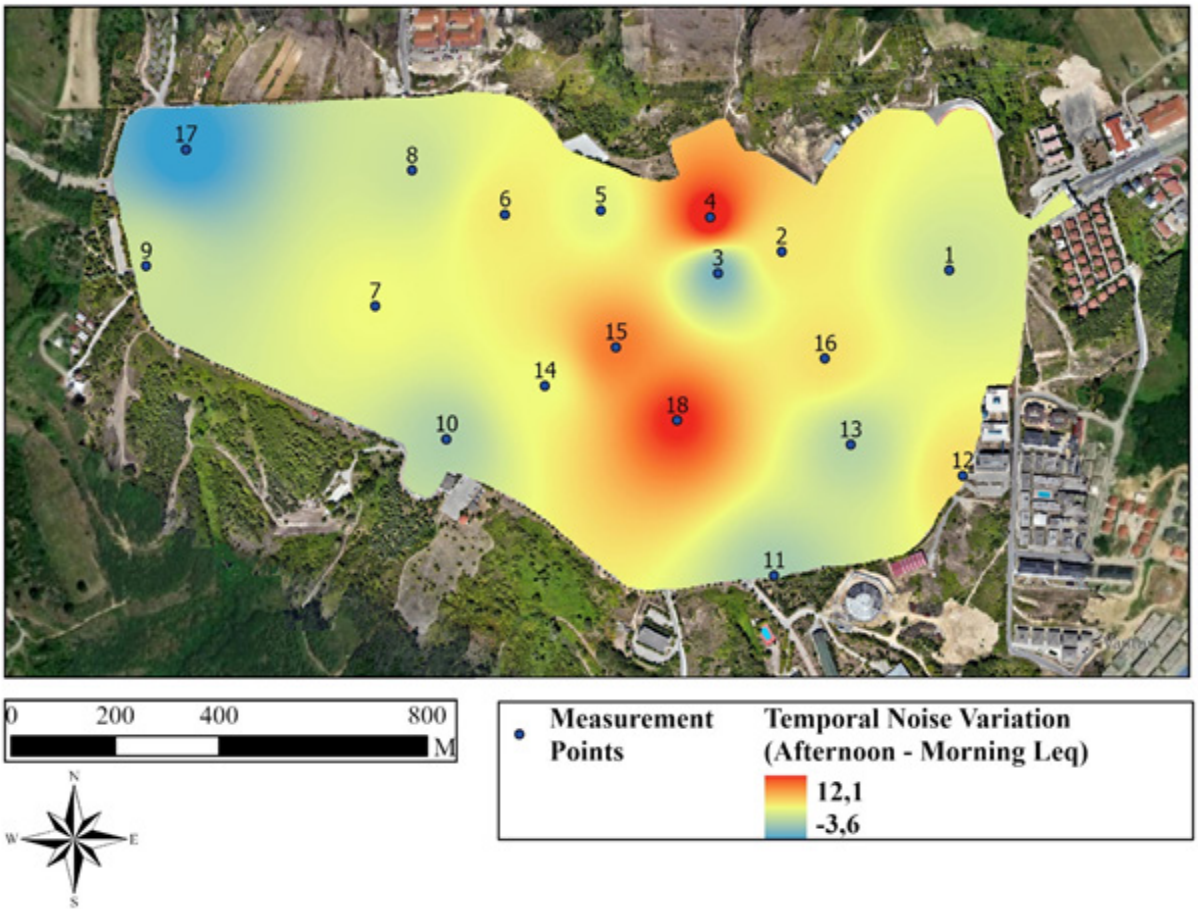
The distribution of quiet areas with minimum noise levels in the afternoon is similar to that in the morning: the vicinity of Location No. 8 (Faculty of Science), Location No. 7 (Faculty of Civil Engineering and Sports Fields Area), Location No. 4 (Campus Mosque), and the area around Location No. 2 (Faculty of Humanities and Social Sciences, Building A) have the lowest Lmin values. The difference is that during afternoon minimums, student activity now takes precedence over vehicle noise. At Location 15 (Library) and Location 5 (Campus Market) (ATM areas, etc.), the increased student traffic following the end of classes raises the low-level sound levels by a few decibels, primarily due to social activity rather than the sounds of cleaning vehicles in the morning.

The maximum noise map for the afternoon period shows that the highest noise levels are found around Location No. 18 (Rectorate), along the route from Location No. 14 (Faculty of Engineering (M2, M3, M4)), the entrance and exit area of Location No. 15 (Library), and the vicinity of Location No.

11 (Ring Road No. 2). The maximum values measured in these areas reached 75 dB(A) and above. The primary causes of these high levels are the increased vehicle traffic in the afternoon and the gathering of student groups after classes. In particular, the sudden noise spikes measured at points near the campus exit and around Location No. 18 (The Rectorate) are attributed to the sounds of numerous vehicle horns or engines, combined with the noise from students speaking in groups. In crowded environments, the combination of conversations and ambient outdoor sounds causes Leq values to rise rapidly; for example, the cumulative effect of just a few people speaking simultaneously can exceed 70 dB(A). Therefore, the coexistence of traffic-related noise and social interaction sounds in the areas highlighted on the afternoon maximum map leads to measurements of 75 dB(A) and above. As generally observed, along Location No. 11 (Ring Road No. 2), vehicles increase their engine RPM due to a slight incline. This situation, particularly at Location No. 12 (TEKNOKENT) and on the uphill slope leading to Location No. 14 (Faculty of Engineering (M2, M3, M4)), has further increased the Leq values in these areas. In addition, the heavy student motorcycle traffic on campus, along with heavy vehicles such as tractors used from time to time for maintenance and landscaping work, contribute to a significant increase in measured noise levels.

Figure 4

Temporal Variation in Noise Levels (Afternoon Leq–Morning Leq)



The Minus map (Afternoon Leq – Morning Leq), which illustrates the difference in noise levels between morning and afternoon, clearly shows the spatial shift in the campus's noise characteristics due to temporal variation. Upon examining the map, it is observed that the areas with the highest positive difference (noise increase) are concentrated in the center of the campus and exhibit a pattern of increase radiating outward from the center.

In particular, the areas surrounding Location No. 18 (Rector's Office) and Location No. 15 (Library) were identified as "hotspots" where noise levels rise the most, with an increase of approximately 12 dB(A) in the afternoon compared to the morning. Similarly, a noticeable increase in noise was observed in the vicinity of Location No. 4 (Campus Mosque) during the afternoon hours. These increases are assessed to be related to the concentration of social activity and vehicle traffic in these areas as the day progresses.

In contrast, negative values (blue areas) were identified around Location No. 17 (Laboratories) in the northwestern part of the map. This situation can be attributed to the decrease in noise levels in the afternoon caused by construction and technical work, which is prevalent in the morning. A slight decrease in noise levels was also observed in the vicinity of Location No. 3 (Ring Road No. 1, Stop 2) in the afternoon compared to the morning.

In conclusion, the Minus map indicates that locations 15, 18, and 4 are the priority areas in terms of landscape interventions and noise barrier.

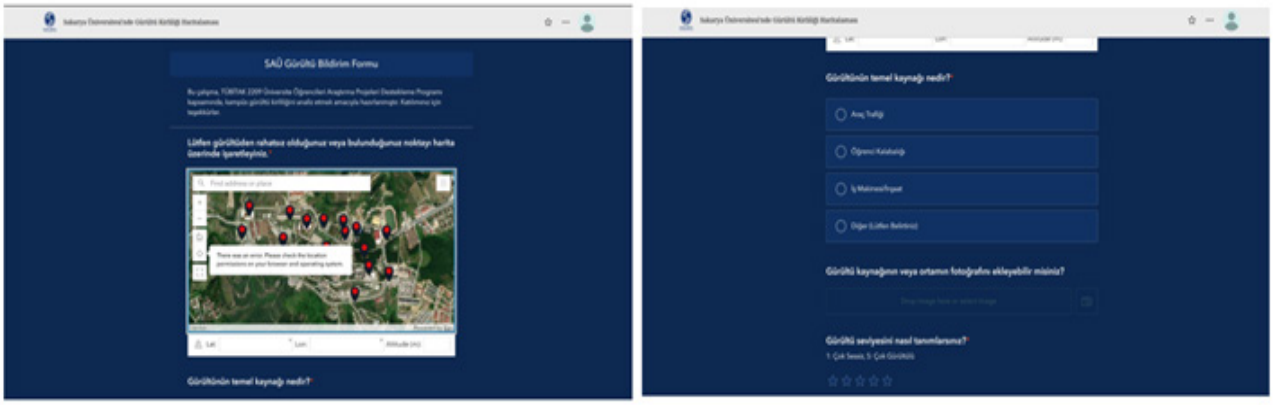
Figure 5

General Interface of the Designed Web-Based Campus Noise Reporting and Monitoring Portal

As shown in Figure 5, the portal has been developed to allow campus residents to view noise pollution maps interactively. Users can click on any point on the map to view the noise levels (Leq, Lmin, Lmax) in that area.

Figure 6

ArcGIS Survey123-Based Noise Report Form and Digital Complaint Workflow Interface



The noise reporting module, which forms the participant management component of the platform, has been made operational through integration with ArcGIS Survey123 (Esri, 2024c).

The interface shown in Figure 6 allows students to mark the location where they are disturbed by noise on a map using GPS, select the noise source (vehicle, construction, crowd, etc.), and document their complaints with visual evidence (photos). The combination of the system's "Report" and "Monitoring" functions provides an infrastructure that ensures the protection of quiet study areas on campus and enables rapid intervention by spatially tracking noise-related complaints.

4. Discussion and Conclusion

In this study, a GIS-based noise map was created using Leq (dB(A)) data collected at 18 predefined measurement points on the Sakarya University Esentepe Campus. The spatial analysis revealed that the lowest noise level, 35.3 dB(A), was recorded around Location No. 7 (Faculty of Civil Engineering and Sports Fields Area), while the highest value, 77.3 dB(A), was detected at Location No. 11 (Ring Road No. 2), a point exposed to heavy vehicle traffic.

When these findings are evaluated in the context of the existing literature, the average morning

noise level of 50.94 dB(A) indicates that Sakarya University has a relatively quieter general acoustic environment compared to other campus studies in Türkiye. For instance, average noise levels were reported as 62.70 dB(A) at Atatürk University (Özer et al., 2014) and 76 dB(A) at Süleyman Demirel University (Morova et al., 2010). However, the peak values reaching 77.3 dB(A) at traffic hotspots within the Sakarya University campus closely align with the traffic-induced noise problems observed at Ordu University (Yeşil & Güzel, 2023). This comparison demonstrates that while the natural and isolated areas of the campus successfully maintain an acceptable acoustic baseline, localized traffic corridors and social hubs experience significant acoustic pressure that requires immediate spatial mitigation.

These findings clearly illustrate the spatial distribution of noise pollution across the campus and provide a solid foundation for ongoing intervention recommendations. One of the most innovative outcomes of the study is the transformation of these technical data into an interactive "Noise Reporting and Monitoring Portal" via the ArcGIS StoryMaps (Esri, 2024b) and Survey123 platforms. This digital infrastructure has established a participatory decision-support mechanism in campus management by enabling students to track noise hotspots and directly submit their complaints to the administration with photographic evidence.

The results of the study indicate that a combination of natural and technological measures is necessary in the noisy areas of the campus. First, along Location No. 11 (Ring Road No. 2) and other major transportation routes, densely planted green belts composed of sound-absorbing plants should be established to provide both visual appeal and functionality. Species such as Cupressus macrocarpa, known for its dense foliage and upright form; *Philadelphus coronarius*, which enhances aesthetics with its shrub-like form; and *Rhododendron ponticum*, with its thick leaves, will both prevent the spread of noise within the campus and strengthen the landscape's integrity.

The parking area located at the end of the slope leading to Location No. 14 (Faculty of Engineering (M2, M3, M4)), near the Office of International Relations (Erasmus–Mevlâna Office), has been identified as a critical point where vehicle traffic increases, leading to a concentration of noise from cars and motorcycles. Therefore, it is recommended that this parking lot be phased out and replaced with a pedestrian-priority corridor, while vehicle parking needs be redirected to a central parking area on the lower level of the campus. While the existing slope route will remain open only to electric service vehicles and emergency vehicles, prohibiting access to all other motorized vehicles—particularly motorcycles—will significantly reduce noise levels. Additionally, a green screen created with dense-leaved shrubbery along both sides of this corridor will both enhance sound insulation and provide an aesthetically pleasing setting for pedestrian traffic. A 20 km/h speed limit, implemented to prevent vehicles from accelerating due to the slope, along with low-profile speed bumps integrated into the surface, will also help minimize engine noise and tire noise.

The area around Location No. 2 (Faculty of Humanities and Social Sciences, Building A), located behind the structure at Location No. 4 (Campus Mosque), offers an extremely quiet environment in the range of 35–40 dB(A) during times when the call to prayer is not being recited; however, during call to prayer times, short-lived but noticeable noise spikes occur due to speaker direction and high sound levels. To minimize the negative impact of this noise on concentration during faculty events and academic work, acoustic panels and double-glazed windows installed on the exterior walls of the faculty building can reduce incoming sound waves by up to 15–20 dB(A). From a landscaping perspective, planting a row of dense-leaved trees and shrubs (such as *Ligustrum japonicum* or *Photinia × fraseri*) along the corridor between the mosque and the faculty building can create a natural sound barrier while also enhancing the visual quality of the space.

Implementing vehicle entry and exit regulations on campus—limiting all vehicle traffic to specific time slots and enforcing a 20 km/h speed limit on campus roads—is an effective method. In particular, to reduce congestion during weekday class start and end times, priority can be given to electric shuttle buses and other quiet vehicles entering the campus. During peak hours for traditional motor vehicles, particularly on days with heavy academic activity, vehicle access can be restricted without granting any entry or exit permits to minimize noise pollution; speed-controlled zones should utilize speed bumps and additional traffic signs to ensure pedestrian and vehicle safety. Relocating the existing open seating area around Location No. 15 (LIBRARY) to a spot slightly farther from the library building will improve the quality of study and relaxation. Additionally, planting dense green screens and tree belts

around the library structure to dampen noise from traffic and student movement will provide a quiet reading environment while also contributing to the visual enrichment of the area.

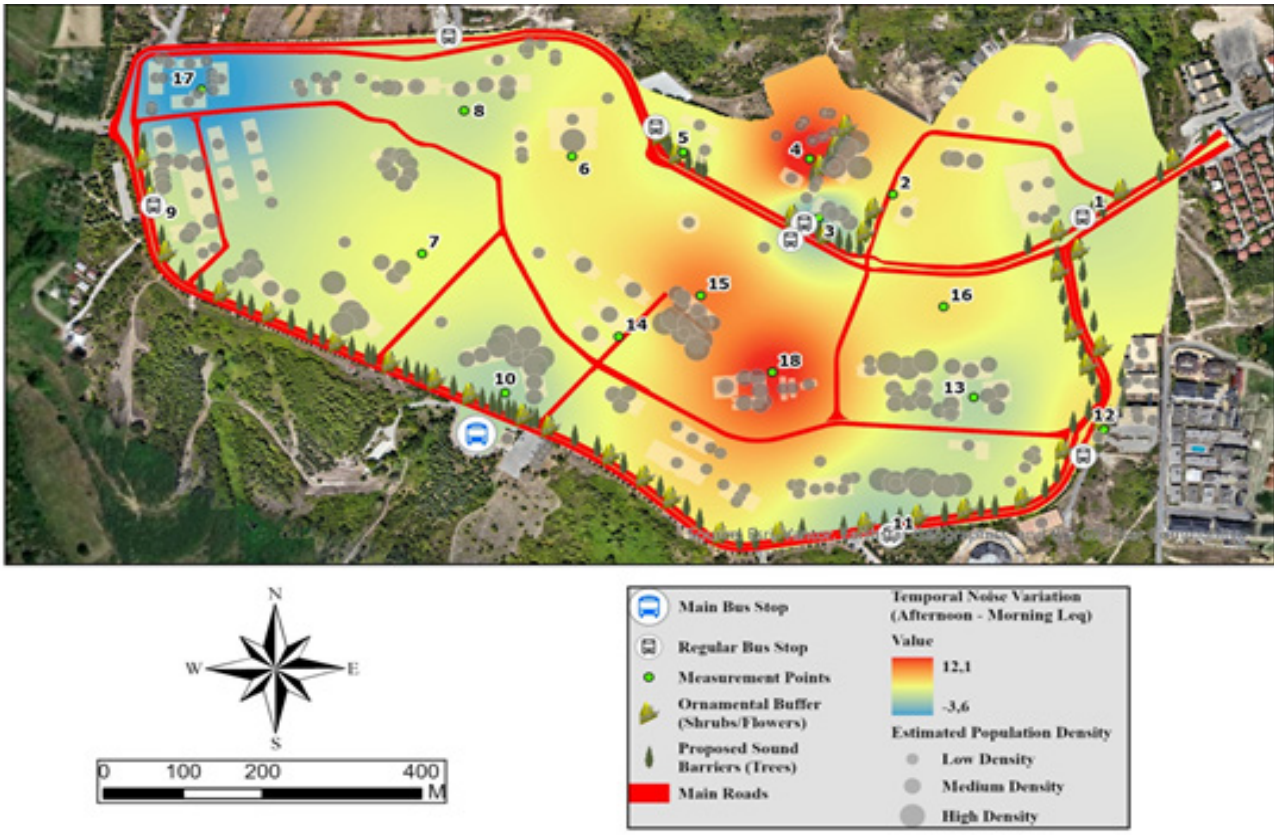
As a result, landscape design reinforced with vegetative barriers, combined with time-controlled and speed-limited traffic regulations and spatial revisions around the library, will enable the effective transformation of high-noise zones identified in the campus noise maps. This holistic approach will both enhance the comfort of students and staff and provide an implementation model aligned with the vision of a sustainable campus. Additionally, since the current concentration of social spaces (cafeteria, rest areas, etc.) in the eastern part of the campus disrupts the noise balance, new socialization and relaxation points should be created in the quiet green areas on the western side. This will not only reduce the pressure in noisy areas but also ensure that existing rest areas and zones where students spend a significant amount of time are distributed evenly across the campus, thereby eliminating the concentration of noise and crowds in a single location. As a result, it will be possible to balance the campus's internal acoustics and encourage users to gravitate toward different, quieter areas.

The Synthesis Map in Figure 7, which translates the study's technical data into a spatial framework, models not only the level of noise pollution but also its potential impact on campus users. Population capacity modeling, conducted based on the physical areas and functional attributes of the buildings, has clearly revealed the human density in the areas where noise levels are highest.

The analysis revealed that this central axis—comprising buildings with the highest user traffic on campus, such as the library, the rector's office, and the engineering faculties—is exposed to a general accumulation of noise. Although the library building itself is not directly adjacent to the bus stops, vehicle emissions from the surrounding Main Bus Stop and ring roads, combined with the population density in the area, create acoustic pressure. Due to this spatial overlap, intensive green screening and vegetative barriers were selected around the building to insulate the library's quiet study environment from this general noise load originating from the external surroundings. Thus, a planning model prioritizing user comfort was developed not only at the noise source but also in these sensitive areas where the population is most concentrated.

Figure 7

Spatial Synthesis Map: Overlay of Temporal Noise Variation, Population Density, and Transportation Hubs



Article Information Form

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References

Büke, C. O. (2016). *Coğrafi bilgi sistemleri tabanlı ağ analizi ve 4 boyutlu bir uygulama: Sakarya Üniversitesi Esentepe Kampüsü (SAUBİS) örneği* [Yüksek lisans tezi, Sakarya Üniversitesi]. Kurumsal Arşiv. https://acikerisim.sakarya.edu.tr/handle/20.500.12619/91277

Dönmez, S., Dölgen, D., Bozkurt, Z., Kınay, E. H., & Alpaslan, M. N. (2023). Karayolu ulaşımından kaynaklanan çevresel gürültünün SoundPLAN ile haritalandırması: DEU Tınaztepe kampüsü örneği. *Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi, 25*(74), 451-466. https://doi.org/10.21205/deufmd.2023257415

Egbenta, I. R., Elugwaraonu, N. F., Ndukwu, R. I., & Okosun, A. E. (2024). Analysis of noise pollution level in Enugu campus, of the University of Nigeria. *SAGE Open, 14*(2). https://doi.org/10.1177/21582440241254910

Erdoğan, S., Doğan, M., Yılmaz, İ., Güllü, M., Baybura, T., Ulu, M., & Şişe, Ö. (2007). Afyonkarahisar il merkezi karayolu trafik gürültü haritasının hazırlanması. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 7*(2), 151-164. https://izlik.org/JA26CB65ZW

Esri. (2024a). *ArcGIS Pro* (Version 3.x) [Computer software]. Environmental Systems Research Institute. https://www.esri.com

Esri. (2024b). *ArcGIS StoryMaps* [Computer software]. Environmental Systems Research Institute. https://storymaps.arcgis.com

Esri. (2024c). *ArcGIS Survey123* [Computer software]. Environmental Systems Research Institute. https://survey123.arcgis.com

International Organization for Standardization. (2003). *Acoustics—Description, measurement and assessment of environmental noise* (ISO Standard No. 1996-1:2003).

Kalıpçı, E. (2017). Avanos ilçe merkezinde trafik kaynaklı gürültü kirliliğinin mekansal analizi. *Nevşehir Bilim ve Teknoloji Dergisi, 6*(1), 20-29. https://doi.org/10.17100/nevbiltek.309489

Kayan, A. (2018). Kentleşme sorunları kapsamında Şanlıurfa'nın çevre sorunları ve çözüm önerileri. *Yönetim Bilimleri Dergisi, 16*(32), 299-328. https://izlik.org/JA64EZ88FT

Maguire, D. J. (1991). An overview and definition of GIS. In D. J. Maguire, M. F. Goodchild, & D. W. Rhind (Eds.), *Geographical information systems: Principles and applications* (Vol. 1, pp. 9-20). Wiley.

Ministry of Environment, Urbanization and Climate Change. (2022). *Çevresel gürültü kontrol yönetmeliği*. T.C. Resmî Gazete, 30 Kasım 2022, Sayı 32029. https://www.resmigazete.gov.tr/eskiler/2022/11/20221130-1.htm

Ministry of Environment, Urbanization and Climate Change. (2023). *Çevresel gürültü ölçüm ve değerlendirme kılavuzu* [Environmental noise measurement and evaluation guide].

Morova, N., Şener, E., Terzi, S., Beyhan, M., & Harman, B. (2010). Süleyman Demirel Üniversitesi yerleşkesinin gürültü haritalarının coğrafi bilgi sistemleri ile hazırlanması. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 14*(3), 271-278.

Murphy, E., & King, E. A. (2016). Testing the accuracy of smartphones and sound level meter applications for measuring environmental noise. *Applied Acoustics, 106*, 16-22. https://doi.org/10.1016/j.apacoust.2015.12.012

Onay, B., & Şahin, C. (2022). Isparta kent merkezindeki eğitim kurumları ve çevrelerindeki gürültülerin analizi üzerine bir araştırma. *Turkish Journal of Forest Science, 6*(2), 457-479. https://doi.org/10.32328/turkjforsci.1131300

Onay, B., Solak, E. B., Sava, B., & Şahin, C. (2024). Afyon Kocatepe Üniversitesi merkez yerleşkesindeki gürültünün değerlendirilmesi üzerine bir araştırma. *Turkish Journal of Applied Sciences and Technology, 5*(1), 1-11. https://izlik.org/JA83KH47XH

Öner, İ., & Sesli, F. A. (2018). İmar planlarının trafik gürültü değerlerinin etkisi açısından incelenmesi: Samsun Atakum bölgesi örneği. *Kent Akademisi, 11*(3), 390-404. https://izlik.org/JA25KU68NA

Özer, S. (2014). Erzurum kent parklarındaki gürültü kirliliğinin belirlenmesi: Aziziye parkı örneğinde. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi, 11*(2), 7-11. https://izlik.org/JA46CR92DR

Özer, S., Zengin, M., & Yılmaz, H. (2014). Determination of the noise pollution on university (education) campuses: A case study of Ataturk University. *Ekoloji, 23*, 49-54.

World Health Organization. (2009). *Night noise guidelines for Europe*. World Health Organization Regional Office for Europe.

World Health Organization. (2011). *Noise*. World Health Organization Regional Office for Europe. https://www.who.int/europe/news-room/fact-sheets/item/noise

Yeşil, M., & Güzel, M. (2023). Üniversite yerleşkelerinde gürültü kirliliğinin ölçülmesi: Ordu Üniversitesi Cumhuriyet yerleşkesi örneği. *Kent Akademisi, 16*(1), 1173987. https://doi.org/10.35674/kent.1173987