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Impact of Changes of the Permissible Railway Noise Levels on Possibilities of Spatial Management in Urban Areas

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1. Introduction

Topic of spatial harmony and life quality are very important in areas located close to railway or situated on post-railway grounds. It was especially important after changes in Law of spatial planning and management, which enable new developments in closed areas of railway transport. Issues of spatial management of railway and post-railway areas are significant for companies, local administration and inhabitants. Evidence of such a situation was conference entitled Spatial planning in post-railway areas, held by Ministry of Infrastructure and Development in October 13th 2015. Lecturers from Polish State Railways, government, local administration, transport experts, designers and scientists discussed how to use railway and discard areas in proper way to create valuable areas for further settlement and investments. It was mentioned, that spatial, economic and demographic development of big cities caused changes like localisation of train lanes inside city centres and housing districts. In the same time, post-railway areas became potential reserve for new functions and are under strong pressure of investing. In the present time this type of landscape in terms of aesthetics and management is different than in surrounding parts of the city (Ryś 2015).

Proper planning of surfaces localised near railway should take into account their real pressure on the environment. Noise is perceived as most important and strongest impact of railway on environment (Makosz 2015). Based on the reports of EU countries, which are collected by European Environmental Agency in the year 2010 the railway noise was a problem for about 12 millions of inhabitants during day time (>55 dB (A)) and for about 9 millions of people during night time (>50 dB(A)) (Clausen 2012).

Taking this into account localisation of new settlements and services near train lanes should be preceded by acoustic analyses. But in the literature related to this issue there are more elaborations touching problem of sound level along roads (Popławski et al. 2012, Profaska 2012, Podawca 2014) or even caused by domestic appliances (Zagubień & Wolniewicz 2017) rather than railways (Deja & Kopeć 2016). Railway noise is perceived as a factor decreasing life quality of citizens and was surveyed in countries like Latvia, Turkey, Korea, Japan and EU (Lim et al. 2006, Paozalyte et al. 2011, Clausen 2012, Demir et al. 2016).

2. Aim and scope analysis

Aim of studies was to evaluate consequences of the law changes in October 1st, 2012 related to increase of permissible noise levels from train lanes for different functions of particular city areas.

To describe this problem actual courses of equal-loudness contours were presented using acoustic maps of Warsaw for the 2017 prepared as digital maps in PUWG 200 system by BMTcom, SVANTEK and PVO companies for President of Warsaw. Following threshold contours were used:

- LN50(2007) equal-loudness contours 50 dB presenting permissible long term average sound level A evaluated for all night times in years 2007-2012,
- LN59(2012) equal-loudness contours 59 dB presenting permissible long term average sound level A after October 1st, 2012,
- LDWN55(2007) equal-loudness contours 55 dB presenting permissible long term average sound level A evaluated for day time (8:00 – 18:00), evening time (18:00-22:00) and night time (22:00-6:00) obligatory in years 2007-2012,
- LDWN60(2007) equal-loudness contours 60 dB presenting permissible long term average sound level A evaluated for day time (8:00 – 18:00), evening time (18:00-22:00) and night time (22:00-6:00) obligatory in years 2007-2012,
- LDWN64(2012) – equal-loudness contour 64 dB showing permissible long term average sound level A evaluated for all days from the year, taking into account day time (8:00-18:00), evening time (18:00-22:00) and night time (22:00-6:00) obligatory after October 1st 2012;
- LDWN68(2012) - equal-loudness contour 68 dB representing permissible long term average sound level A evaluated for all days from the year, taking into account day time (8:00-18:00), evening time (18:00-22:00) and night time (22:00-6:00) obligatory after October 1st 2012.

The course of border of equal-loudness contours LN and LDWN 2007 were taken directly from acoustic maps and contours of LN and LDWN 2012 were estimated by means of interpolation and using of Interpolation and

Reclassify tool from the Arcgis program as acoustic maps became very popular tool in landscape planning.

In this paper the main task was not exact depiction of sound levels. The idea was to describe the belts located in studied area where land development was restricted according to the law from year 2007 and possible since the year 2012. These belts of noise were presented as certain area (Fig. 1, Fig. 2) and also using area-noise coefficients showing the rate of studied terrain, which is not treated as a noise sensitive area according to actual normative.

Due to the characteristics of studied issue and accepted methodology presented paper is a case study. Case studies are increasingly used method in architecture and city planning. The single case study used in the article is based on a detailed analysis of a particular object, through the identification of features and qualitative elements of a certain urban area (Niezabitowska 2014).

Criteria used in selection of areas for studies were:

- direct neighbourhood of railway and housing-trading areas,
- presence of obligatory spatial management plan,
- presence of investments in housing and trading,
- presence of objects under cultural heritage protection (on the base of the list of municipal record of heritage items for Warsaw, July 11th, 2018),
- localisation inside Warsaw administrative borders.

Area selected for further studies was located in Włochy district of Warsaw. It is situated in areas 2-08-10 and 2-08-11 and is crossed by railway line 447. This line is very busy and connect Warsaw West with Grodzisk Mazowiecki and historically it was line connecting Warsaw and Vienna. Lines of long-distance tram are also crossing studied area.

3. Method of analysis

3.1. Normatives regulating the impact of railway and management of real estates

There are several legal documents, which partially regulate way of the real estate management in areas located close to railway. Act on train transport, chapter 9, article 53 define the distance of buildings from the border of railway area as not smaller than 10 meters and distance from lane not smaller than 20 metres. Simultaneously, these distances should be increased to maintain permissible noise level in case of houses, hospitals, kindergartens and schools [Journal of Laws 2003, No. 85, pos. 789].

Table 1. Permissible noise levels in environment caused by railway (based Dz.U. Nr 120 z dnia 5 lipca 2007 r., poz. 826 and Dz.U. 2012, poz. 1109)

Type of area	Permissible noise level A [dB] for railway							
	2007				2012			
	$L_{Aeq\ D}$	$L_{Aeq\ N}$	L_{DWN}	L_N	$L_{Aeq\ D}$	$L_{Aeq\ N}$	L_{DWN}	L_N
a/ protected zone A – health resorts b/ hospitals outside cities	50	45	50	45	50	45	50	45
a/ housing areas b/ areas with long or short term stay of kids and youths c/ areas of social welfare d/ hospitals in cities	55	50	55	50	61	56	64	59
a/ housing development areas, residential districts b/ croft buildings c/ recreation areas d/ housing and servicing areas	60	50	60	50	65	56	68	59
Downtowns of cities > 100,000 inhabitants	65	55	65	55	68	60	70	65

In case of railways the permissible noise levels are depending on function, which is assigned to certain area and type of index. Indices LAegD and LAeqN can be used for setting and controlling of environment usage according to the one day during daytime and night. LDWN index means longterm average noise level A evaluated during all days in the year taking into account day time (8:00–18:00), evening time (18:00-22:00) and night time (22:00-6:00). LN index means long term average noise evaluated for night time during whole year. These indices have application in longterm policy in protection against noise.

Duties in the protection of areas and objects against noise have a background in:

- art. 5 of Construction law stated, that building item as a whole, its parts, building devices need to be designed and constructed concordantly with future time span of usage, standard technical knowledge and maintaining needs defined in attachment I to the directive of European Parliament and European Council No. 205/2011, March 9th, 2011 harmonising conditions of introduction building products to market and cancelling of directive EU 89/106/EWG (protection against noise among others),

- section IX of directive of Ministry of Infrastructure (April 12th, 2002) describing terms of technical conditions for building and their localisation. Houses, housing districts and public buildings should be situated in places with negligible presence of noise and vibrations. If they are present and their values exceeded permissible thresholds the effective protection is necessary like proper distance from source of problem, use of elements decreasing rate of vibrations, screening elements, rational displacement of rooms and isolation inside external construction items (Ministry of Infrastructure April 12th, 2002),
- sections III and IV of Environmental Protection Law stated, that in Study of Conditions and Directions of Spatial Management (SCDSM) and in local plans of spatial management the necessary conditions for nature balance and rational management of environmental resources (among others by protection against noise and emissions from railway) cannot cause any decline of environmental quality outside the railway real estate borders,
- general provisions of the Act on spatial planning and development, including SCDSM is taking into account conditions of life quality of inhabitants including health protection, which should be in agreement with local plan of spatial management (Spatial Planning and Land Development Act of 27 March 2003).

In particular, the requirements of the last two legal acts are consistent with the fundamental principles of sustainable development, which is considered as a socio-economic development where the process of integrating political, economic and social activities takes place. In the same time, maintaining of the natural balance and durability of basic natural processes, in order to guarantee the possibility of satisfying the basic needs of present and future generations are necessary (Environmental Protection Act of 27 April 2001).

3.2. Pressure of railway noise in studied areas

To show the rate of railway noise conditions in studied areas several features were selected for further evaluation. Particular features were representing different indices potentially applicable in long term policy in protection against noise and thus in spatial planning. As many as 22 features were presented in Table 2:

- area between railway and equal-sound contour 50 dB at night, P_{50dBLN},
- area between railway and equal-sound contour 59 dB at night, P_{59dBLN},
- area between railway and equal-sound contour 55 dB at day-evening-night time, $P_{55dBLDWN}$,
- area between railway and equal-sound contour 60 dB at day-evening-night time, $P_{60dBLDWN}$,

- area between railway and equal-sound contour 64 dB at day-evening-night time, $P_{64dBLDWN}$,
- area between railway and equal-sound contour 68 dB at day-evening-night time, $P_{68dBLDWN}$,
- number of buildings vulnerable to noise exceeding standards for night time according to law of 2007, LB_{50dBLN} and law of 2012, LB_{59dBLN},
- number of buildings vulnerable to noise exceeding standards for day-evening-night according to law of 2007, $LB_{55dBLDWN}$, $LB_{60dBLDWN}$ and law of 2012, $LB_{64dBLWN}$, $LB_{68dBLDWN}$,
- number of buildings under conservational protection vulnerable to noise exceeding standards at night time according to law of 2007, LBK_{50dBLN} and law 2012, LBK_{59dBLN},
- number of buildings under conservational protection vulnerable to noise exceeding standards from the year 2007 $LBK_{55dBLDWN}$, $LBK_{60dBLDWN}$ and from the year 2012, $LBK_{64dBLDWN}$, $LBK_{68dBLDWN}$,
- distance from closest housing developments to the railway, LMW-GK,
- distance from closest housing developments to the far lane, LMW-OT,
- distance from closest housing areas to the railway, LMN-GK,
- distance from closest housing areas to the far lane, LMN-OT.

Table 2. Features of vulnerability to noise inside borders of studied area (own elaboration)

No.	Sign	Unit	Value	No.	Sign	Unit	Value
1.	P_{50dBLN}	m^2	113765	12.	$LB_{68dBLDWN}$	pcs.	4
2.	P_{59dBLN}	m^2	28906	13.	LBK_{50dBLN}	pcs.	11
3.	$P_{55dBLDWN}$	m^2	162979	14.	LBK_{59dBLN}	pcs.	0
4.	$P_{60dBLDWN}$	m^2	77466	15.	$LBK_{55dBLDWN}$	pcs.	7
5.	$P_{64dBLDWN}$	m^2	38550	16.	$LBK_{60dBLDWN}$	pcs.	5
6.	$P_{68dBLDWN}$	m^2	21734	17.	$LBK_{64dBLDWN}$	pcs.	2
7.	LB_{50dBLN}	szt.	52	18.	$LBK_{68dBLDWN}$	pcs.	0
8.	LB_{59dBLN}	szt.	10	19.	L_{MW-GK}	m	24
9.	$LB_{55dBLDWN}$	szt.	30	20.	L_{MW-OT}	m	28
10.	$LB_{60dBLDWN}$	szt.	21	21.	L_{MN-GK}	m	31 (6)
11.	$LB_{64dBLDWN}$	szt.	9	22.	L_{MN-OT}	m	39 (11)

4. Results of the analyses

4.1. Indices of railway noise effect

Increase of the risk of noise in studied area due to mitigation of permissible noise level s in the year 2012 was showed using indices of acoustic release, that is to say presentation areas, which were under protection of train noise according to law from the year 2007 and not protected after law changes in the year 2012. Studied indices were as follows:

- acoustic release indices for night time expressed as $W_{uaLN}=(P_{50dBLN}-P_{59dBLN})/P_{50dBLN}$, (Fig. 2),
- acoustic release indices for day-evening-night expressed as $W1_{uaLDWN}=(P_{55dBLDWN}-P_{64dBLDWN})/P_{55dBLDWN}$, (Fig. 1),
- acoustic release indices at night expressed as $W2_{uaLDW}N=(P_{60dBLN}-P_{68dBLDWN})/P_{60dBLDWN}$ (Fig. 1).

In the paper impact of law changes on particular buildings was showed according to their category of protection against noise.

Such analysis was executed using building-acoustic indices, as like:

- building-acoustic overall index for night time expressed as $W_{baLN} = (LB_{50dBLN}- LB_{59dbLN}) / LB_{50dBLN})$,
- building-acoustic overall index for day-evening-night expressed as $W1_{baLDWN}=(LB_{55dBLWN}- LB_{64dbLDWN})/LB_{55dBLDWN})$ and $W2_{baLDWN} = (LB_{60dBLWN}- LB_{68dbLDWN}) / LB_{60dBLDWN})$,
- building-acoustic cultural area index for day-evening-night expressed as $W3_{baLDWN}=(LBK_{55dBLDWN}-LBK_{64dBLDWN})/LBK_{55dBLDWN}$ and $W4_{baLDWN}= (LBK_{60dBLDWN}-LBK_{68dBLDWN})/LBK_{60dBLDWN}$.

Table 3. Acoustic indices of studied area (own elaboration)

Index	Sign	Unit	Value
Night release indices			
Night time	W_{uaLN}	-	0.746
Day-evening-night (55-64 dB)	$W1_{uaLDWN}$	-	0.763
Day-evening-night (60-68 dB)	$W2_{uaLDWN}$	-	0.719
Building-acoustic indices			
Night overall	W_{baLN}	-	0.808
Overall, day-evening-night (55-64 dB)	$W1_{baLDWN}$	-	0.700
Overall, day-evening-night (60-68 dB)	$W2_{baLDWN}$	-	0.809
Cultural areas, day-evening-night (55-64 dB)	$W3_{baLDW}$	-	0.714
Cultural areas, day-evening-night (60-68 dB)	$W4_{baLDWN}$	-	1.000

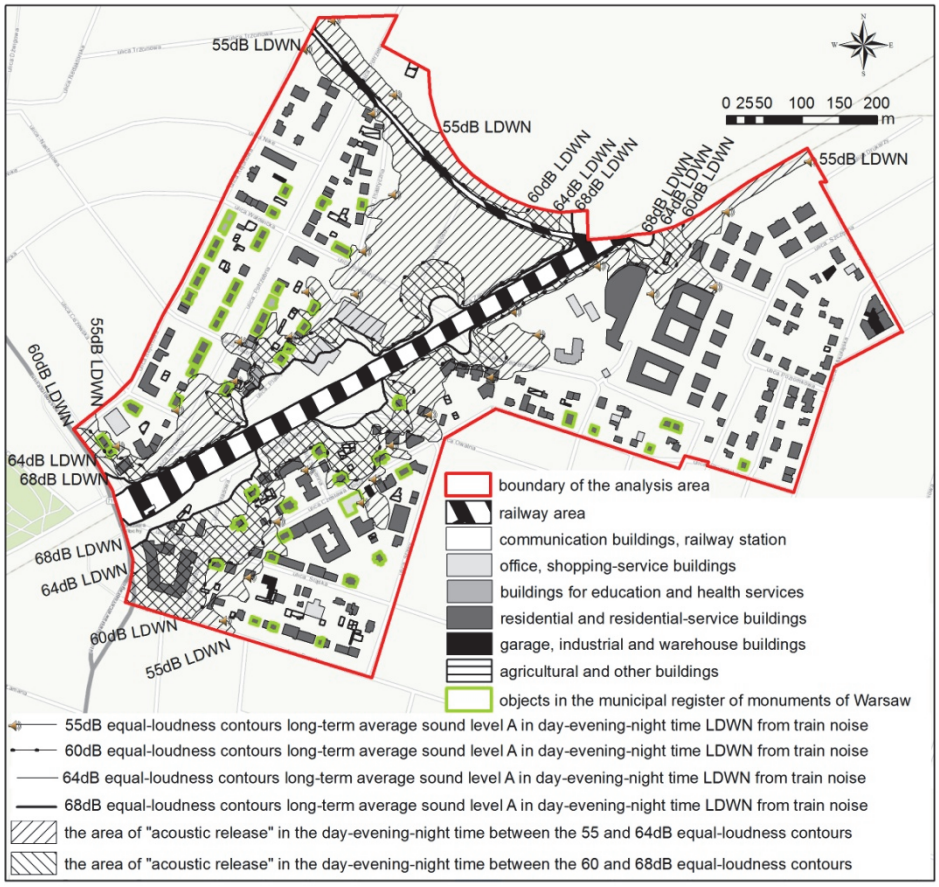

Fig. 1. The area of "acoustic release" when changing the permissible sound levels in the day-evening-night time (own elaboration)

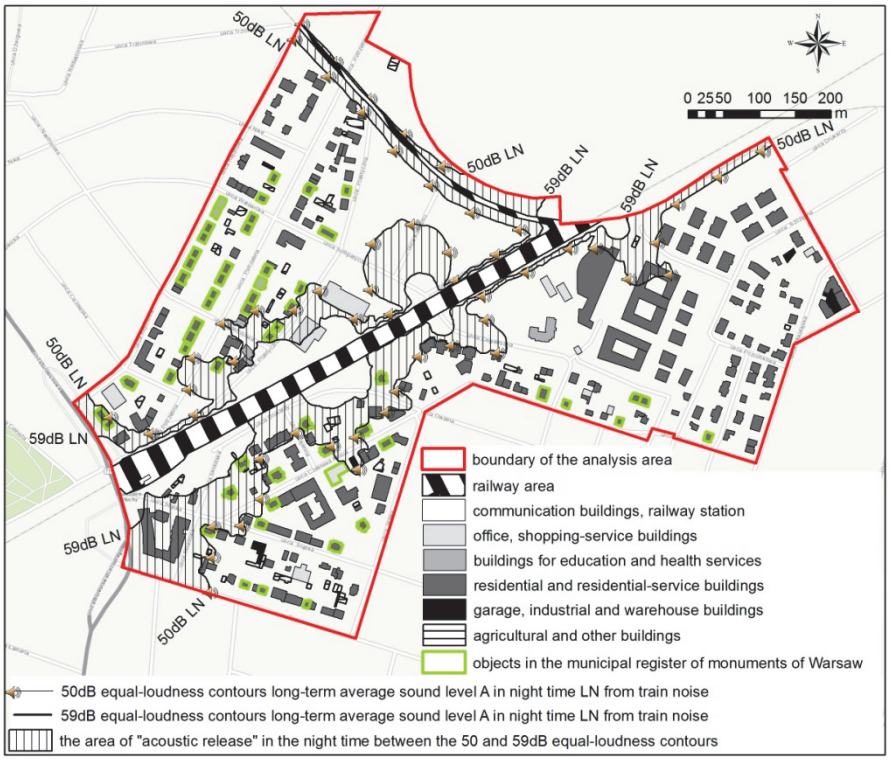

Fig. 2. The area of "acoustic release" when changing the permissible sound levels in the night time (own elaboration)

4.2. Railway noise and spatial planning

For part of studied area the local plan of spatial management is known (Stare Włochy, Stawy street area, law No. XXXVII/1119/2008, Warsaw City Council, July 10th, 2008). Unfortunately it is difficult to find there any information about noise problem, although such a danger is present. Only notation, which could minimise impact of railway is mentioned in §5 where rules of protection and shaping of spatial planning and needs of development of public areas using acoustic barriers were set.

It is worthy to emphasize, that in proposed directions of development of studied area listed in Study of Conditions and Directions of Spatial Management (SCDSM) for Warsaw, there is no decision about areas located between railway and housing developments. In most of the terrain houses should be higher than 12 meters but in some parts height of buildings can reach even 20 meters in

height. Some protection can give note, that on the southern part of railway 40 to 60% of biologically active area should be left in case of surrounding individual houses (Fig. 3).

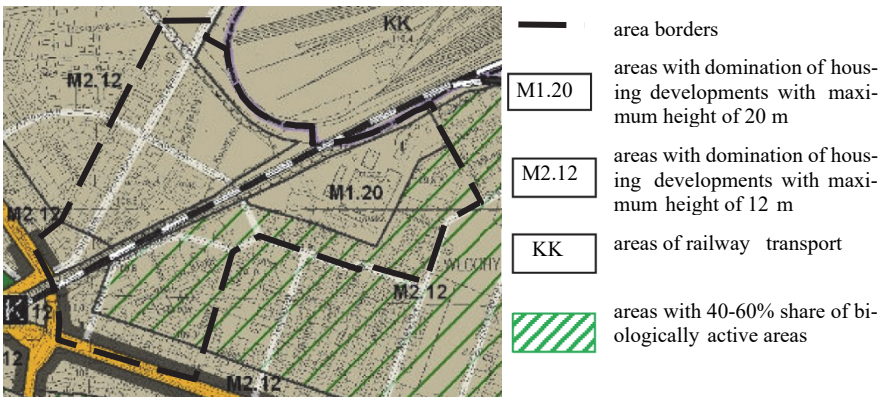

Fig. 3. Planned functions of spatial planning in studied area based on SCDSP for Warsaw

As it was presented on analysed example topic of noise is often marginalized by local groups of experts preparing planning documents. This situation was found in many towns and cities and means, that chapter 14 of Law of environment protection are not realised. This is causing problems in proper categorisation of areas due to their actual state of protection against noise (Kowalczyk 2011).

5. Summary and conclusions

Spatial analyses showed precisely how important is impact of spatial management on the increase of permissible levels of noise for so called fragile functions. Using accepted parameters it can be stated, that:

- the noise present during night time the area treated as fragile was minimised for 75% and rate of buildings vulnerable for noise decreased for 80%, from 52 buildings (including 11 with conservational protection) according to law in year 2007 and 10 after changing law in the year 2012 (with no building encompassed by conservational protection),
- according to day-evening-night noise in areas of private housing, areas connected with stay of kids and youths, social welfare and hospitals change of permissible sound level from 55 to 64 dB caused decrease of fragile territory for 76% and the same time from 30 different buildings mentioned above only 9 were still under protection,

- in case of the noise (day-evening-night time) in residential district, building developments, housing-servicing and recreational areas change from 60 to 68 dB limited fragile surface for 72%, thus only 4 buildings left from initial number equal to 21,
- in the context of acoustic protection of landmarket buildings it should be mentioned, that according to LDWN index there are no buildings in areas with noise above 68 dB, two of them above 64 dB, 5 buildings in area with noise level above 60 dB and 7 in case of 55 dB,
- there are not protected buildings above the 59 dB threshold, while formerly with noise level equal to 50 dB as many as 11 objects were present.

Taking into account presented data it is visible, that investors have greater possibilities to develop areas situated near railway without additional acoustic barriers. Unfortunately, inhabitants will be exposed for negative pressure of noise. Law changes caused fast development of housing areas in the studied part of Warsaw and good example are residential areas 73/6 an 73/4 (Fig. 4).

Of course possibility of development of degraded surfaces near railway is positive aspect of studied issue. Actually only few cases of proper usage of such areas, with regard to actual or future inhabitants and creation of landscape structure avoiding spatial conflicts are known (Makosz 2015).

Knowing above arguments it can be mentioned, that positive aspects of spatial management in areas near railway are location of different services between lanes and housing developments.

But still negative points are predominating, like:

- short distance between railway and houses (real estate no. 67),
- discrete line of acoustic barriers near housing areas (Fig. 5).

Acoustic barriers are perceived as economic and effective way to reduce noise impact on surrounding areas and is recommended in some countries together with additional alternative routes inside and outside of cities, which can increase distance between lanes and housing districts (Demir et al. 2016). Studies of other authors showed, that noise pollution related to transport is sometimes very annoying for inhabitants and as a consequence the number of grievances would be send to local administration, especially in countries like Korea and Japan (Lim et al. 2006). In some cases screens of 2 or 4 metres height and optimal design of housing district are enough to prevent significant part of noise pollution ranged from 2 to 15 dBA (Demir et al. 2016).

In summary, it should be emphasize that near railway areas always generates some conflicts. For instance, after settling of certain areas new residents complain despite being conscious about existing train lanes before start of the

construction project. Nowadays, some grievances will have no any legal bases due to change of permissible sound levels. In areas where noise is higher, than new thresholds it is necessary to form local spatial structure in considered way.

Fig. 4. New residential development near the railway area [autor's photo]

Fig. 5. The discontinuity of acoustic barriers [autor's photo]

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Abstract

In this paper problem of noise caused by railway in cities was studied. This aspect was often marginalised in spatial planning process. Using example of areas located in Włochy district (Warsaw, Poland) the function of area and the new permissible sound levels were shown. Analyses based on data obtained from Warsaw acoustic maps generated in the year 2017, spatial management plans and current state of development and investments inside borders of real estate 2-08-10 and 2-08-11.

Based on 22 superficial and quantitative features related to 50 and 59 dB limit sound levels at night and 55, 60, 64 and 68 dB at day-evening-night time, changes in the spatial development possibilities in the analysed area were shown. On the base of area indices and using ArcGis software positive and negative aspects of studied area were presented. The analysis clearly showed that the increase in sound levels by 9 dB at night and 8-9 dB during daylight-night-time resulted in the reduction of areas considered to be susceptible to noise before 2012 by 71.9-76.3%, and decrease of the number of buildings exposed to noise by 70-80%. However, the analysis of the local spatial development plans and the Study of Conditions and Directions of Spatial Development showed that the problem of noise is minimized in documents and planning studies. The effect of law changes is possibility of the implementation of housing projects in the near vicinity of the railway area and the approval of the discontinuity of acoustic barriers along the railway tracks.

Keywords:
spatial planning, railway noise, permissible noise levels, sustainable development

Wpływ zmian dopuszczalnych poziomów hałasu kolejowego na możliwości zagospodarowania przestrzennego terenów miejskich

Streszczenie

W artykule poruszono problem zagrożenia hałasem kolejowym w miastach. Aspekt ten jest często marginalizowany w procesie planowania przestrzennego. Na wybranym przykładzie obszaru położonego w dzielnicy Włochy w Warszawie ukazano lokalizację funkcji terenu na tle zmian dopuszczalnych poziomów hałasu. Analiza została oparta o dane z map akustycznych dla Warszawy opracowanych w 2017 r., opracowań planistycznych oraz obecnego stanu zagospodarowania i realizowane inwestycje w granicach obrębu 2-08-10 i 2-08-11.

Na podstawie 22 cech powierzchniowych i ilościowych odniesionych do granicznych poziomów dźwięku 50 i 59 dB w nocy oraz 55, 60, 64 i 68 dB w porze dzienno-wieczorowo-nocnej ukazano zmiany w możliwościach zagospodarowania przestrzennego na analizowanym obszarze. Na podstawie wskaźników powierzchniowych opracowanych z wykorzystaniem oprogramowania ArcGis, ukazano mocne i słabe strony badanego terenu. Wykonana analiza jasno pokazała, że zwiększenie dopuszczalnych poziomów dźwięku o 9dB w nocy i 8-9dB w porze dzienno-wieczorowo-nocnej spowodowała zmniejszenie terenów uznawanych za wrażliwe na hałas przed 2012 r. o 71,9-76,3%, oraz zniwelowanie liczby budynków narażonych na hałas o 70-80%. Natomiast analiza zapisów miejscowych planów zagospodarowania przestrzennego oraz Studium Uwarunkowań i Kierunków Zagospodarowania Przestrzennego pokazała, że problem hałasu jest minimalizowany w dokumentach i opracowaniach planistycznych. Efektem tego jest dopuszczanie realizacji inwestycji mieszkaniowych w bliskiej odległości obszaru kolejowego oraz zgoda na niecią-głość ekranów akustycznych wzdłuż torów kolejowych.

Słowa kluczowe:
planowanie przestrzenne, hałas kolejowy, dopuszczalne poziomy hałasu, zrównoważony rozwój