Chapter 11

Selection of the vibration impact estimation parameter for environmental assessments

Piotr Stecz
Cracow University of Technology

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Abstract
Frequently encountered problem with estimating the impact of vibrations for new investments, which may have adverse effects, it seems important to select an assessment parameter that will ensure compliance with the relevant legal provisions. In this papers shows the correct selection of the parameter for the assessment of the impact of vibrations for new or renovated sections of railways in relation to the current legal situation in our country. It also shows the practical aspect of the issue with the use of examples of implementation based on vibration measurements made for investments that may have a significant impact on the environment in terms of vibration generation.

Keywords: vibration, vibration influence on humans in buildings, vibration comfort, human perception, transport vibration

1. Introduction

Due to the more and more frequently encountered errors, which pose a problem related to the estimation of the impact of vibrations for new investments, which in turn may have adverse effects and affect the comfort of people in the neighboring buildings [1], the correct selection of the evaluation parameter seems to be important. It is designed to meet the relevant legal provisions and, above all, efficiently to protect people in buildings located in the vicinity. In these papers was introduced correct selection of the parameter to assess the impact of vibrations for new or renovated sections of railways and others investments.

2. The origin of the problem

Because of recent increase in expenditure on investments in transport infrastructure, the construction market is experiencing a revival in the creation of new communication routes and the renovation of the existing ones. According to Regulation of the Council of Ministers of 10th September, 2019 on projects that may significantly affect the environment [2] they include, among others:

§1:

29) railway lines [...]

31) motorways and expressways [...]

§ 2:

60) railway lines [...]

62) hard surface roads [...]

63) tram lines, overhead or underground railways, including metro [...].

For investments of this type, it is necessary to develop an environmental impact assessment, and as part of such an assessment, the selection of an appropriate parameter concerning the impact on the environment, also with regard to vibrations. Unfortunately, often due to the superficial knowledge of the issue by the authors of the report, there may be a situation where the parameter used for such an assessment will be incorrectly defined. In this case, the interests of both the investor and the local residents are not adequately protected despite the apparent fulfillment of the conditions required by Polish law.

3. Example of implementation of the procedure based on the decision of the District Management for Environmental Protection

This publication was inspired by the analysis of the terms of the contract, which were included in one of the procedures concerning post-completion research based on the District Management for Environmental Protection (DMEP) decision. In the announced tender for the performance of works for the assessment of the impact of vibrations and noise, objections were raised with regard to the currently applicable legal provisions:

1. What is the legal basis for choosing a parameter for the assessment of the impact of vibrations, which is the impact on buildings and not on people in buildings, which is contrary to the provisions [3] Art. 3 point 13b in the Regulation [2] (which refers to the protection of the environment and counteracting pollution).

2. Specifying only the Standard [4] Why is the impact on buildings, and not on people in buildings, a critical parameter for the assessment of the impact of vibrations, which is contrary to the provisions of Art. 3 point 13b (which refers to the protection of the environment and counteracting pollution)? The purpose of this standard is to estimate the impact of vibrations on the structure of buildings, i.e. to what extent their structure is resistant to vibrations. In essence, it is the building structure that is less sensitive

to vibration than the effects on people in the buildings. According to this rule, it is the people in the building that will experience the negative impact of vibration first, and only then the structure of the building. So, is the Principal's goal to protect empty buildings and their structures, or is the influence of vibrations affecting people significant? It should be the basic criterion to be met in accordance with [5] – Assessment of the impact of vibrations on people in buildings, and not adopted by the Employer.

3. In addition, the legislator, in Art. 3 point 49 of the Act [3], defines "pollution" by emission (vibrations are also included in the emissions in accordance with Article 3 point 4b), which may be harmful to human health or the environment, may cause damage to material goods, may deteriorate the aesthetic values of the environment or may conflict with other, justified ways of using the environment.

The interpretation used by the Principal allows only the protection of material goods while disregarding the impact of vibrations on people, which is contrary to the provisions of the Act [3], which was referred to.

As a conclusion, on the basis of the issued decision, the performance of measurements of the impact of vibrations on buildings, excluding analyzes of the impact of vibrations on people in buildings, does not protect the interests of the Principal against future claims for vibration emissions, which results directly from [3] Article 6.1, 2, Article 7.1 and 2 of the Act [2], and thus – the issued decision has a legal defect and as such its execution should be immediately suspended.

The answer that was obtained from DMEP to the allegations made does not exhaust the points contained in the inquiry and does not substantively explain the reasons for making such decisions [Quoted]: *„[…]*

1. The condition concerning the assessment of the impact of vibrations on buildings was formulated in this and no other way, as its content was based on the documentation collected in the administrative procedure, including the report on the environmental impact of the project.

2. The body cooperating in the proceedings aimed at obtaining, inter alia, the decision on environmental conditions is also the sanitary inspection body, whose competences include, first of all, the analysis of the impact of implemented projects on the living conditions and health of people. The sanitary inspection authority also participated in the proceedings cited in the correspondence, and the conditions for the implementation of the project indicated by this authority were fully included in the position of the Regional Director for Environmental Protection.

3. It should also be pointed out that the decisions of administrative bodies are issued on the basis of the legal provisions in force in Poland, to which the norms cited in the above-mentioned writing does not

belong. Moreover, it is not the competence of a state administration body to indicate to experts who perform specialized tests, legal norms to be applied in their performance.

To sum up, the authority here does not see the legal flaws in the issued environmental decision, which has in fact already been "consumed" by issuing a decision based on it, taking into account the conditions for the implementation of the project, arising in the procedure of issuing a building permit decision, as well as a building permit. The investment has been completed and commissioned".

As can be seen, the decision is issued only seemingly in accordance with the regulations, as shown below. Additionally, it is contrary to common sense. It remains to be determined who is responsible for the enforcement of the procedure throughout the procedure, which will properly protect the interests of all parties, including people living in the vicinity of the investment being implemented. Otherwise, the law thus interpreted should be considered harmful. It should be mentioned that the law clearly specifies the requirements in this respect.

The basic document regulating the legal issues of environmental protection is the Act [3]. Pursuant to its provisions (Art. 3 point 13), environmental protection is understood *as taking or omitting actions that enable the preservation or restoration of natural balance; this protection consists in particular in:*

a) rational shaping of the environment and management of environmental resources in accordance with the principle of sustainable development,

b) counteracting pollution,

c) restoring natural elements to their proper condition.

And when it comes to the impact on the environment, it also means the impact on human health (Art. 3 point 11). In Art. 3 also states that whenever the act mentions:

(…)

4) emissions – it means direct or indirect input, as a result of human activity, into air, water, soil or soil:

a) substances,

b) energies such as heat, noise, ***vibration*** or electromagnetic fields.

(…)

49) pollution – shall mean the emission that may be harmful to human health or the state of the environment, may cause damage to material goods, may deteriorate the aesthetic values of the environment or may conflict with other, justified ways of using the environment;

(…)

The juxtaposition of these records shows that vibrations are classified as energy, energy is classified as emission, and emissions are classified as pollutant, that is:

vibrations = energy = emission of pollution into the environment

Thus: all provisions and requirements in the Act [3] relating to the emission of pollutants also apply to the emission of vibrations (the same applies to noise). In connection with this, it is worth quoting several articles of the law in question, which are related to protection against vibrations:

Art. 6

1. Whoever undertakes activities that may have a negative impact on the environment, is obliged to prevent this impact.

2. Whoever undertakes activities, the negative impact of which on the environment is not yet fully identified, is obliged, guided by caution, to take all possible preventive measures.

Art. 7

1. Whoever pollutes the environment bears the costs of removing the effects of this pollution.

2. Whoever may cause pollution of the environment bears the costs of preventing this pollution. (…)

Art. 137

Counteracting pollution consists in preventing or limiting the release of substances or energy into the environment.

(…)

Art. 139

The managers of these facilities ensure compliance with environmental protection requirements related to the operation of roads, railways, trams, airports and ports.

Pursuant to Art. 137 counteracting vibrations consists in preventing the emission of vibrations or limiting the emission of vibrations into the environment.

Article 139 obliges the administrators of roads, railways, trams, airports and ports to comply with the environmental protection requirements related to the operation of these facilities. In the light of this article and Art. 7, if there is a complaint about excessive vibrations, e.g. road vibrations in a given building, the road operator is obliged to check, at his own expense, what is the impact of road vibrations on this building and on people in this building. And if the excessive impact of vibrations is confirmed, he should repair any damage to the building at his own expense and take steps to remedy the situation (protect the building against excessive vibration impact).

Requirements regarding the necessity to take into account the influence of vibrations in the design of buildings are also included in [6], which § 325 reads as follows:

§ 325. Appropriate location of buildings

*1. Residential buildings, collective residence buildings and public utility buildings should be located in places least exposed to the occurrence of noise and **vibrations**, and if they occur and their levels will result in exceeding the permissible noise and vibration levels in the premises of these buildings, specified in the **Polish Standards** on admissible sound level values in rooms and the assessment of the impact of **vibrations** on buildings and people in buildings, effective protection should be used.*

§ 326. Acoustic insulation

*1. The level of noise and **vibrations** penetrating into rooms in residential buildings, collective residence buildings and public utility buildings, with the exception of buildings for which it is necessary to meet specific noise protection requirements, may not exceed the permissible values specified in the Polish Standards on noise protection for rooms in buildings and the assessment of the impact of **vibrations** on people in buildings, designated in accordance with Polish Standards on the method of measuring the A sound level in rooms and assessing the impact of **vibrations** on people in buildings.*

4. Practical example based on the results of vibration measurements

In the laboratory's measurement practice, so far there has been no situation in which the measured level of the impact of vibrations on people in a building (in accordance with [5]) would be lower than the impact of vibrations on the structure of this building (in accordance with [4]). Therefore, the measurement of the impact of vibrations on the building structure is the appropriate parameter for assessing the impact of vibrations on the environment when the impact of vibrations on people is consciously ignored.

This mainly applies to vibrations caused by construction works in the vicinity of existing buildings. Then the main goal is to protect the structures of these buildings against damage, while the assessment of the impact of vibrations on people in these buildings is omitted due to the temporary nature of this impact. It is assumed that in order to enable construction works to be carried out, people must bear the nuisance of vibrations and noise caused by these works, provided that they are not carried out at night. ***Similar approach is to the influence of short-term vibrations, such as e.g. the effects of mining tremors, quarrying shots, etc., here the aim is also to protect the structure of buildings against***

damage. On the other hand, in cases where both influences are taken into account, i.e. on the structure of the building and people in this building, as is the case when monitoring long-term dynamic effects, e.g. transport vibrations – the decisive factor will always be the impact on people in the building in accordance with the standard [5]. Such a system was implemented in the Warsaw Metro and since 2003 to date no violations of the impact of vibrations on the structure have been recorded, but the threshold for perceptibility of vibrations by people in buildings has been exceeded many times [7] (see Figure 1).

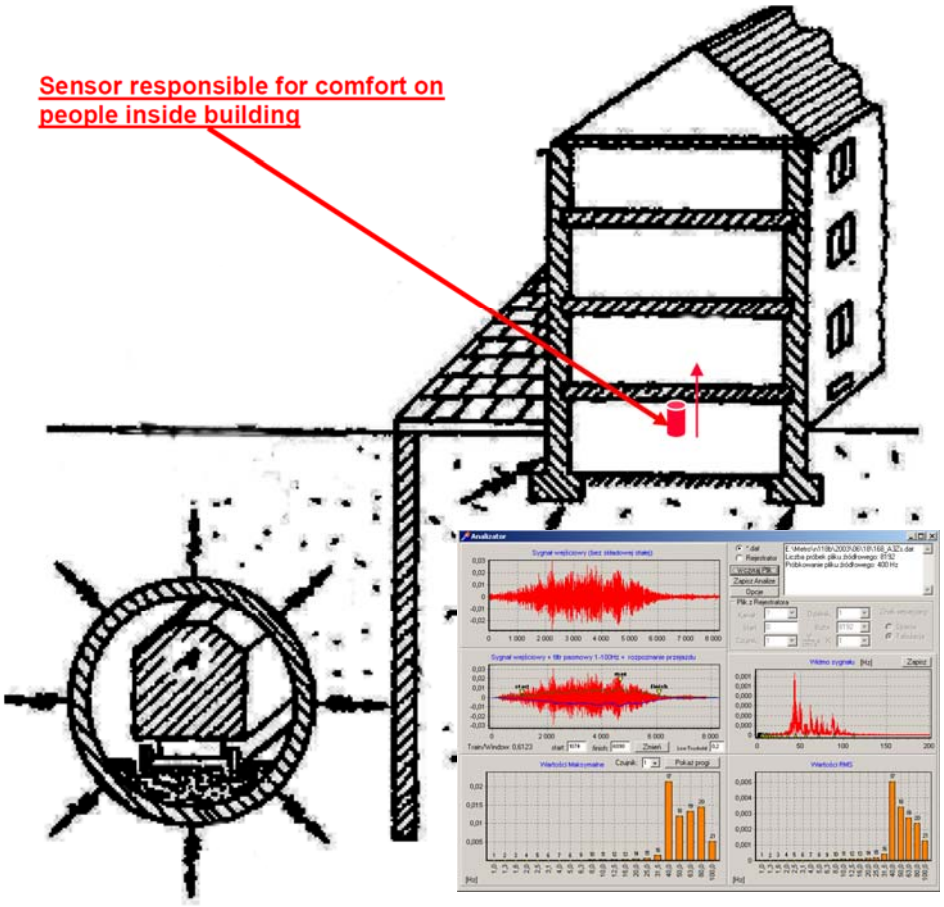

Figure 1. Schematic of sensor positioning in Warsaw Metro and part of control panel of analysis of comfort on people inside buildings

Below there is an example of some measurements of vibrations of building which was located in the neighborhood of vibration stripes (on road). This solution was in aim to minimize speed of passing of heavy lories coming from near stone-pit. Some vibrograms were recorded and analyzed (see Figure 2 and Figure 3). Figures below shows recorded vibrogram and result of analysis. For each measurement the same procedure was applied.

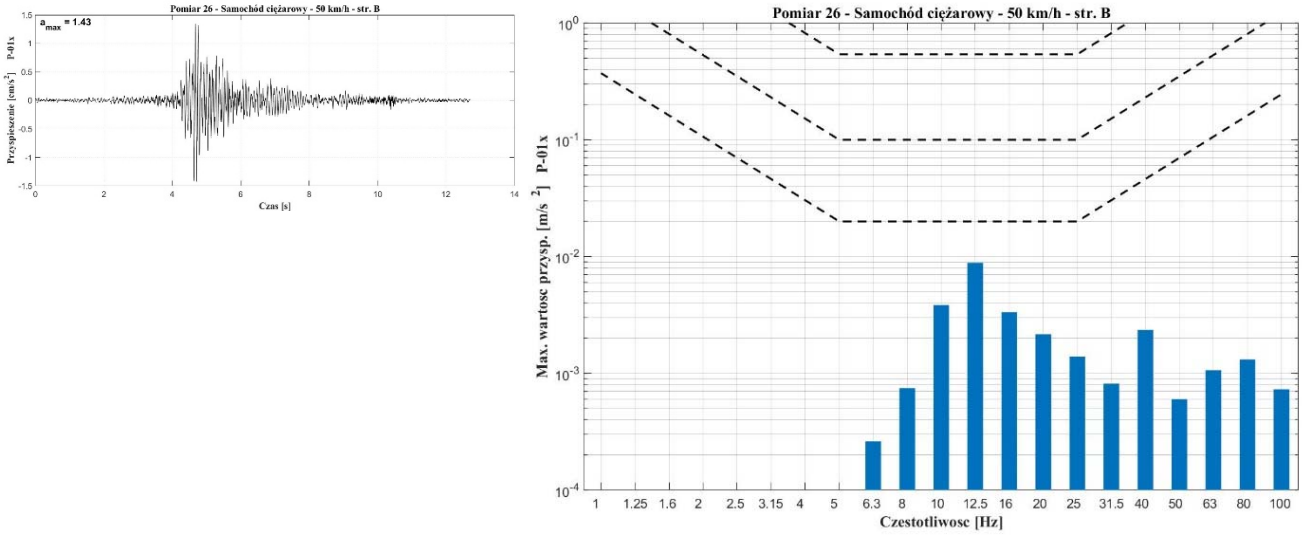

Figure 2. Measurement 26: left side vibrogram and right side third octave band analyze result; lorry pass by analysis of the impact of vibrations on the building structure in the horizontal direction X, in accordance with [4] (the building is subject to rough assessment according to SWD-I) – results for the measurement from Table 1

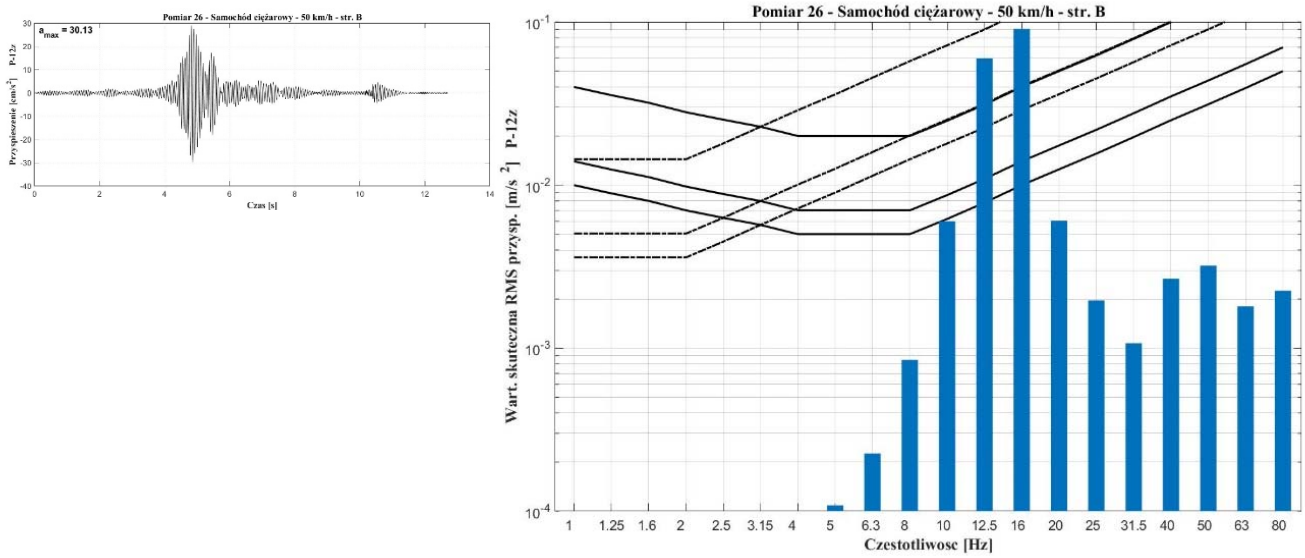

Figure 3. Measurement 26: left side vibrogram and right side third octave band analyze result; lorry pass by analysis of the impact of vibrations on people in the building vertical direction Z according to [5] – results for the measurement from Table 2

Selected results were shown in Table 1 (impact on buildings) and Table 2 (influence on people inside buildings).

Table 1. BVPR (Building Vibration Perceptivity Ratio) index for all measurements in the building under study

DESCRIPTION	P-01x		P-02y	
	Cubic on construction			
	f [Hz]	BVPR	f [Hz]	BVPR
Measurement 3 Heavy truck 38 km/h lane B	12.50	0.27	12.50	0.19
Measurement 6 Light truck 40 km/h lane B	20.00	0.07	16.00	0.05
Measurement 7 Light truck 43 km/h lane B	12.50	0.09	12.50	0.08
Measurement 9 Light truck 31 km/h lane B	16.00	0.08	12.50	0.06
Measurement 10 Heavy truck 51 km/h lane B	12.50	0.07	12.50	0.05
Measurement 11 Heavy truck 50 km/h lane B	12.50	0.24	12.50	0.19
Measurement 12 Light truck 50 km/h lane B	16.00	0.06	12.50	0.04
Measurement 14 Heavy truck 45 km/h lane B	12.50	0.25	16.00	0.14
Measurement 16 Heavy truck 42 km/h lane B	12.50	0.13	12.50	0.08
Measurement 17 Heavy truck 48 km/h lane B	12.50	0.23	12.50	0.25
Measurement 19 Light truck 48 km/h lane B	16.00	0.08	16.00	0.06
Measurement 20 Heavy truck 38 km/h lane B	10.00	0.26	10.00	0.17
Measurement 21 Light truck 52 km/h lane B	16.00	0.04	16.00	0.04
Measurement 22 Light truck 42 km/h lane B	20.00	0.07	16.00	0.03
Measurement 23 Heavy truck 30 km/h lane B	12.50	0.17	16.00	0.11
Measurement 24 Heavy truck 45 km/h lane B	12.50	0.30	12.50	0.17
Measurement 26 Heavy truck 50 km/h lane B	12.50	0.44	12.50	0.28
Measurement 27 Heavy truck 45 km/h lane B	12.50	0.24	12.50	0.17
Measurement 30 Heavy truck 43 km/h lane B	12.50	0.31	12.50	0.18
Measurement 33 Light truck 48 km/h lane B	12.50	0.29	12.50	0.17
Measurement 34 Light truck 54 km/h lane B	12.50	0.02	12.50	0.02
Measurement 35 Heavy truck 54 km/h lane B	12.50	0.32	12.50	0.27
Measurement 36 Heavy truck 54 km/h lane B	12.50	0.34	12.50	0.23
Measurement 37 Heavy truck 51 km/h lane B	12.50	0.27	12.50	0.19
Measurement 39 Heavy truck 51 km/h lane B	20.00	0.17	12.50	0.12
Measurement 41 Light truck 46 km/h lane B	12.50	0.04	12.50	0.03
Measurement 42 Heavy truck 51 km/h lane B	12.50	0.27	12.50	0.18
Measurement 43 Heavy truck 52 km/h lane B	12.50	0.40	12.50	0.30
Measurement 45 Heavy truck 46 km/h lane B	12.50	0.32	12.50	0.38
Measurement 47 Light truck 44 km/h lane B	20.00	0.02	16.00	0.02
Measurement 50 Heavy truck 37 km/h lane B	12.50	0.29	12.50	0.16
Measurement 52 Heavy truck 36 km/h lane B	12.50	0.35	12.50	0.20
Maximum value		**0.44**		**0.38**

The last line shows the maximum value of the BVPR index, which was recorded during the Measurements for the horizontal direction x and y, respectively. A value below 1 means the results without exceeding the A-limit, i.e. vibrations are classified as imperceptible by the building structure.

Table 2. HVPR (Human Vibration Perceptivity Ratio) indicator for all Measurements in the tested building – yellow fields indicate the results exceeding the threshold of perceptibility of vibrations by humans (WODL value above 1)

Description	P-04x		P-06z		P-10x		P-12z	
	Disc no 1 Gnd floor Living Room				Disc no 2 Attic Room			
	f [Hz]	HVPR	f [Hz]	HVPR	f [Hz]	HVPR	f [Hz]	HVPR
Measurement 3 Heavy truck 38 km/h lane B	8	0.02	16	1.8	12.5	0.12	12.5	7.97
Measurement 6 Light truck 40 km/h lane B	16	0.02	16	1.19	16	0.05	12.5	2.17
Measurement 7 Light truck 43 km/h lane B	12.5	0.03	16	0.75	12.5	0.04	12.5	4.05
Measurement 9 Light truck 31 km/h lane B	16	0.02	16	1.31	16	0.06	12.5	3.03
Measurement 10 Heavy truck 51 km/h lane B	63	0.01	12.5	0.42	63	0.01	12.5	3.11
Measurement 11 Heavy truck 50 km/h lane B	12.5	0.05	16	2.09	16	0.11	16	7.54
Measurement 12 Light truck 50 km/h lane B	12.5	0.01	16	0.87	16	0.04	16	2.13
Measurement 14 Heavy truck 45 km/h lane B	12.5	0.05	16	1.38	16	0.09	12.5	6.5
Measurement 16 Heavy truck 42 km/h lane B	8	0.04	16	0.83	8	0.07	12.5	2.47
Measurement 17 Heavy truck 48 km/h lane B	12.5	0.07	16	1.62	16	0.08	12.5	7.95
Measurement 19 Light truck 48 km/h lane B	16	0.02	16	1.79	16	0.06	16	3.4
Measurement 20 Heavy truck 38 km/h lane B	10	0.06	12.5	0.52	10	0.17	12.5	1.78
Measurement 21 Light truck 52 km/h lane B	16	0.01	16	0.81	80	0.01	16	2.59
Measurement 22 Light truck 42 km/h lane B	12.5	0.01	20	0.59	16	0.03	16	2.22
Measurement 23 Heavy truck 30 km/h lane B	12.5	0.04	16	2.02	16	0.11	16	8.14
Measurement 24 Heavy truck 45 km/h lane B	12.5	0.07	16	1.51	10	0.07	16	4.21
Measurement 26 Heavy truck 50 km/h lane B	12.5	0.09	16	2.58	16	0.11	16	9.08
Measurement 27 Heavy truck 45 km/h lane B	12.5	0.05	16	2.07	16	0.12	16	7.56
Measurement 30 Heavy truck 43 km/h lane B	12.5	0.09	16	1.14	10	0.11	16	3.04
Measurement 33 Light truck 48 km/h lane B	12.5	0.09	16	1.28	12.5	0.08	12.5	6.07
Measurement 34 Light truck 54 km/h lane B	6.3	0.01	16	0.26	16	0.01	12.5	1.2
Measurement 35 Heavy truck 54 km/h lane B	12.5	0.09	12.5	1.62	12.5	0.11	12.5	12.01
Measurement 36 Heavy truck 54 km/h lane B	12.5	0.12	12.5	2.12	12.5	0.11	12.5	13.59
Measurement 37 Heavy truck 51 km/h lane B	12.5	0.07	16	1.41	16	0.09	12.5	7.27
Measurement 39 Heavy truck 51 km/h lane B	12.5	0.05	16	1.07	16	0.05	16	2.9
Measurement 41 Light truck 46 km/h lane B	12.5	0.01	16	0.3	16	0.01	12.5	0.49
Measurement 42 Heavy truck 51 km/h lane B	12.5	0.08	16	2.42	16	0.09	12.5	8.66
Measurement 43 Heavy truck 52 km/h lane B	12.5	0.12	16	2.69	12.5	0.12	12.5	15.5
Measurement 45 Heavy truck 46 km/h lane B	12.5	0.11	16	2.5	12.5	0.13	12.5	11
Measurement 47 Light truck 44 km/h lane B	16	0.01	20	0.26	16	0.02	16	0.95
Measurement 50 Heavy truck 37 km/h lane B	12.5	0.09	12.5	1.27	10	0.14	12.5	6.58
Measurement 52 Heavy truck 36 km/h lane B	12.5	0.1	16	1.86	12.5	0.07	12.5	5.92
Maximum value		**0.12**		**2.69**		**0.17**		**15.5**

Color legend:

HVPR > = 4

4 > HVPR > = 1.4

1.4 > HVPR > = 1

The last line shows the maximum value of the HVPR index, which was recorded during the measurements for the horizontal x, y and vertical z directions. A value below 1 means the results without exceeding the threshold of human vibration perception. Such values were recorded mainly for the vertical sensor in the attic (last column).

Despite such high values measured for the impact of vibrations by people in the building (Table 2), none of the measurements reported exceeding the threshold of perceptibility of vibrations by the building structure (Table 1).

Based on the observation of many thousands of measurement results, it can be concluded that so far there has not been a situation where the BVPR value above 1 was observed, and the impact of vibrations on people would not be exceeded (HVPR). The occurrence of such a result may indicate the occurrence of anomalies most often caused by the wrong location of the sensor, chafing plaster or the location of the sensor to assess the comfort of people directly on the ground, etc.

To sum up, the ***basic parameter of environmental assessments concerning transport vibrations (investments in transport infrastructure) should be the assessment of the impact of these vibrations on people in buildings***, made in accordance with [5]. Measurements of the impact of vibrations on the building structure should then not be the sole basis for such an assessment.

5. Conclusions

Due to the provisions of the Act [3], it seems to be unjustified from the point of view of environmental assessments – testing only the impact of vibrations on the structure of buildings. ***The negative effects of vibration on people in a building will occur much sooner, before it is manifested on the building structure***. The provisions of the law in force in Poland oblige the investor to ensure comfort due to vibrations also for people in the buildings, and not only for the building structure, which was demonstrated on the basis of a thorough analysis of the current legal situation.

On the basis of the presented materials, it can be concluded that the provisions of the law ***allow for the correct selection of the parameter that should be used to assess the environmental impact of transport vibrations***, but often people who perform environmental assessments and reports and make environmental decisions ***lack knowledge*** in this regard. This may lead to possible claims of users and building owners, and, consequently, may be the basis for obtaining compensation in the event of exceeding the limits of the vibration comfort due to humans.

Thus, incorrectly formulated requirements as to the scope of environmental assessments in relation to the impact of vibrations do not sufficiently protect the interests of the Investor of the transport infrastructure, or the users of the neighboring buildings.

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