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Examination of Relationship Between Railway Noise, Lifestyle Activities and Passive Noise Protection Solutions Among the Population Living Near the Train Marshalling Yard of Sopron

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Abstract

Noise pollution from traffic is a growing social challenge. The effects of railway noise are concentrated in transport hubs, such as marshalling yards. Various sources of vehicle noise negatively affect quality of life and can disrupt everyday activities. Despite this, protection against sound effects at the individual level is practically limited to the use of passive noise protection solutions. The purpose of this article was therefore to examine the subjective correlations between railway noise events, disrupted daily activities and passive noise protection solutions found in households by means of a questionnaire survey among the population living in the vicinity of the train marshalling yard of Sopron, Hungary. The received binary (yes or no) answers were evaluated using Fisher tests, first between noise events and disturbed activities, and then between activities and noise protection solutions. The correlation values included in tables were also supplemented with correlations between the groups, combined from answer options. It could be concluded that the role of passenger and freight trains in this environment goes far beyond train marshalling. In addition, the effects on resting and recreation are outstanding, and effective solutions are to plant vegetation and use thermal insulation to reduce them. To expand the results above in the future, it is necessary to compare the answers with objective acoustic parameters with independence tests and to repeat the questionnaire survey in similar living environments in other cities to recognize regional trends.

Keywords

train noise, questionnaire survey, disturbed activities, passive noise protection, Fisher test

1 Introduction

Although it is now well known that rail transport can manage increased mobility needs in the most efficient and environmentally friendly way, the increase in noise pollution caused by it also poses an increasing challenge for a society that is sensitive to the negative effects on the environment (Kovács and Cziegler, 2009). According to surveys, 20% of people feel that noise from railways and another 60% from road traffic are more significant, whereas the former affects only 8-10% of the population and this proportion can be further reduced by taking environmental noise and vibration protection aspects into account (Tulipánt, 2007).

From the point of view of the quality of life, it is particularly justified to examine the environment of transport junctions located in the immediate vicinity of populated areas, where the expected negative effects are concentrated due to the trains waiting with running engines or ventilation fans, as well as the servicing of passenger traffic, loading or logistics activities and operational noise related to railway facilities (Czupy and Rozs, 2022). Regardless, few studies deal, for example, with the population's responses to noise when there is a subsequent change in traffic or with periodic surveys in the given area, even though changes in traffic noise conditions by time can result in significant response differences (Müller et al., 2023). The purpose of this study is to map the subjective perception of railway noise with the help of a population survey in the area next to the train marshalling yard of Sopron and thereby contributing to the development of a more inhabitable settlement structure.

1.1 Effects of railway noise on residential environments

Various noise sources have a negative impact on the quality of life (Fiorini, 2022) and can be associated with physical

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and mental health problems, such as headache, stress, sleep, and concentration disorders or deteriorating speech understanding (Stróbl and Suri, 2010). When comparing the sound exposures at marshalling yards, in terms of the total acoustic energy, freight trains can cause a more unpleasant feeling, like marshalling, with a higher impulse maximum (Rozs and Czupy, 2023), which according to Smith et al. (2013), represents a special risk due to low-frequency effects.

The reaction of people is largely predetermined by how they relate to the noise sources (Tánczos et al., 2007). Another "acute" but important aspect of sound effects in everyday life is they can disrupt activities such as reading or resting, in addition to changing the usual sound image (De Coensel et al., 2007). At the same time, studies indicate that non-acoustic variables play a significant role in determining the individual level of disturbance and expected complaining reactions through the relationship of the people to the noise source and their environment (Schultz, 1978).

The presence or absence of passive noise protection solutions that are used in households can also be considered an important parameter of the quality of living space, since, in contrast to the traffic control and diversions used in different points of cities with a rigid structure, the individual reduction of the effects is primarily limited to these devices (Bozóki et al., 2011). Replacement of out-of-date windows also can be an effective solution for noise reduction, which is more widespread than planting vegetation or using sound insulation on the walls (Stróbl and Suri, 2010). The study also highlights that besides available solutions and legal possibility of public complaints as a result, nowadays defense is also the task of individuals. At the same time, it should be noted that advanced industrial solutions are also available to reduce noise, and vibration loads, such as viscous rail dampers built into the rail web (Csortos et al., 2020), or the use of automatic rail lubrication to reduce wheel friction noise (Csortos et al., 2021), however, the usage rate of these devices in Hungary is currently low.

Considering the above, the purpose of this article was to determine the correlations between railway noise events, residential environment activities and the prevalence of passive noise protection solutions that can be implemented by the individuals.

2 Materials and methods

In the chapters below, general properties of the selected area and the marshalling yard are described first. This is followed by the guidelines used when compiling the questionnaire survey and the methodology used in processing the answers.

2.1 Characterization of the selected environment

The location of the survey was a residential area close to the train marshalling yard of Sopron, whose satellite image is illustrated in Fig. 1. The marshalling yard consists of a plain track facing the street, a rolling hill without built-in braking equipment, a connecting track to the railway station in the direction of the service road, a pull-out track lying between the latter two pairs of rails, and storage tracks running parallel to the plain track. The embankment strip that separates the residential area from the plain track, is at least 1.5 m high in relation to the rails and gets wider in the direction of the station, contains both maintained and unmaintained shrubs and trees, as well as 8 rows of garages, but it has no noise protection wall.

It should also be mentioned that residential buildings in the area are located on a hillside rising perpendicular to the axis of the plain track (Fig. 1). Industrial activity behind the service road running on the other side of the tracks and the degree of noise reflection emitted by trains is verifiable by previous measurements (Czupy and Rozs, 2022).

Households selected for the survey together with the zoning classification and topographical numbers indicated in Town Regulatory Plan (General Assembly of the Municipality of Sopron County, 2022) are illustrated in Fig. 2. Considering the divided properties, the total of 134 households can be classified into 5 zones identified as small-town area shown

Fig. 1 Satellite view of the selected residential area, where 1. and 2. are views of the hillside from the marked points (Author's own photo)

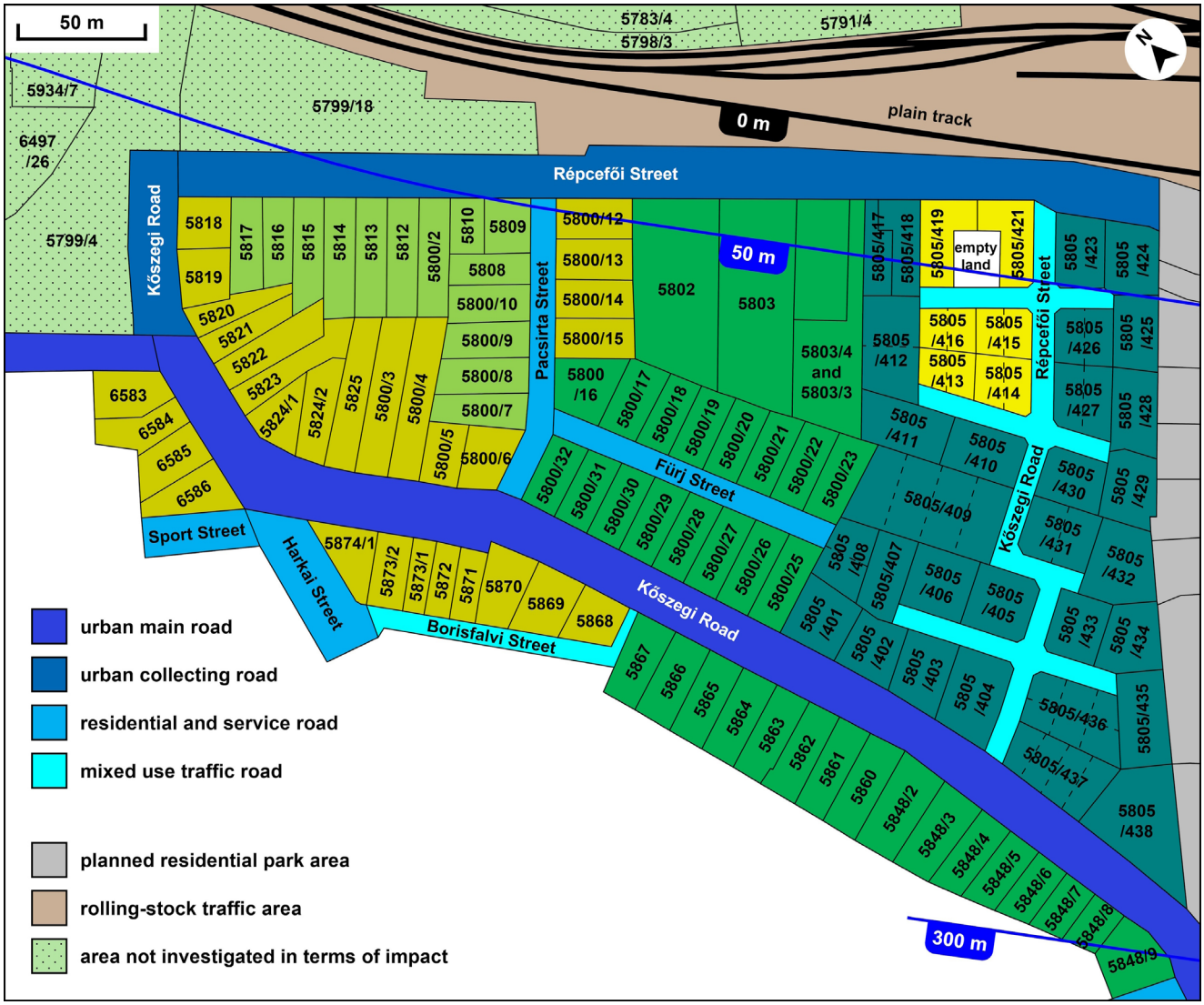

Fig. 2 Residential zone classification of selected households based on the Town Regulatory Plan (General Assembly of the Municipality of Sopron County, 2022)

in Table 1. Almost 80% of the selected addresses lie between the Répcefői Street and Kőszegi Road (functioning as the agglomeration's main road), to which the houses on the side of the road further from the tracks was added. Due to urban development reasons, most of the properties located on both sides of Kőszegi Road were built approximately 30 years ago but have since been rebuilt or modernized. At the same time, zones marked Lk– SZ/36 and Lk–Z/9 functioned as a state

Table 1 Main parameters of zone classifications (General Assembly of the Municipality of Sopron County, 2022)

Color code	Zone sign	Maximal site coverage [%]	Minimal green space [%]	Minimal site size [m^2]	Number of sites	Number of adresses
	Lk–SZ/36	30	55	450	30	46
	Lk–O/26	30	50	300	35	35
	Lk–Z/3	30	40	300	15	15
	Lk–IKR/28	40	40	500	28	28
	Lk–Z/9	40	30	300	6	10
∑	-	-	-	-	114	134

Lk – small town living construction zone; SZ – free placement: within the site, the new building is free to be placed; O – build on the side: the building can be built on one side of the site, on a land border, or tangentially determined by the construction authority; Z – build in continuous line: the end walls of the building can be built on site boundaries perpendicular to or in different angle from the street; IKR – twin buildings: on two adjacent sites a twin house can be built; /number – serial number of sub-categories in tables published by construction authorities.

economic area in the last century, which was expropriated, reclassified, and divided after 1990, and then gradually incorporated from the beginning of the 2000s until today.

In terms of noise impact, 13 of the selected sites are located within the protective distance of 50 m from the plain track (permission only be granted for renovation or demolition). At the same time, every point of the connecting track is more than 50 m away from the facades of the houses and the distance between the furthest property and the plain track is approximately 300 m.

As a result of this value, the survey area is located within the theoretical impact range of the connecting track (570 m), based on sound attenuation calculation for line sources, which does not include acoustic dampening and amplifying effects. According to studies (Diao et al., 2015; Lee and Pang, 2022), an increase in the value of real estate is expected in this range after a protection wall installation, which can provide a suitable basis for conducting objective financial calculations for further examination.

In terms of the actuality of this research, the partial construction of a new hillside residential park with 309 sites (details can be found in the Regulatory plan) has already begun from the side of Kőszegi Road. To create a healthier living environment, this justifies the completion of a public questionnaire survey of the subjective attitude to railway noise effects.

2.2 Description of the questionnaire survey

Different surveys are a necessary and useful tool for investigating the everyday impact of noise on people, but their practical implementation may require much effort and costs (Namba et al., 2010). Proper design of the questions is a complex task, as the general wording, the type of question (open or closed), the description of the reaction (perception, disturbance), the words referring to the acoustic environment (noise, sound), the choice of conditions (day/night, in/outdoor), the type of answer scale (numbered, textual) and the number of answer options on the scale (4 points, 11 points) can be diverse and can greatly influence the quality of the answer (Fields et al., 2001).

Considering the above aspects, the questionnaire provided 3 specific questions about the perceived noise events indicated in the title, the noise-disturbed activities, and the existence of different passive noise protection solutions in the household. In the simplest and most understandable way, each event, activity, and solution had a yes or no answer option for the questions, and it was possible to answer yes to more than one noise event, activity, and solution or to none of them.

After assessing the composition of the vehicle fleet, the functions of the individual tracks and the traffic conditions (Czupy and Rozs, 2022), as well as the sound sources appearing in these (Bozóki et al., 2011), the perceptibility of the following noise events was asked as a question:

1. clacking on the rail and switches,
2. sound of the diesel/electric engine,
3. screeching of the car frame and body,
4. braking and blowing of the air brake,
5. friction noise (between wheels and rail),
6. collision of bumpers and screw couplers,
7. train passing noise.

Air horn and electric signal horn were omitted from the above list, since their use in marshalling yard activities cannot be considered a generally occurring noise event and their task is to produce a sound effect that can be clearly distinguished from the background even from a great distance in the event of an accident.

In everyday life, studies highlighted sleep disturbance and reduced work performance as harmful consequences related to noise effects and even mentioned resting and entertainment activities (listening to radio/television) (Jeon, 1996; Maljaee, et al., 2024). Supplementing these with the tasks and typical activities of small-town residential areas, the selectable disturbed activities in the questionnaire were the following:

1. work (home office),
2. housework,
3. garden work,
4. leisure/hobby activities,
5. resting/recreation,
6. entertainment.

Based on the observation of residential properties and different kind of researches (Akin and Alptekin, 2023; Cosola et al., 2022; Mohamed et al., 2019; Stróbl and Suri, 2010; Witczak et al., 2021), the listed passive noise protection solutions could be indicated in parallel with the above:

1. closed brick/plate fence at least 1.5 m high from the tracks side,
2. densely planted row of plants at least 1.5 m high next to the house/fence from the tracks side,
3. at least 5 cm thick external thermal insulation,
4. windows with sound-insulating glass,
5. internal sound-absorbing covering/insulation.

2.3 Answer evaluation methods

The questionnaires were delivered in November 2023 to each mailbox in a sealed envelope containing questionnaire paper and a response envelope marked with the address of the University of Sopron and postmarked for free return. To ensure comparability with objective parameters (for example, the distance from tracks or minimal green space ratio), the topographical number assigned to the household was included on the header of each questionnaire, but at the same time, in accordance with general data management principles, the received answers were processed cumulatively. Out of the 134 inquiries delivered, 42 fully filled out questionnaires were returned by the end of February, which represents a response rate of 31% and can already be considered a large sample from the point of view of general statistical methods. A partially completed questionnaire was not, but an unanswered one was received, in which people wrote that they were not bothered by railway noise.

Based on Bower (2003) and Upton (1992), the degree of correlations was determined using the Fisher test also used by Morihara et al. (2021), which, unlike the chi-square test, can also be used in the case when a field of the contingency table contains a value smaller than five. The first step in conducting the tests was the investigation of noise events and disturbed activities and the second step to explore the correlations between the disturbed activities and the applied passive noise protection solutions.

In addition to accepting and marking the relationship between them at 95% significance level (α = 0.05), the 90% level (α = 0.10) were marked for future examinations. Parallel to this, one-sided (first lines in every activity and activity group) and two-sided p probability values (second lines in every activity and activity group) were also calculated (strength of correlations can fall into various categories), making it easier to interpret the results.

For specific comparison, groups were defined for all three questions by combining individual alternatives, with the condition that the respondent was classified in a group if answered yes to at least one of the options belonging to the given group. Considering the railway sound effects typical of traffic conditions and track conditions (Czupy and Rozs, 2022), the noise events include the passenger train (clacking, engine, friction and passing), the freight train (clacking, engine, screeching, braking and friction) and the marshalling activity (clacking, engine, screeching, braking and collision) groups were created. In parallel, the activities could be divided into daily life (work, housework, garden work) and relaxation (garden work, hobbies, resting and entertainment). The groups of noise protection solutions were made up of sets that reduce external, outdoor noise effects (fence, row of plants), as well as internal effects when staying in the property (insulation, windows and covering). It should also be mentioned that each answer option was placed in at least one group, and one answer option could be classified into several groups, for example, gardening, which could be considered a task or recreation activity for respondents.

3 Results

In this chapter, first the conclusions from general statistics are described, followed by the results of the Fisher tests in the order described in evaluation methods.

3.1 Results from general statistics

Among the general statistical values, Fig. 3 summarizes the proportion of responses to individual noise events, activities, and solutions. Among the noise events, engine sounds and passing were given similarly few marks, even clacking was found to be clearly perceptible by almost half of the respondents. Corresponding to the trend noted in the literature, rest/recreation stood out among the disturbed activities with a rate of almost 2/3, whereas the effects on regular housework in everyday life did not appear to be disturbing. The high prevalence rate of thermal insulation and windows with sound-insulating glass is also confirmed by governmental home modernization programs of the last decade, but at the same time, the 2.4% value of internal coverings indicates the low prevalence of this innovative solution compared to the others.

Important conclusions can also be drawn from the rate of the number of noise events, activities and solutions indicated in the questionnaire, which can be seen in Fig. 4. Almost 1/3 of the respondents perceived two types of noise events, and 1/3 of them perceived three types. The same proportion belonged to zero and three types for disturbed activities, and similarly to noise events, belonged to two and three types of solutions. The largest number of outliers occurred in disturbed activities, but every respondent perceived at least one of the events and, except for one case, all properties have some kind of passive noise protection solution. In the case of noise events and activities, the sum percentages of all of them, as well as the one and two less, do not even reach 10%, which indicates that the respondents did not want to distort the result in a negative direction, increasing subjective reliability. Overall, it can be established that the respondents living in the residential environment perceive an average of three (2.7) types of noise events, these events disturb them in at least one (1.3) activity, even though their property has at least two (2.2) passive noise protection solutions.

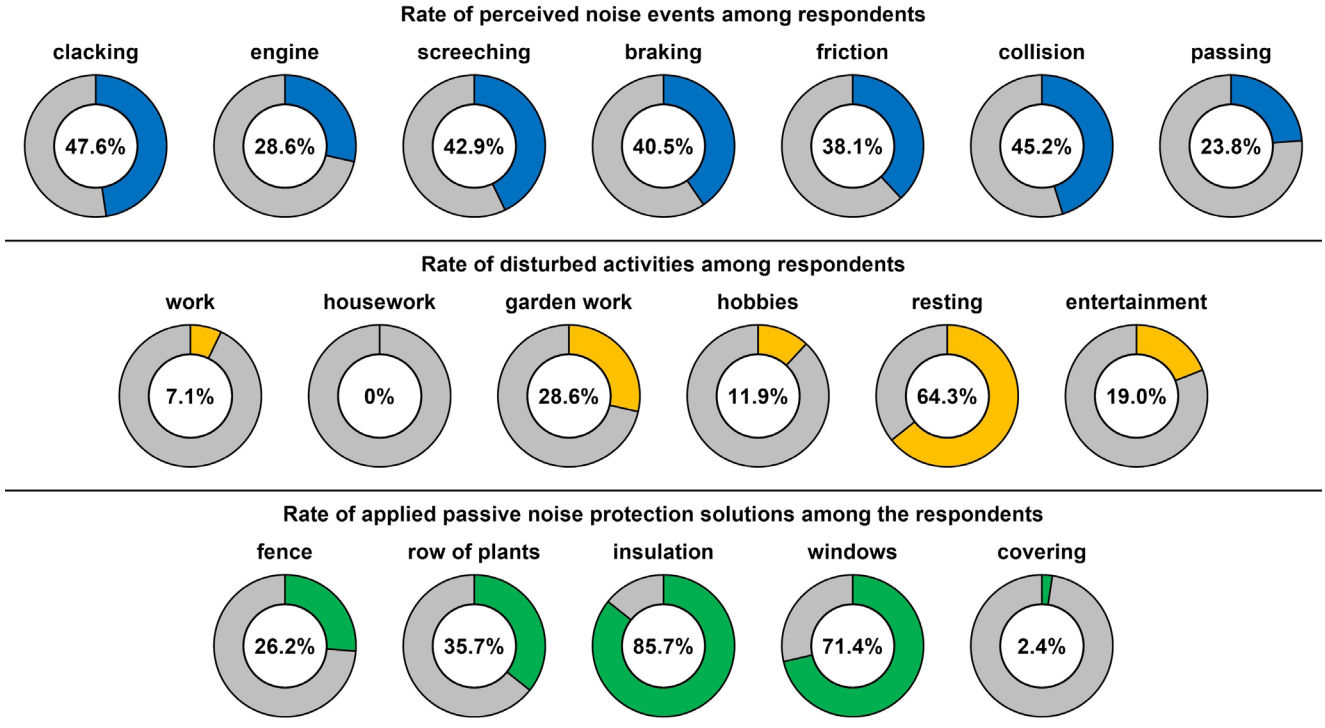

Fig. 3 Rate of responses for each noise event, activity, and solution

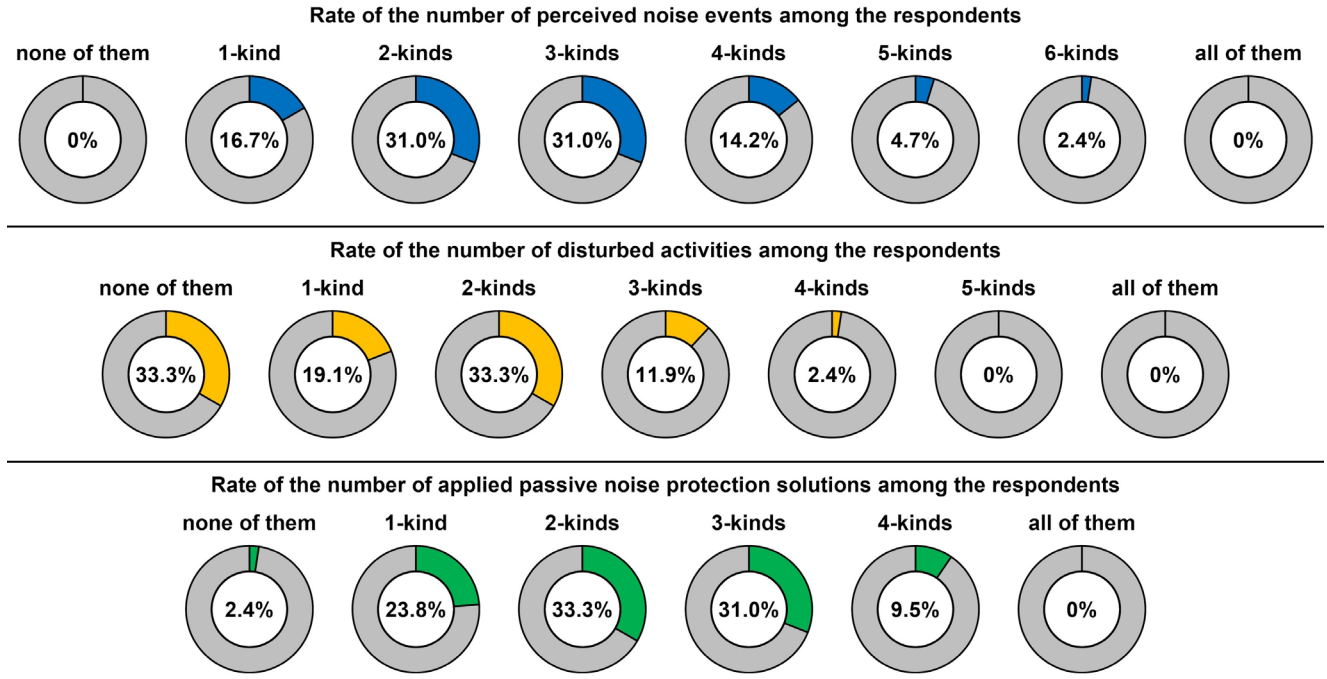

Fig. 4 Rate of the number of marked noise events, activities, and solutions

3.2 Results from Fisher tests

Table 2 shows the degree of correlation between noise events and disturbed activities, and Table 3 summarizes the relationships between defined groups of combined noise events and disturbed activities. Apart from passing and screeching with a two-sided probability that did not reach 90%, all noise events showed a level of correlation suitable for further investigation, and among the activities, housework was not affected (in the absence of a yes mark) by noise effects. In terms of number, work and entertainment are negatively affected by one noise event, garden work and hobbies by two, and relaxation by three events. At the same time, the most negative effect on the activities can be attributed to the engine and braking, which can be linked to both activities above.

Table 2 Correlation of noise events and disturbed activities based on Fisher tests (one-tailed and two-tailed)

Disturbed activity	Noise event						
	clacking	engine	screeching	braking	friction	collision	passing
work	0.536	0.353	0.609	0.059	0.320	0.572	0.567
	1	0.545	1	0.059	0.547	1	1
housework	1	1	1	1	1	1	1
	1	1	1	1	1	1	1
garden work	0.295	0.061	0.400	0.325	0.227	0.077	0.399
	0.499	0.068	0.731	0.498	0.316	0.097	0.695
hobbies	0.143	0.130	0.096	0.315	0.060	0.593	0.340
	0.174	0.130	0.146	0.392	0.060	1	0.577
resting	0.008	0.019	0.520	0.043	0.446	0.428	0.486
	0.010	0.030	1	0.056	0.746	0.749	0.725
entertainment	0.091	0.411	0.197	0.411	0.648	0.243	0.625
	0.122	0.667	0.256	0.693	1	0.432	1

< α = 0.05: 95% significance level correlation (strong relationship)

< α = 0.10: 90% significance level correlation (further investigation needs)

Table 3 Correlation of combined noise events and disturbed activities based on Fisher tests (one-tailed and two-tailed)

Disturbed activity	Combined noise event		
	passenger train	freight train	train marshalling
work	0.567	0.796	0.928
	1	1	1
housework	1	1	1
	1	1	1
garden work	0.399	0.646	0.714
	0.695	1	1
hobbies	0.236	0.676	0.880
	0.314	1	1
resting	0.014	0.039	0.357
	0.020	0.039	0.357
entertainment	0.374	0.521	0.809
	0.654	1	1

< α = 0.05: 95% significance level correlation (strong relationship)

By conducting the tests with noise event groups, it can be further confirmed that the feeling of disturbance is most closely related to resting, while the correlation with other disturbed activities is significantly weaker. From the point of view of vehicle traffic, it is also interesting to note that there is a strong connection with passenger trains, even though in the group, two of the four noise events (friction and passing) only correlate at a low level with resting. This rate with two out of five events (screeching and friction) for freight trains causing the impact, is the same as the marshalling that forms the backbone of railway traffic (screeching and collision). However, the impact of the latter group on the population cannot be verified with the chosen analysis method.

Regarding the relative importance of individual noise events and disturbed activities, similar conclusions can be drawn by examining the noise events and activity groups shown in Table 4, as well as the combined groups shown in Table 5. Based on this, among the noise events most associated with daily life activities is braking, which can be explained by a higher correlation with the activities classified in the group compared to the engine and collision that cause an impact in garden work. Compared to the ungrouped results, the role of clacking and engine through the resting part of relaxation is also shown in Tables 4 and 5, even freight trains do not significantly affect the relaxation group.

Table 4 Correlation of noise events and disturbed activity groups based on Fisher tests (one-tailed and two-tailed)

Disturbed activity group	Noise events						
	clacking	engine	screeching	braking	friction	collision	passing
daily life	0.408	0.192	0.479	0.055	0.446	0.133	0.486
	0.748	0.291	0.754	0.099	0.746	0.202	0.725
relaxation	0.017	0.029	0.627	0.072	0.548	0.293	0.559
	0.023	0.066	1	0.102	1	0.514	1

< α = 0.05: 95% significance level correlation (strong relationship)

< α = 0.10: 90% significance level correlation (further investigation needs)

Table 5 Correlation of combined noise events and disturbed activity groups based on Fisher tests (one-tailed and two-tailed)

Disturbed activity group	Combined noise event		
	passenger train	freight train	train marshalling
daily life	0.486	0.713	0.642
	0,725	1	1
relaxation	0.050	0.253	0.333
	0.059	0.539	0.333

< α = 0.05: 95% significance level correlation (strong relationship)

< α = 0.10: 90% significance level correlation (further investigation needs)

Based on the tests completed in the second step of the search for correlations, the values between disturbed activities and the passive noise protection solutions are summarized in Table 6, and the relationship between activity groups and the solutions is shown in Table 7. It is important to mention that during the investigation, the lack of solutions was assigned to the activity by inverting the answer sets, which means a marked logical difference of interpretation.

In contrast to the noise events in this case, the lack of more than one solution was not associated with any of the activities, but for relaxation and entertainment, an effect of strength corresponding to the chosen significance level was detectable, and results can be compared to Schäffer et al. (2020), according to which green vegetation contributes beneficially to the subjective assessment of noise effects. Another similarity is that the relaxation group also shows a connection with the solutions, even in the chosen area the effect of thermal insulation with a high residential prevalence needs to be analyzed in more detail in the future.

When comparing the lack of combined passive noise protection solutions, only entertainment showed a minimal level of relationship based on Table 8, as the pair of entertainment and the row of plants that can be classified in the external group had the strongest correlation in Table 6. Considering

Table 6 Correlation of the lack of passive noise protection solutions and disturbed activities based on Fisher tests (one-tailed and two-tailed)

Disturbed activity	Lack of passive noise protection solution				
	fence	row of plants	insulation	windows	
work	0.608	0.254	0.621	0.191	0.928
	1	0.294	1	0.191	1
housework	1	1	1	1	1
	1	1	1	1	1
garden work	0.381	0.192	0.560	0.468	0.714
	0.699	0.291	1	0.715	1
hobbies	0.199	0.595	0.443	0.455	0.880
	0.302	1	0.584	0.613	1
resting	0.383	0.024	0.107	0.566	0.357
	0.716	0.042	0.154	1	0.357
entertainment	0.311	0.016	0.256	0.588	0.809
	0.419	0.016	0.328	1	1

< α = 0.05: 95% significance level correlation (strong relationship)

Table 7 Correlation of the lack of passive noise protection solutions and disturbed activity groups based on Fisher tests (one-tailed and two-tailed)

Disturbed activity group	Lack of passive noise protection solution				
	fence	row of plants	insulation	windows	covering
daily life	0.333	0.458	0.638	0.192	0.542
	0.480	0.743	1	0.291	1
relaxation	0.459	0.040	0.083	0.646	0.333
	0.723	0.085	0.155	1	0.333

< α = 0.05: 95% significance level correlation (strong relationship)

< α = 0.10: 90% significance level correlation (further investigation needs)

Table 8 Correlation of the lack of passive noise protection solution groups and disturbed activities based on Fisher tests (one-tailed and two-tailed)

Disturbed activity	Lack of passive noise protection solution group	
	external	internal
work	0.536	0.928
	1	1
housework	1	1
	1	1
garden work	0.557	0.714
	1	1
hobbies	0.546	0.880
	1	1
resting	0.144	0.357
	0.208	0.357
entertainment	0.091	0.809
	0.122	1

< α = 0.10: 90% significance level correlation (further investigation needs)

the data in Table 9, when examining the combined activity and solution group, the lower significance level effect did not exist even for one-tailed probability values. This clearly shows that group combining also has limitations, and the selection of evaluation criteria can significantly influence the results of the survey.

4 Conclusions

In summary of the results above, the following conclusions can be made:

Table 9 Correlation of the lack of passive noise protection solution groups and disturbed activity groups based on Fisher tests (one-tailed and two-tailed)

Disturbed activity group	Lack of passive noise protection solution group	
	external	external
daily life	0.591	0.642
	1	1
relaxation	0.222	0.333
	0.337	0.333

1. Among the listed noise events, the sound of the diesel/electric engine, the clacking sound of the wheels passing over rails and switches and the braking and blowing of the air brake had the greatest impact on activities. Acoustically, these events differ significantly in time and in frequency, which poses difficulties in terms of creating uniform passive defense solutions.
2. Negative perception of the noise effects typical of passenger and freight trains could be verified by the survey, but despite the similar nature to freight trains, effects of train marshalling cannot be demonstrated solely by the subjective relationship of noise events and disturbed activities.
3. In accordance with literature, among the responses to disturbed activity, the role of resting and the relaxation group can be considered prominent, even the lifestyle activities of the local population are less affected by railway noise events.
4. In the case of hobby and garden activities, the negative effects similarly show a lower correlation in relation to noise events, regardless of whether the former can be considered an indoor and outdoor activity, and the latter is an outdoor activity.
5. Summarizing the test results of passive noise protection solutions and disturbed activities, clearly fewer significant relationships were detected in individual and grouped forms than when paired with noise events.
6. The dominant role of resting and relaxation can also be established, but in parallel, the correlation between the effect of thermal insulation and entertainment, as well as the external solution group, cannot be proven.

Overall, findings of the survey represent a suitable starting point for investigation of the perception of the local population regarding the railway traffic, but objective parameters must also be considered. According to

Weidenfeld et al. (2021) for example, recent studies have already shown that in case of intermittent traffic, the number of passing railway vehicles is also an important acoustic factor in terms of the degree of subjective disturbance.

To verify this, it is necessary to determine the daily average number of passenger trains, freight trains, and train marshalling operations and to perform independence tests with subjective responses, as well as to compare them with data from sound pressure level measurements. Results also can be extended then by repeating the questionnaire survey in other small towns next to rural marshalling yards, which also contributes to the knowledge of regional and national population trends.

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