



JIGE 7 (2) (2026) 1961-1970

JURNAL ILMIAH GLOBAL EDUCATION

ejournal.nusantaraglobal.ac.id/index.php/jige

DOI: <https://doi.org/10.55681/jige.v7i2.5558>

The Effect of Train Noise on Comfort Perception and Adaptive Behavior of Urban Café Visitors

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Article Info

Article history:

Received April 25, 2026

Approved May 24, 2026

Keywords:

Acoustics, Cafe, Train, Behavior

ABSTRACT

Cafes located near railway lines face the challenge of environmental disturbances that can potentially affect the comfort and behavior of users. This study aims to analyze the influence of disturbance levels on the comfort perceptions and adaptive behavior of cafe visitors and employees. The study was conducted at a café in South Jakarta, approximately 40 meters from an active railway line. The research method used a quantitative, descriptive, explanatory approach through field disturbance measurements using a sound level meter and a Likert-based user perception survey. The study showed that disturbance levels in the outdoor area of the café consistently met the recommended comfort threshold, while the indoor area experienced a decrease in sound intensity but remained in the moderate category. However, visitors' perceptions of discomfort remained at low to moderate levels, accompanied by the emergence of adaptive behaviors such as selecting seating areas, adjusting speaking volume, and tolerating short disturbance durations. These findings indicate that train disturbances influence user comfort and behavior, but these effects are moderated by the spatial context and individual adaptability. This research has important implications for cafe design in areas exposed to rail transportation disturbances.

for café design in areas with exposure to rail transportation noise.

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How to cite: Supriyadi, L. A.-Q., & Puspitasari, P. (2026). The Effect of Train Noise on Comfort Perception and Adaptive Behavior of Urban Café Visitors. *Jurnal Ilmiah Global Education*, 7(2), 1961–1970. <https://doi.org/10.55681/jige.v7i2.5558>

INTRODUCTION

The development of urban areas is characterized by the intensity of economic activity, population mobility and the use of very high public transportation (Surya et al., 2020). This development encourages the closeness between commercial space and transportation infrastructure, after the COVID-19 pandemic, the work patterns of urban communities have undergone a significant shift, one of which is through the increasing phenomenon of *work from café* (WFC). The café functions as a multifunctional public space that supports social and work activities. This condition demands an adequate level of environmental comfort, especially acoustic comfort, as an important factor in determining the user experience.

On the other hand, many cafes in Jakarta are thriving in strategic locations adjacent to public transportation routes, including railway lines. The café's proximity to the railway line provides the advantage of accessibility but the café located near the railway line faces exposure to train noise that is impulsive and repetitive with an intensity that has the potential to disrupt communication, concentration and psychological comfort. The noise generated by trains comes from engine noises, horns and wheel and rail friction, the intensity of which can exceed 80 dB. Various international guidelines, the World Health Organization (WHO) affirm that environmental noise above the threshold limit can reduce the quality of life and comfort of human activities.

Previous research on environmental noise due to rail transportation has developed rapidly in the last two decades, especially in terms of human health and comfort. Internationally reputable studies indexed by Scopus show that train noise not only affects acoustic noise but also has a significant impact on other aspects such as psychological aspects and behavior of space users. Basner et al. (2014) and McGuire (2018) emphasized that repetitive rail transportation noise is associated with increased stress, concentration disorders and serious illnesses. In line with this, research conducted by Foraster et al. (2024) strengthens the evidence that train noise has long-term health implications, especially in urban environments with high crossing intensity. From the technical side, Calleri et al. (2023) showed that the integration of field measurements and acoustic simulations was able to validate the performance of building facades in reducing noise, while Kang et al. (2020) developed a digital technology-based noise monitoring approach to understand spatial and vertical variations in sound exposure. However, most of the research still focuses on housing or public health, relatively minimal research examines commercial public spaces.

Previous researchers generally separated between objective noise analysis and user perception studies. Some studies examined the acoustic comfort of cafes or public spaces through perception surveys and others focused on noise simulations or mapping without directly linking them to user behavioral responses. The gap in this research arises from the lack of integratives that associate measured and simulated noise data with the perception of comfort and adaptive behavior of space users.

Research on rail transportation noise in urban areas has discussed its impact on human health and comfort in the residential environment. on residential areas and their impact on public health and quality of life (Basner & McGuire, 2018; Foraster et al., 2024). A number of studies have also emphasized the importance of objective measurement of noise through acoustic parameters such as LAeq and Lmax to assess the level of noise exposure in the built environment (Calleri et al., 2023 Kang et al., 2020). However, these studies generally focused on one dimension of the analysis, both on the physical aspects of noise and the long-term health impacts, without directly linking it to the perceptual responses and behaviors of space users in the context of daily activities.

Research examining acoustic comfort in commercial public spaces, such as cafes, is still relatively limited, especially in locations directly adjacent to active rail transportation infrastructure (Yang et al., 2021). Most studies on the acoustic comfort of public spaces rely on user perception surveys without being supported by measurable noise data, so the relationship between objective acoustic conditions and the subjective user experience has not been comprehensively depicted. In addition, the dimension of user adaptive behavior as an adjustment mechanism for environmental noise is still rarely systematically analyzed within a single integrated research framework.

Based on these conditions, there is a significant research gap in the lack of an integrative approach that links measured noise data with the perception of acoustic comfort as well as the adaptive behavior of commercial public space users exposed to rail transportation noise. Therefore, this study seeks to fill this gap by integrating field noise measurement and user perception surveys to simultaneously analyze the influence of train noise on the comfort and adaptive behavior of visitors and café workers in urban environments.

The main problem of this study is how noise from railway lines affects the perception of comfort and adaptive behavior patterns of visitors and café workers. This study examined (1) the noise level in the indoor and outdoor areas of the café compared to acoustic comfort standards, (2) the difference in the perception of comfort between visitors and workers to noise exposure, and (3) the forms of adaptive behavior that emerged in response to the noise.

The novelty of this study lies in an integrative approach that combines objective noise measurement with the analysis of users' perception of comfort and adaptive behavior in cafes located near active railway lines. Different from previous studies that focused on residential areas or long-term health impacts, this study positions cafes as commercial public spaces with a high intensity of social and work activities.

By linking measurable noise data, user perception, and adaptive behavior patterns in a single analytical framework, this study makes a new empirical contribution to the study of environmental comfort. The findings of this study also strengthen the application of *the evidence-based design* approach as the basis for designing cafes in urban environments with exposure to rail transportation noise.

METHODS

Explanatory Descriptive Quantitative is the approach used in this study to examine the effect of train noise on the perception of acoustic comfort and adaptive behavior of café users. This approach was chosen because it allows the integration between objective data from noise measurement results with subjective data on perception and behavioral responses of space users, so that the relationship between variables can be analyzed systematically and measurably.

The research location is in an urban café in South Jakarta which is about 40 meters away from the active railway line. The selection of the location was carried out with consideration of the high frequency of train crossings throughout the day, which makes noise a dominant environmental factor. The subjects of the study included visitors and café workers who were on site during operating hours and had first-hand experience of exposure to train noise.

Data collection is carried out through two main methods. First, environmental noise measurement using a sound level meter to obtain sound intensity data in decibels (dB), which is carried out at several points in indoor and outdoor areas as well as at several operational time ranges to capture noise variations due to railway crossings. Second, user perception surveys use Likert scale questionnaires to measure acoustic comfort during activities, the level of noise disturbance and forms of adaptive behavior carried out by visitors and workers.

Data analysis was carried out in stages, starting with descriptive statistical analysis to describe the characteristics of noise levels, perception of comfort and adaptive behavior of users, then followed by correlation tests to identify the direction and strength of relationships between variables, as well as differences between indoor and outdoor areas to assess the influence of the physical conditions of the space on acoustic comfort. The results of the analysis were then interpreted with reference to the theory of environmental comfort and adaptive behavior, so that

the research findings have academic relevance as well as practical implications for the design of cafes in urban areas with exposure to rail transportation noise.

The study respondents consisted of visitors and café workers who had direct experience of exposure to train noise while at the research site. The sampling technique used purposive sampling with the criteria that respondents were in the café for at least 30 minutes. The comfort perception and adaptive behavior instruments were compiled using a five-point Likert scale and have met the reliability test with Cronbach's Alpha values above 0.70.

Data analysis was carried out through descriptive statistical analysis to describe the noise characteristics, perception of comfort, and adaptive behavior of the user. Furthermore, a correlation test was conducted to analyze the relationship between measured noise levels and perception of comfort and adaptive behavior, as well as a differential test to compare user responses in indoor and outdoor areas as well as between visitors and café workers.

RESULTS AND DISCUSSION

The café's location is in direct proximity to active railway lines, its spatial proximity and high frequency of crossings indicate the potential for intense and repetitive noise exposure throughout the day, especially during the morning and evening rush hour.



Figure 1. Research Location Data

(Source: Author via Google Maps, 2025)

Noise level measurement is carried out using a sound level meter (SLM) to record sound intensity in decibels as a representation of human hearing perception. Measurements were taken at 15 points representing the characteristics of the noise receiver in the café area. Points 1–4 are in the outdoor area (terrace) to record noise directly from the surrounding environment, while points 5–15 are inside the café to determine the level of sound attenuation by walls and interior elements.

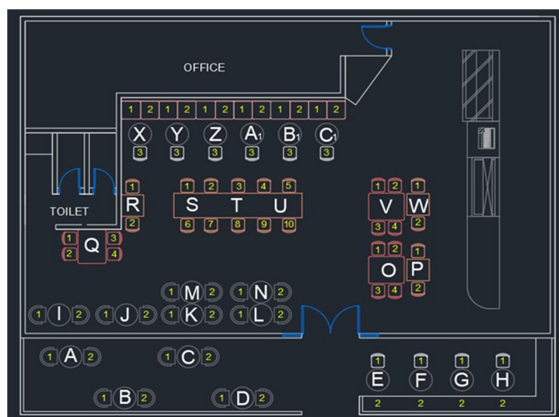


Figure 2. Cafe Building Plan

(Source: Author via Autocad, 2025)

Based on LAeq measurement data, the outdoor area of the café shows a higher noise level (85 – 88 dB(A)) compared to the indoor area (55 – 73 dB(A)). The highest outdoor value was recorded at the nearest point of the train track (up to 88 dB(A)), showing the dominance of rubber sound, especially in the afternoon and evening (12.00 – 18.00 WIB). On the other hand, indoor areas experience a noise reduction of around 20-25 dB, with the highest value near the opening and the lowest in the innermost part of the space. These results show that the average noise in the cafe section exceeds national and international standards

Table 1. Average Noise Level (LAeq) in Indoor and Outdoor Areas of Cafes

Area	LAeq Range	LAeq Letters	WHO/Ministry of Agriculture Standards	Categories
Outdoor	85 – 88	87	Inconvenient	Height
Indoor	55 – 74	64	Relatively Comfortable	Medium – High

(Source: Author's Analysis Through Data Calculation, 2025)

The highest Lmax value occurred in the outdoor area of 88.8 dB(A) and in the indoor area of 77.4 dB(A) in the afternoon period. These results show that outdoor noise has exceeded the threshold of acoustic comfort, while indoor noise despite being lower still exceeds the comfort standards of commercial spaces, so additional acoustic mitigation efforts are needed.

Table 2. Peak Noise (Lmax) by Area

Area	Lmax Morning	Lmax Noon	Lmax Sore	Lmax Night	Highest Lmax
Outdoor	86.6 dB	87.3 dB	88.8 dB	88.6 dB	88.8 dB
Indoor	72.7 dB	74.7 dB	77.4 dB	71.7 dB	74.7 dB

(Source: Author's Analysis Through Data Calculation, 2025)

The measurement results show that the noise level due to railway crossings in the café area is in the medium to high category. Outdoor areas consistently recorded noise levels that exceeded the recommended comfort threshold for commercial spaces, while indoor areas experienced a decrease in sound intensity, but were still at the noise level that could be perceived by the user. This difference indicates that physical elements of buildings play a role in reducing noise, although they have not completely eliminated exposure to outside sound.

Table 3. Noise Level Characteristics

No.	Cafe Area	Noise Level Characteristics	Categories
1.	Outdoor	High Intensity when the train passes	Inconvenient
2.	Indoor Near Openings	Medium Intensity	Quite Convenient
3.	Indoor area Dalam	Lower Intensity	Relatively Comfortable

(Source: Author's Analysis Through Data Calculation, 2025)

These findings confirm that train noise is the dominant environmental factor that shapes the acoustic conditions of cafes, especially in areas with direct exposure to sound sources. Although the measured noise level is relatively high, the survey results show that the perception of visitors' discomfort is in the low to medium category. Most respondents stated that the sound of the train was heard clearly but was not always considered to be very disruptive to activities, indoor areas were considered more comfortable than outdoor areas, especially for work and conversation activities.

Café workers show higher perception of disturbance than visitors. This is related to longer and repeated duration of noise exposure during working hours. However, both visitors and workers tend to judge that the café environment is still at the limit of comfort tolerance. These findings are in line with the theory of environmental comfort which explains that comfort is not only determined by the physical conditions of the environment but also by the subjective perception and expectations of users of the function of the space.

Table 4. Average Perception of Acoustic Comfort of Visitors

No.	Perception Indicators	Red	Categories
1.	The Sound of the Train affects the atmosphere	2.77	Medium
2.	Noise Reduces Comfort	2.90	Medium
3.	Indoor area feels more comfortable	3.56	Height
4.	Noisy Outdoor Area	3.46	Medium

(Source: Author's Analysis Through Data Calculation, 2025)

Adaptive behavior in this study is understood as a conscious or unconscious response carried out by individuals to maintain comfort and continuity of activities when faced with exposure to train noise. The results of the study show the emergence of adaptive behavior in response to train noise. In general, visitors prefer passive adaptation strategies, such as moving to an indoor area or adjusting the volume of talk, while café workers show functional adaptation, especially to maintain smooth communication and service.

The results of the analysis showed that the adaptive behavior of visitors was dominated by social and spatial adjustments, while physical adaptations were carried out at a lower frequency. This shows that visitors still tolerate noise within a certain limit and tend to adjust to the condition of the available space. The results of the data show that adaptive behaviors that are often carried out such as increasing the volume of speech when the train passes, using earphones or earplugs and moving to a quieter place (indoor). These results indicate that adaptive behavior is not extreme. Visitors rarely show a strong desire to leave the café, which signifies that despite the perceived noise, the overall experience of the space is still acceptable. The preference to move

to indoor areas is the main strategy because these areas are considered to be more able to reduce noise pollution.



Figure 3. Adaptive Behavior of Visitors Using Earphones
(Source: Author, 2025)



Figure 4. Visitor Behavior When Trains Pass
(Source: Author, 2025)

Both images show visitors using earphones as a form of individual adaptation to reduce noise disturbances. In addition, it can be seen how visitors show comfortable behavior when chatting when the train passes through the café. These findings show that noise does not necessarily encourage visitors to leave the café, but rather triggers adaptive strategies that are spatial and personal.

These results indicate that adaptive behavior is not extreme, which indicates that despite perceived noise, the overall spatial experience is still acceptable. The preference to move to indoor areas is the main strategy because these areas are considered to be more able to reduce noise pollution.

In contrast to visitors, café workers are exposed to noise for a longer and more repetitive duration, thus showing more consistent and functional adaptation. This adaptation aims to maintain work effectiveness and service quality. Adaptive behaviors that are often carried out by café workers such as increasing the volume of the voice when serving customers and Using gestures/nonverbal to communicate. These findings show that workers have high adaptability. Adaptive behavior in café workers makes workers feel exhausted and impaired, indicating that

noise still causes psychological and cognitive burdens, although it does not directly stop work activities.

Comparatively, visitors tend to choose adaptations based on space choices, while workers develop task-oriented adaptations. This difference is influenced by the duration of exposure, the responsibility of the activity, and the level of control over the environment.

Table 5. Comparison of Adaptive Behavior Patterns

No.	Asepek Behavior	Visitors	Cafe Worker
1.	Duration of Exposure	Short – medium	Long and repetitive
2.	Dominant Adaptation	Spatial and Social	Social and functional
3.	Adaptability Intensity	Low – medium	Medium – high
4.	Noise Tolerance	Relatively medium	Relatively moderate

(Source: Author's Analysis Through Data Calculation, 2025)

These results confirm that adaptive behavior is an indirect indicator of the level of comfort of space. The greater the need for adaptation, the greater the environmental pressure felt by users.

The results show that the design of cafes located near railway lines needs to apply a design approach that is responsive to environmental noise levels and the user experience of the space. The findings regarding noise variation between spatial zones indicate the importance of implementing noise-based spatial zoning, where areas with the highest noise exposure are directed as transition zones or areas with short activities, while spaces that support concentrated activities, such as work and discussion, are placed in zones with lower noise levels. This strategy allows for a distribution of activities that is more in tune with the acoustic conditions of the space and supports the user's functional comfort.

In addition, the results of the study confirm the crucial role of façade design and opening systems in controlling the transmission of noise from external sources. Openings that are oriented directly to the railway line need to be designed with a layered system, such as the use of laminated glass or secondary skin, to reduce the impulsive noise that arises when trains pass through. This approach is in line with the principles of adaptive building design that places the building envelope as a protective element against environmental disturbances.

In terms of interiors, the use of building materials with high acoustic performance, especially those with good Sound Transmission Class (STC) and Noise Reduction Coefficient (NRC) values, has proven to be important in reducing the average noise level in indoor spaces. The optimization of materials on walls, ceilings, and interior elements not only serves as a sound dampen, but also contributes to improving the quality of communication and the comfort of activities inside the café.

The existence of outdoor areas as part of the café space experience can still be maintained, but it needs to be designed adaptively. The application of buffer elements such as tight vegetation, outdoor acoustic panels, and the addition of distance (setback) from noise sources are important strategies to minimize sound interference without detracting from the character of the outdoor space. Thus, outdoor areas retain functional and aesthetic value despite being in noisy environments.

Overall, the implications of this study confirm the importance of applying an evidence-based design approach in café design in noisy urban environments. Acoustic design decisions based on measured noise data and user perception allow for space design that not only meets

aesthetic aspects, but is also responsive to real environmental conditions as well as user comfort needs, as recommended in sustainable architectural design practices

CONCLUSION

This study concludes that noise due to railway crossings is a dominant environmental factor that significantly shapes the acoustic conditions of cafes located near rail lines. The measurement results showed that the noise level in the outdoor area was in the high category and exceeded the recommended comfort threshold, while the indoor area experienced a decrease in sound intensity thanks to the attenuation of building elements, although at certain times it was still above the comfort standards of commercial spaces. These findings confirm that the spatial proximity of cafes to rail transport infrastructure has direct implications for the quality of the acoustic environment and needs to be a key consideration in spatial planning. However, user perceptions show that the perceived discomfort is at low to moderate levels, especially in indoor areas, which indicates the role of subjective perception and user tolerance to noise. Train noise triggers the emergence of adaptive behaviors, where visitors tend to make spatial and personal adjustments, while café workers develop functional adaptations to maintain smooth activities and communication. Overall, the study confirms that the acoustic comfort of cafes is not only determined by the physical conditions of noise, but also by the user's perception and adaptive behavior, so that an integrative approach based on objective and subjective data is key in designing cafes in urban environments with high noise exposure.

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