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Land development policy as related to real estate influenced by railway noise in the context of allowable indicators that have been recently modified in Poland

Abstract

The paper deals with the problem of rail noise pollution in cities in the context of legal amendments. This aspect is often neglected in the process of spatial planning. The authors were motivated to undertake this analysis both by legal changes permitting higher levels of acceptable noise thresholds, which were introduced and legalised in October 2012, and by the intensified levels of investment in areas neighbouring railways. On selected examples of residential areas in Warsaw, Poland (the city districts of Ursus, Białołęka and Ursynów), relevant land development sites were analysed against the course of isophones showing permissible noise levels. The analysis was based on data taken from acoustic maps for Warsaw from 2012 and 2017, planning studies, the Topographic Objects Database (BDOT10k) and the current state of land development. Using ArcGis software, 22 features, three study areas, and corresponding quantitative indicators were assessed. The authors presented the level of railway noise pollution set against the general spatial development. The analysis demonstrated that the changes in legislation have resulted in the "acoustic release" of land near railways; i.e., in these areas new, less-restrictive regulations on noise pollution have become permissible. In turn, the number of buildings that were considered at risk of noise pollution before 2012 has fallen.

The aforementioned regulatory changes may unfavourably impact residential areas neighbouring railways and this has even provoked a wider discussion at the European Union level.

Keywords

Rail noise risk • L_N and L_{DWN} indicators • spatial planning • spatial land development

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Introduction

Ever larger numbers of people are living in cities. The dynamic urbanisation that began in the mid-nineteenth century was mainly driven by industrialisation. These days, it is caused by the desire for a better quality of life access to services and entertainment and, in general, improved working conditions and remuneration. Over 55% of the world's population and almost 75% of Europeans live in cities, including 60% of Poles (World Urbanization Prospects 2018). The Polish capital, Warsaw, is a good example of the considerable changes to city populations over the last 70 years. In 1951, Warsaw had 803,800 inhabitants. By 1975, 25 years later, this had risen to 1,463,400. Over the next 25 years, this number increased again to 1,671,700 and, by the beginning of 2019, Warsaw's population had reached almost 1,778,000 inhabitants (Statistical Office in Warszawa 2021). The progressive urbanisation of cities continuously reduces the amount of available land for investment. The characteristics of urbanisation and suburbanisation have become the subject of both global and local (in our case, Polish) research on different levels (Degórska 2012; ed. Śleszyński 2012; Spórna 2018; Podawca & Mrozik 2019; Podawca et al. 2019), with particular regard to the uncontrolled development of other large cities such as, for example, Barcelona (Roca et al. 2004), Rome (Di Zio & Montanari 2010), Seoul (Woo 2014), Moscow (Brade & Rudolph 2004) and metropolitan areas in the USA (Huang et al. 2017). The huge demand for apartments and services is driving the search for new sites, even if the location is not environmentally favourable for residential purposes; e.g., areas near railway lines that are subject to intense investment pressure. The landscape here currently differs both aesthetically and in development character from the surrounding regions (Ryś 2015). However, proper spatial planning of areas near railway lines should include consideration of their actual impact on the environment. Noise is the primary and most substantial risk (Makosz 2015; Podawca & Staniszewski 2019; Preis et al. 2019). According to reports from EU member states received by the European Environment Agency in 2010, railway noise during the day was a problem for about 12 million EU inhabitants who were exposed to noise levels above 55dB (EU Directive 2002/49/WE) and, at night, for about 9 million people, who were exposed to noise levels exceeding 50dB (Clausen et al. 2012). Therefore, the decision to site new residential and service buildings close to sources of railway noise should be preceded by appropriate acoustic analysis. Unfortunately, the subject literature contains many more studies on the impact of

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road noise (Popławska et al. 2012; Profaska 2012; Podawca 2014), or even noise from household devices (Zagubień & Wolniewicz 2017) than on the impact of noise pollution from railway infrastructure (Deja & Kopeć 2016; Podawca & Staniszewski 2019). The issue of noise pollution – including railway noise – the methodology for studying it, and the visualisation guidelines for hazard maps are presented in Felcyn et al. 2018. That paper presents a proposal for a methodology of data collection and presentation based on the example of the city of Poznań (Poland). In that case, the issue of noise pollution from railway lines was studied, in particular in the context of European standards – the Environmental Noise Directive (END); here, projects called 'Noise Action Plans' (NAP) deserve special attention.

The level at which railway noise causes a (negative) human response is estimated to be 42dB (Miedema & Oudshoorn 2001; Petersen & Waye 2007). For night time noise, research shows that adverse changes in sleep quality start to appear when the noise level exceeds 30dB. Such sound intensity may cause waking up (Sobotova 2010). Sleeping at the sound level of 55-60dB does not provide the desired quality of rest and almost certainly leads to waking up (Sobotova 2010; Berregard & Stansfeld 2014). The World Health Organisation (WHO) estimates that 40dB of noise outside buildings at night is the upper limit at which people are still protected against the harmful effects of noise on sleep and health (WHO 2009).

Additionally, some reports have appeared suggesting even that the risk of heart attacks slightly increases at noise levels from 30dB to 55dB at night, (Passchier-Vermeer & Passchier 2000). Finnish studies, performed on a population of 7019 adults, showed that people with greater levels of fear and those suffering from anxiety might experience sleep disorders at levels 5dB lower than the so-called "ordinary" population, for whom such disturbances appear at night-time sounds of 50dB (Halonen et al. 2012). Environmental noise increases the risk of hypertension when exposed to levels above 65dB. The risk of hypertension increases with higher decibels (Jarup et al. 2008; Pawlas 2015). Short-term surveys show that, for each 10dB increase in the volume of sound from the surrounding environment, one can observe an increase of 1 mm Hg (95% CI: 0.3 to 1.6, $p = 0.004$) in systolic pressure and 0.6 mm Hg (95 % CI: 0.1 to 1.2, $p = 0.025$) in diastolic pressure of (Babisch et al. 2009).

Noise-prevention approaches combine all required actions aimed at improving the acoustic climate in areas at risk (Vogiatzis & Remy 2017). In general, noise-protection policy deals with two types of impact: reducing noise emitted by infrastructure facilities, (as represented by relevant indicators), and reducing the number of people who are exposed to high levels of environmental noise (as defined by existing legislation), i.e., limiting the size of residential areas.

It should be added that noise level is one of the critical factors taken into account when deciding where to live (Zwierzchowska 2017). Along with other specific parameters of a given area, such as land cover and land-use types, and other anthropogenic elements, this falls under the comprehensive concept of Ecosystem Services (ES), illustrating the potential of a particular area. ES evaluation results set the tone for the development of urban space, e.gl, towards a corresponding increase in the share of green areas. To underline this point, reference can be made to publications 2008a and 2008b by Beim and Tölle. They show that the main motivation for deciding to leave a city is a combination of multiple negative factors, among which heavy traffic and even the age and technical condition of buildings play an essential role (Beim & Tölle 2008b). Factors such as these, including noise levels, form one component of a larger puzzle that defines quality of life, shapes the main directions in spatial planning (Von der Dunk, 2011), and determines property values (Simons & Jaouhari 2004). Unique indicators (relevant for the EU – including Poland) showing the noise levels affecting people are presented in detail in Wrótny and Bohatkiewicz 2020, and Podawca and Karpiński 2021. The authors studied the impact of railway noise on quality of life with respect to acoustic maps and European Union Directive 2002/49/EC. It is particularly noticeable in this context that the relevant legal amendments concerning noise indicators, approved in Poland after 2012, may not fully meet the requirements of said Directive. To clarify these ambiguities, the new noise pollution standards (in the case of this article referring to railway noise) have been discussed extensively by the European Commission (EC Press release from 18 February 2021). What is more, one should mention crucial regulations of the EC which aim to reduce the noise level of rolling stock which runs through urbanized areas e.g., Commission Implementing Regulation (EU) 2015/429 of 13 March 2015, or Commission Implementing Regulation (EU) 2019/774 of 16 May 2019). Therefore, it can be concluded that the issue of data modelling aimed at the practical management of noise pollution is a universal one and is of particular relevance to residential areas located close to railway lines.

Research problem

The aim of the performed analysis was to show the effects of the changed legislation to increase permissible noise levels caused by railway lines (which came into force on 1 October 2012) on spatial development. As the central part of the scientific objective, the following research tasks (RT) were formulated:

- demonstration of the changes which took place between 2012 and 2017 in the "acoustic climate" in selected areas – RT1;
- presentation of the railway noise hazard in the analysed regions, according to the regulations on permissible noise levels from 2007 and 2012, based on a developed list of 22 superficial and quantitative features related to this hazard – RT2;
- differential analysis of phenomena that appear while doing spatial research on these areas due to the reduction of permissible railway noise levels – RT3.

The research areas chosen for analysis were based on the following selection criteria:

- the presence of an active railway line, through which rail transportation is conducted at national or regional level,
- the existence of functions and objects within the areas which, following the applicable legal regulations, are classified as areas exposed to noise and, hence, are subject to permissible levels of railway noise,
- variation in the degree of urbanisation in the area.

To investigate the above-mentioned problems, we selected three areas located in Warsaw, Poland; namely the city districts of Ursus, Białołęka and Ursynów (Fig. 1).

The selection of test sites was driven by their slightly different nature, as well as their location in the territorial area of Warsaw. It should be mentioned that no investments related to the reconstruction of railway lines or other modernisation activities that could quickly change the noise parameters in the immediate vicinity have been carried out in the chosen areas. In order to draw reliable conclusions, we should add that the study areas lack noise protection screens (Ursynów, Białołęka), or only have sections of them installed along the railway lines (Ursus).

Each study area can be easily identified using the 'Geoportal' public map portal, authorised and maintained by the head office of the Polish Office of Geodesy and Cartography; details can be found at www.geoportal.gov.pl. Moreover, the areas can also be localised using a publicly-available, interactive map of railway lines, published by Polish State Railways (http://mapa.plk-sa.pl).

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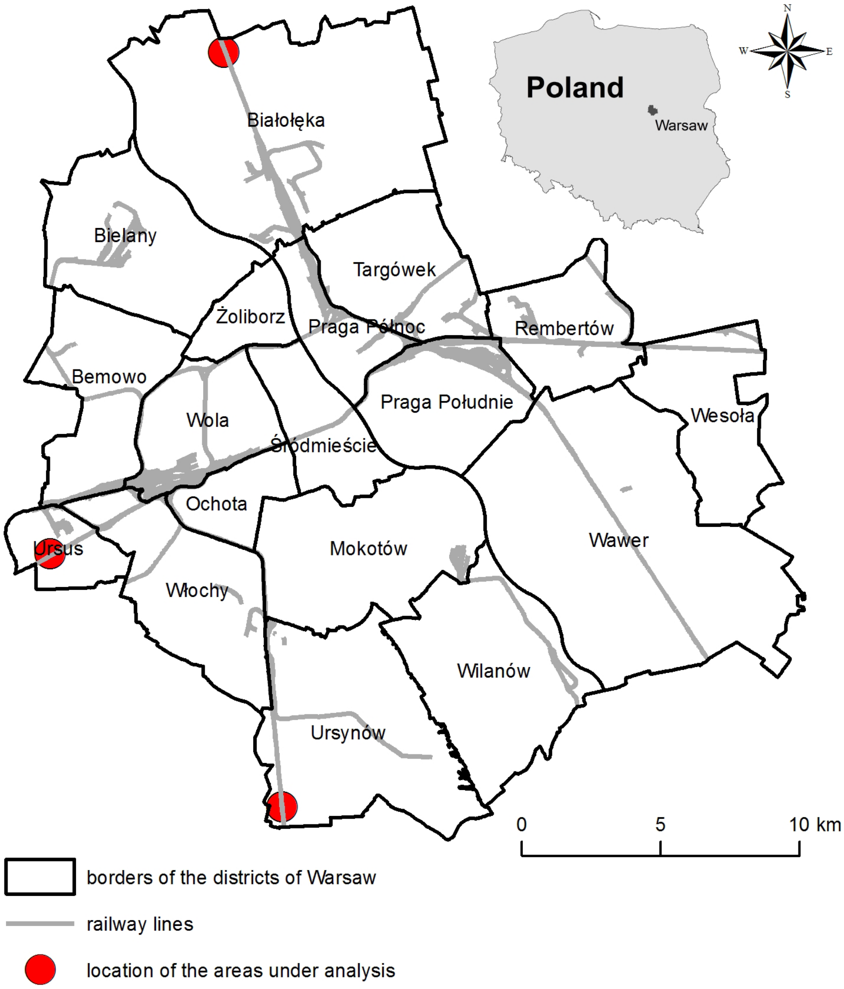

Figure 1 Location of the analysed areas, Warsaw, Poland
Source: own elaboration

The first area analysed is in Ursus (Area I), with the centroid represented by geographic coordinates: N52°11'45'', E20°53'3''. The area is delimited by the cadastral units (territorial entity for settlements in Poland) 2-09-06 - "Piastów" to the West, 2-11-09, 2-11-02 to the South, 2-09-08 to the East and 2-09-07 and 2-09-06 to the North. The analysed area covers 49.65 ha, and the railway lines take up 2.82 ha. Warszawa Ursus - Niedźwiadek railway station is located within this area, and the E65 railway line (route VI) to Katowice runs through here as well. The railway line is one of the main international routes, with permissible traffic speeds of 60 km/h to 120 km/h (with four rail gauges for different purposes).

The second study area is located in Białołęka (Area II), with the centroid represented by geographic coordinates: N52°19'45'', E21°0'30''. The area is delimited by the cadastral units 4-02-06, 4-02-11 to the West; 4-02-17, 4-17-08 to the South, 4-17-02, 4-17-06 to the East and 4-02-25 and the border of the Jabłonna municipality to the North. The analysed area covers 65.65 ha, including railway area of 2.77 ha. The railway line to Gdańsk runs through the district and the Warszawa Choszczówka railway station is situated here. The railway line is one of the main high-speed routes with permissible traffic speeds of up to 160 km/h.

The third area analysed is located in Ursynów (Area III), with the centroid represented by geographic coordinates: N52°09'00'', E21°02'43''. The area is delimited by cadastral units 1-09-60 – "Zgorzała" to the West, 1-09-69 – "Mysiadło" to the South, 01-09-70 to the East and units 01-09-57 and 01-09-55 to the North. The total study area covers 125.14 ha. In this case, the area covered by the railway is 2.84 ha, and the main railway line runs to Kraków. The railway track is also a main high-speed route with permissible traffic speeds of up to 160 km/h.

Methods

Due to the nature of the principal problem and the research methodology, the analysis was performed as a case study. The case study has become the prevalent analytical method in architecture and urban planning.

To proceed with the RT1 research task, we used acoustic maps for Warsaw from the years 2012 and 2017, produced digitally in the Polish national 'PUWG 2000' coordinate system by the publishing houses "BMTcom", "SVANTEK" and "PVO" for the office of the Mayor of the Capital City of Warsaw. We used ArcGIS software to overlay the course of individual isophones on the map of each research area. Areas exposed to railway noise of different levels were determined in relation to the railway line terrains.

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Table 1. Analysis indicators

Indicator name	Indicator symbol	Indicator formula
„Acoustic release" - Night	WUA_{LN}	$\frac{F_{LN\rightarrow 50dB} - F_{LN\rightarrow 59dB}}{F_{LN\rightarrow 50dB}}$
"Acoustic release" - Day-Dawn-Night	W_1UA_{LDWN}	$\frac{F_{LDWN\rightarrow 55dB} - F_{LDWN\rightarrow 64dB}}{F_{LDWN\rightarrow 55dB}}$
	W_2UA_{LDWN}	$\frac{F_{LDWN\rightarrow 60dB} - F_{LDWN\rightarrow 68dB}}{F_{LDWN\rightarrow 60dB}}$
"Acoustic-functional release"- Night	$WUFA_{LN}$	$\frac{FTU_{LN\rightarrow 50dB} - FTU_{LN\rightarrow 59dB}}{FTU_{LN\rightarrow 50dB}}$
"Acoustic-functional release" - Day-Dawn-Night	W_1UFA_{LDWN}	$\frac{FTU_{LDWN\rightarrow 55dB} - FTU_{LDWN\rightarrow 64dB}}{FTU_{LDWN\rightarrow 55dB}}$
	W_2UFA_{LDWN}	$\frac{FTU_{LDWN\rightarrow 60dB} - FTU_{LDWN\rightarrow 68dB}}{FTU_{LDWN\rightarrow 60dB}}$
„Construction-acoustic" - General/Night	WBA_{LN}	$\frac{LB_{LN\rightarrow 50dB} - LB_{LN\rightarrow 59dB}}{LB_{LN\rightarrow 50dB}}$
"Construction-acoustic" – General/Day-Dawn-Night	W_1BA_{LDWN}	$\frac{LB_{LDWN\rightarrow 55dB} - LB_{LDWN\rightarrow 64dB}}{LB_{LDWN\rightarrow 55dB}}$
	W_2BA_{LDWN}	$\frac{LB_{LDWN\rightarrow 60dB} - LB_{LDWN\rightarrow 68dB}}{LB_{LDWN\rightarrow 60dB}}$

Source: own elaboration

As a result, a spatially-oriented map showing deterioration or improvement of the acoustic climate was obtained.

The implementation of task RT2, as a detailed characteristic of railway noise risk, was based on the analysis of 22 features already used in the subject literature (Podawca & Staniszewski 2019; Podawca & Karpiński 2021). These features (all abbreviations and marks in line with domestic terminology officially accepted in the legal regulations) include:

- the terrain surface from the border of the railway area to the range of the isophone L_N 50dB for night time marked as $F_{LN\rightarrow 50dB}$ (feature No. 1) and to the range of the isophone L_N 59dB for night time marked as $F_{LN\rightarrow 59dB}$ (feature No. 2);
- the terrain surface from the border of the railway area to the range of the isophone L_{DWN} 55dB for the day-evening-night time, marked as $F_{LDWN\rightarrow 55dB}$ (feature No. 3), to the range of the isophone L_{DWN} 60dB for the day-evening-night time, marked as $F_{LDWN\rightarrow 60dB}$ (feature No. 4), to the range of the L_{DWN} isophones 64dB in the day-evening-night time, marked as $F_{LDWN\rightarrow 64dB}$ (feature No. 5), to the range of the L_{DWN} isophone 68dB for the day-evening-night time, marked as $F_{LDWN\rightarrow 68dB}$ (feature number 6);
- the number of buildings exposed to above-normal noise situated within the L_N 50dB isophone at night time according to the regulations from 2007, marked as $LB_{\rightarrow 50dBLN}$ (feature No. 7), the number of buildings located within the isophone L_N 59dB at night time according to the rules from 2012, marked as $LB_{LN\rightarrow 59dB}$ (feature No. 8), the number of buildings located within the isophone L_{DWN} 55dB in the day-evening-night time according to the regulations from 2007, marked as $LB_{LDWN\rightarrow 55dB}$ (feature No. 9), the number of buildings located within the isophone L_{DWN} 60dB in the day-evening-night time according to the rules from 2007, marked as $LB_{LDWN\rightarrow 60dB}$ (feature No. 11), and the number of buildings located within the L_{DWN} 68dB isophone in the day-evening-night time according to the rules of 2012, marked as $LB_{LDWN\rightarrow 68dB}$ (feature No. 12);
- the distance of the nearest multi-family residential buildings from the railway area, marked as $L_{MZW\rightarrow TK}$ (feature No. 13), from the axis of the outermost railway line, marked as $L_{ZM\rightarrow OT}$ (feature No. 14);
- the distance of the nearest one-family residential buildings from the railway area, marked as $L_{ZJ\rightarrow TK}$ (feature No. 15), from the axis of the outermost railway line, marked as $L_{ZJ\rightarrow OT}$ (feature No. 16);
- areas of residential, one-family housing where children and adolescents stay permanently or temporarily, nursing homes and city hospitals located within the range of the L_{DWN} 55dB isophone, marked as $FTU_{LDWN\rightarrow 55dB}$ (feature No. 17), and located within the range of the L_{DWN} 64dB isophone, marked as $FTU_{LDWN\rightarrow 64dB}$ (feature No. 18);
- areas of multi-family and collective residences, farm buildings, recreation and leisure, residential and service areas located within the isophone L_{DWN} 60dB, marked as $FTU_{LDWN\rightarrow 60dB}$ (feature No. 19), and located within the isophone L_{DWN} 68dB, marked as $FTU_{LDWN\rightarrow 68dB}$ (feature No. 20);
- areas of one-family housing connected with the permanent or temporary stay of children and youth, social care homes, city hospitals, multi-family and collective housing, farm buildings, recreation and leisure, residential and service buildings located within the isophone L_N 50dB, marked as $FTU_{LN\rightarrow 50dB}$ (feature No. 21), and located within range of isophone L_N 59dB, marked as $FTU_{LN\rightarrow 59dB}$ (feature No. 22).

The terms "day", "evening" and "night" are precisely defined in Directive 2002/49/EC of the European Parliament and Council of 25 June 2002. The definition determines "day" as between 6:00 to 18:00 (6:00AM to 6:00PM), "evening" from 18:00 to 22:00 (6:00PM to 10:00PM) and "night" from 22:00 to 6:00 (10:00PM to 6:00AM).

The most analytical task, RT3, utilises a proprietary set of indicators. The indicators were based on the Regulation of the Ministry of the Environment from 1 October 2012 concerning the permissible environmental noise levels according to art. 113 § 1 of the Legal Act from 27 April 2001 – Environment Protection Law and the Regulation of the Ministry of the Environment from 14 June 2007 on permissible noise levels in the environment. We have proposed nine relevant indicators of so-called "Acoustic release" which are listed in Table 1.

Results and discussion

Isophones indicated on the acoustic maps as the result of interpolation of the 59dB, 64dB and 68dB levels performed for the two periods: 2012 and 2017 (Table 2).

The calculated results show that the acoustic environment deteriorated in areas with a higher degree of urbanisation (Areas I and II). This deterioration was 5.39% in Area I and 9.81% in Area II in the night time. In the case of day-evening-night time, the relevant differences were smaller in Area I, 3% for 64dB and 1.22% for 68dB, but much more significant in Area II, 11.28% for 64dB and 7.61% for 68dB. The increasing area of the terrains

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Table 2. Areas and percentage shares of the terrains with exceeded noise levels caused by rail noise within the analysed boundaries according to acoustic maps from 2012 and 2017

Isophone name	DISTRICT	Year 2012		Year 2017	
		Noise-endangered area	Terrain percentage	Noise-endangered area	Terrain percentage
		[ha]	[%]	[ha]	[%]
$L_{N} \rightarrow 59$ dB	URSUS (I)	3.79	7.64	6.46	13.03
$L_{DWN} \rightarrow 64$ dB		8.61	17.38	10.10	20.38
$L_{DWN} \rightarrow 68$ dB		4.33	8.74	4.94	9.96
$L_{N} \rightarrow 59$ dB	BIAŁOŁĘKA (II)	4.55	6.93	10.99	16.74
$L_{DWN} \rightarrow 64$ dB		6.68	10.18	14.09	21.46
$L_{DWN} \rightarrow 68$ dB		2.71	4.13	7.71	11.74
$L_{N} \rightarrow 59$ dB	URSYNÓW (III)	1.53	1.23	1.27	1.01
$L_{DWN} \rightarrow 64$ dB		4.13	3.30	3.07	2.45
$L_{DWN} \rightarrow 68$ dB		1.23	0.98	0.85	0.68

Source: own elaboration

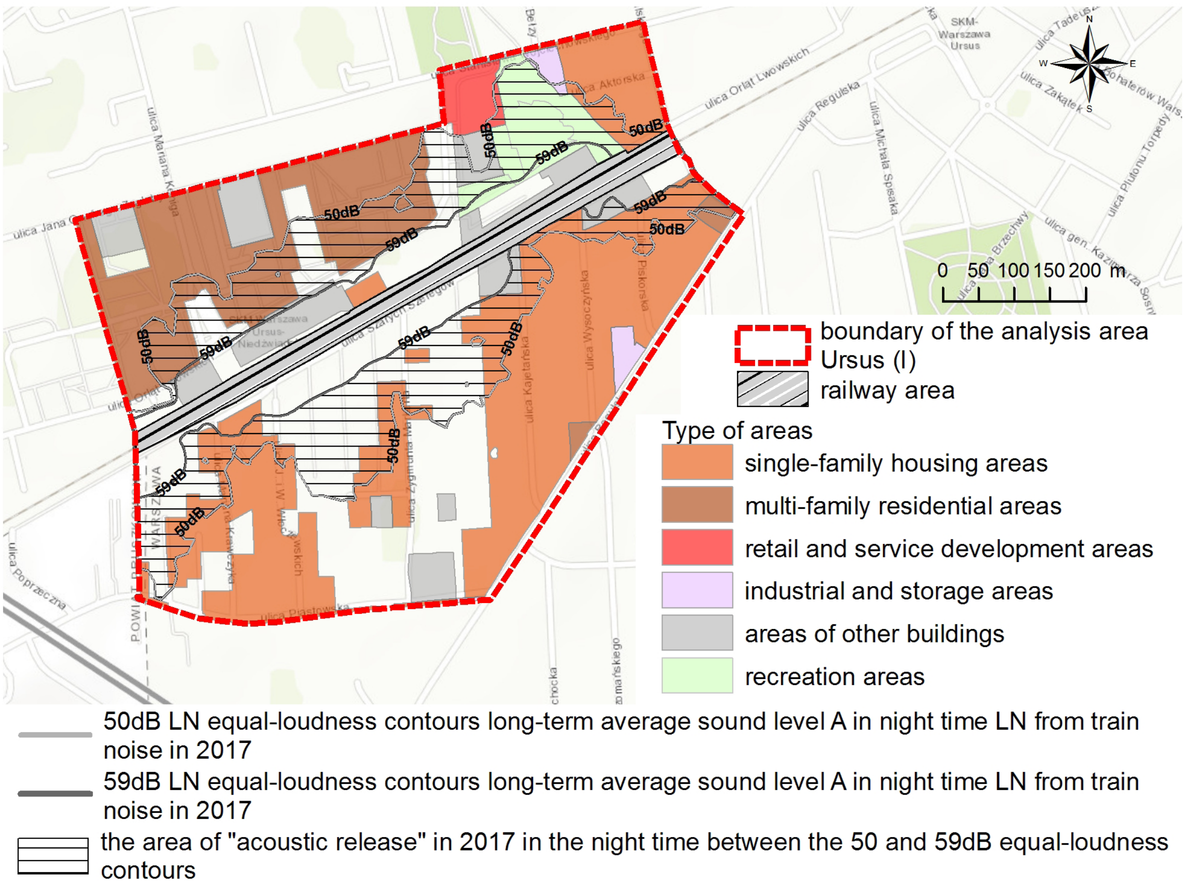

Figure 2. The area of "acoustic release" after changing the permissible sound levels in the night time in the area under analysis, Area 1 (Ursus)
Source: own elaboration

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Table 3. Features of sensitivity to noise within the boundaries of the analysed areas

Feature No.	Feature symbol	Feature unit	Feature value		
			URSUS (I)	BIAŁOŁĘKA (II)	URSYNÓW (III)
1	$F_{LN \rightarrow 50dB}$	m^2	208 637	323 317	120 815
2	$F_{LN \rightarrow 59dB}$	m^2	64 584	109 909	12 656
3	$F_{LDWN \rightarrow 55dB}$	m^2	254 671	412 510	197 708
4	$F_{LDWN \rightarrow 60dB}$	m^2	166 783	242 193	79 266
5	$F_{LDWN \rightarrow 64dB}$	m^2	101 011	140 877	30 685
6	$F_{LDWN \rightarrow 68dB}$	m^2	49 357	77 107	8 495
7	$LB_{LN \rightarrow 50dB}$	units	138	163	12
8	$LB_{LN \rightarrow 59dB}$	units	38	39	0
9	$LB_{LDWN \rightarrow 55dB}$	units	171	197	27
10	$LB_{LDWN \rightarrow 60dB}$	units	102	124	7
11	$LB_{LDWN \rightarrow 64dB}$	units	55	59	1
12	$LB_{LDWN \rightarrow 68dB}$	units	33	17	0
13	$L_{MZW \rightarrow TK}$	m	64	-	-
14	$L_{ZM \rightarrow OT}$	m	75	-	-
15	$L_{ZJ \rightarrow TK}$	m	11	22	18
16	$L_{ZJ \rightarrow OT}$	m	24	34	24
17	$FTU_{LDWN \rightarrow 55dB}$	m^2	58 305	14 3670	17 326
18	$FTU_{LDWN \rightarrow 64dB}$	m^2	1 643	48 851	1 096
19	$FTU_{LDWN \rightarrow 60dB}$	m^2	61 237	99 139	4 157
20	$FTU_{LDWN \rightarrow 68dB}$	m^2	1 643	25 607	255
21	$FTU_{LN \rightarrow 50dB}$	m^2	91 538	134 242	8 531
22	$FTU_{LN \rightarrow 59dB}$	m^2	6 550	39 126	351

- indicators that were in force before 2012

- new obligatory indicators

Source: own elaboration

Table 4. The values of acoustic indicators within the analysed areas

Feature symbol	Feature value		
	URSUS (Area I)	BIAŁOŁĘKA (Area II)	URSYNÓW (Area III)
WUA_{LN}	0.38	0.66	0.90
W_1UA_{LDWN}	0.60	0.66	0.98
W_2UA_{LDWN}	0.70	0.68	0.89
$WUFA_{LN}$	0.93	0.71	0.96
W_1UFA_{LDWN}	0.97	0.66	0.64
W_2UFA_{LDWN}	0.97	0.74	0.94
WBA_{LN}	0.72	0.76	1.00
W_1BA_{LDWN}	0.68	0.71	0.96
W_2BA_{LDWN}	0.67	0.86	1.00

Source: own elaboration

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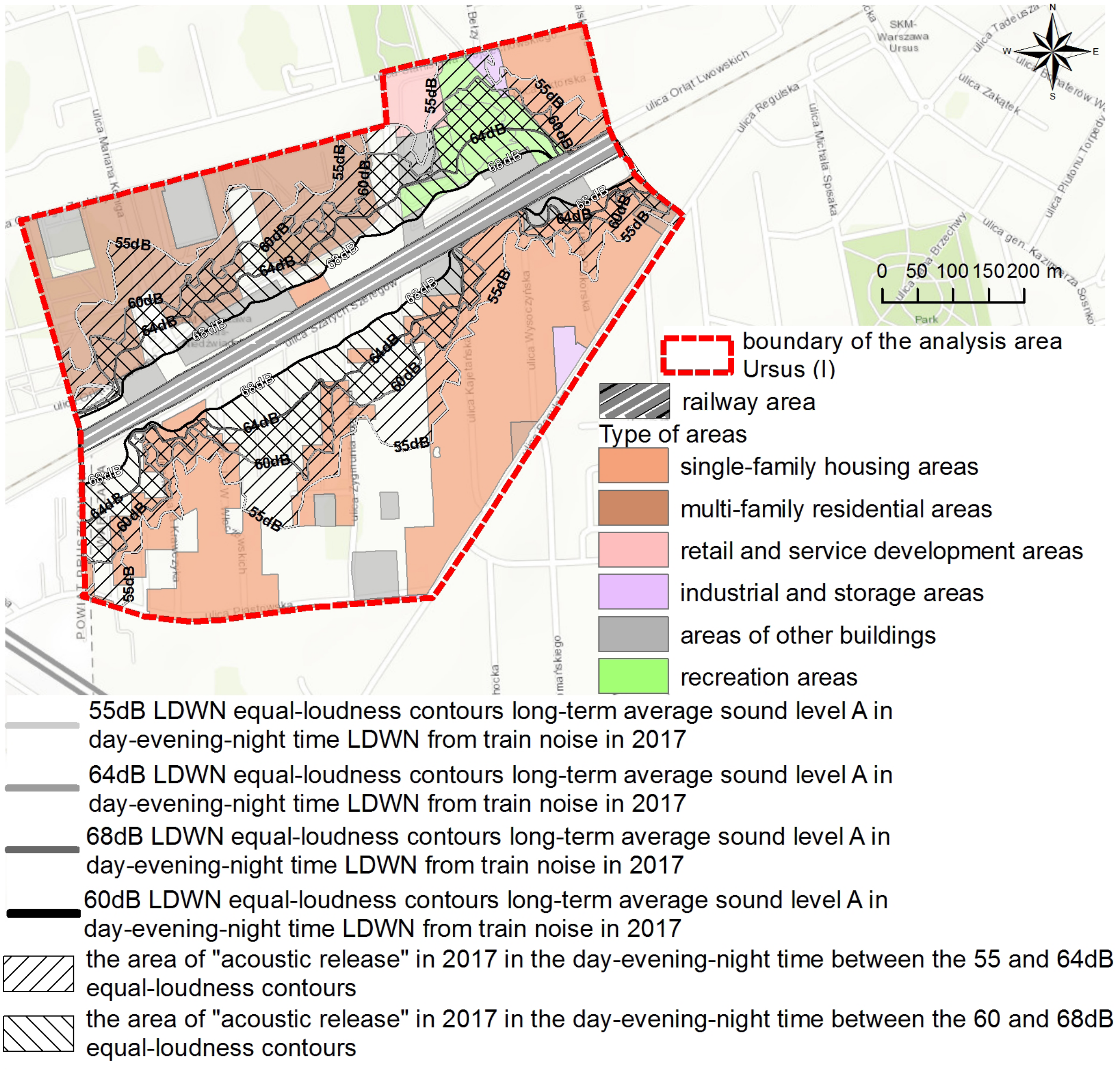

Figure 3. The area of "acoustic release" after changing the permissible sound levels in the day-evening-night time in the area under analysis, Area 1 (Ursus)
Source: own elaboration

exposed to railway noise may indicate a deterioration in the technical condition of the rails and rolling stock as well as a failure to install noise-reduction elements as part of the spatial development which took place. In the case of the least urbanised area located within Area III, the acoustic conditions over the five years remained at similar levels and even slightly improved by 0.22% at night (at 59dB) and 0.85% (at 64dB), and by 0,3% (at 68dB) for day/evening/night time.

The results concerning the spatial and construction features resulting from the risk of a railway noise are given in Table 3.

The values of the acoustic and spatial indicators for the analysed areas are presented in Table 4.

Analysing the above values, one can conclude that permissible levels of railway noise influence the interpretation of acoustic hazard in urbanised areas. Based on the results shown in Table 4, the amendment to the legal regulations has reduced the size of areas considered as noise-sensitive by 38% within Area I (Ursus) (Fig. 2), 66% in Area II (Białołęka) (Fig. 4) and by as much as 90% in Area III (Ursynów) (Fig. 6). The amendment directly led to a fall in the number of buildings exposed to noise pollution and their inhabitants. In Area I, one can observe a fall of 72%; in Area II – 76%, and in Area III the potential threat was entirely eliminated. The increase in the permissible noise standards LDWN for the day-evening-night time, from 55dB to 64dB, resulted in a reduction of the area considered to be threatened by railway noise by 60% in Area I (Fig. 3), 66% in Area II (Fig. 5) and as much as 98% in Area III (Fig. 7). Similarly, it reduced the number of buildings considered to be threatened by 68% in Area I, 71% in Area II and as much as 96% in Area III. The changes looked even more unfavourable where LDWN noise levels were increased from 60dB to 68dB. The areas at risk in Area I (Ursus) were reduced by 70% (Fig. 3), in Area II

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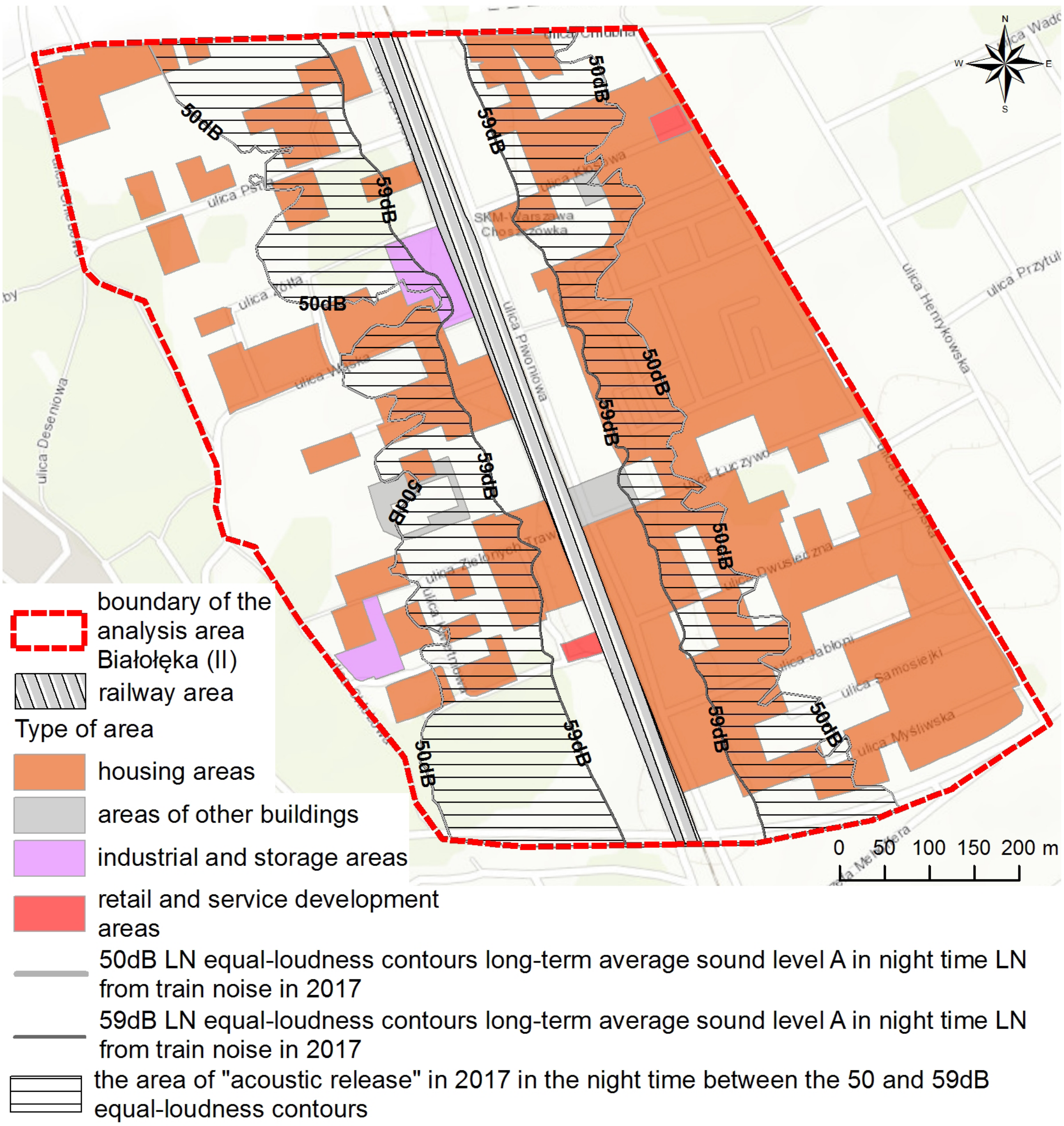

Figure 4. The area of "acoustic release" after changing the permissible sound levels in the night time in the area under analysis, Area II (Białołęka)
Source: own elaboration

(Białołęka) by 68% (Fig. 5), and in Area III (Ursynów) by 89% (Fig. 7). For the 60dB LDWN, this was, in turn, 67%, 86% and 100%.

The indicators of functional and acoustic release are more objective because they refer only to areas that are considered noise-sensitive according to the legal regulation. Regarding single-family housing areas, buildings related to the permanent or temporary dwelling of children and youth, social care homes and city hospitals, the change of the permissible value of the LDWN parameter from 55dB to 64dB resulted in the reduction of the size of the hazardous areas by 97% in Area I, 66% in Area II and by 64% in Area III. For multi-family and collective housing, farm buildings, recreational, residential and service buildings, the amendment to the legal regulation resulted in a decrease in the area affected by railway noise of 97% in Area I, 74% in Area II and 94% in Area III. In the context of night time, the change in the permissible noise level from 50dB to 59dB led to a reduction in the size of noise-sensitive areas of 93% in Area I, 71% in Area II and 96% in Area III.

Conclusions

The studies performed made it possible to solve the research tasks (RT's) presented in the "Research problem" section. The performed analysis confirms that the acoustic climate in the

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study areas has deteriorated over the five years between 2012 and 2017 (RT1). In the districts of Ursus and Białołęka (Areas I and II), the surface area of the isophone ranges $L_{DWN}68$, $L_{DWN}64$, $L_{DWN}60$, $L_{DWN}55$, $L_{N}50$ and $L_{N}59$ increased between 2012 and

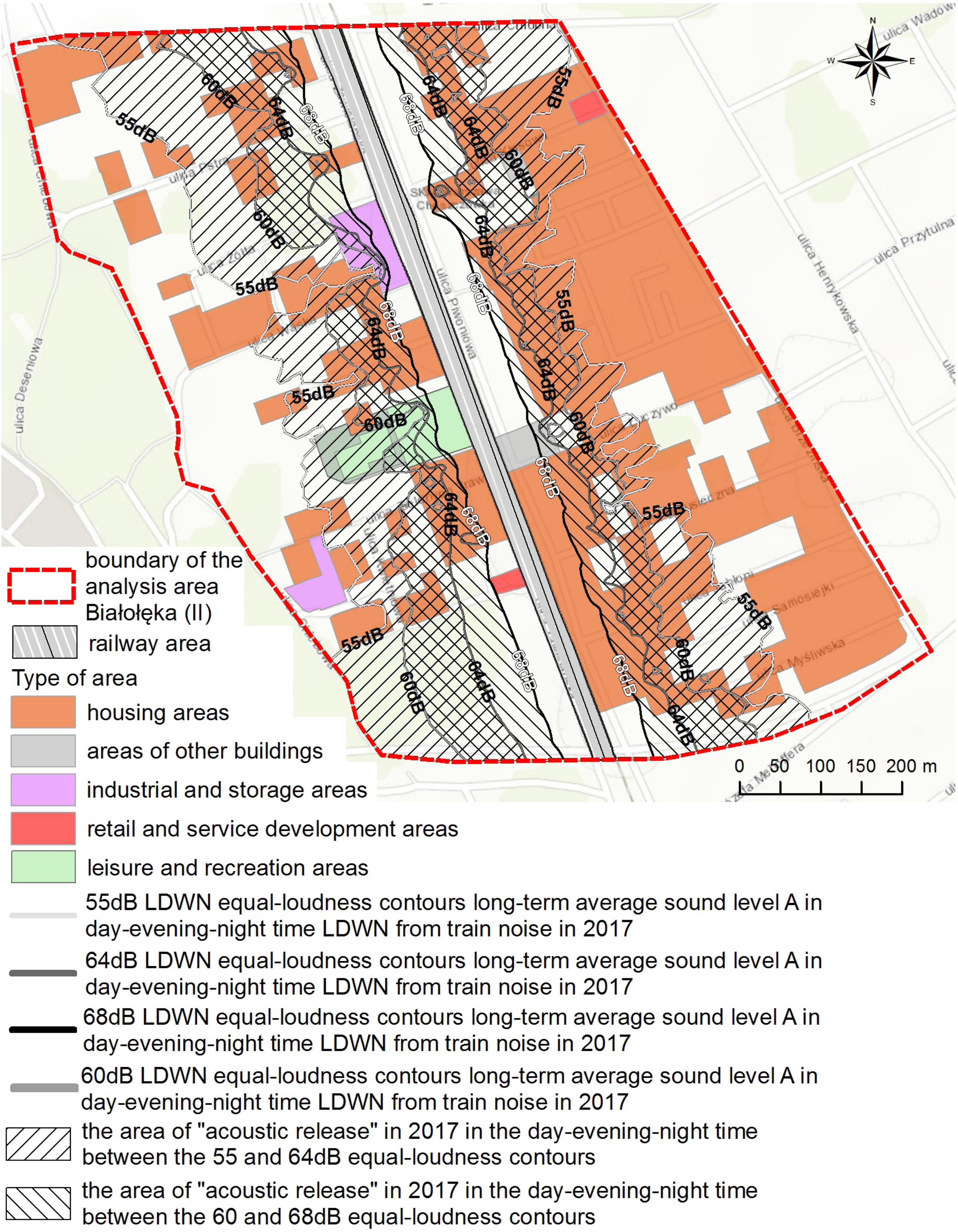

Figure 5. The area of "acoustic release" when changing the permissible sound levels in the day-evening-night time in the area under analysis, Area II (Białołęka)
Source: own elaboration

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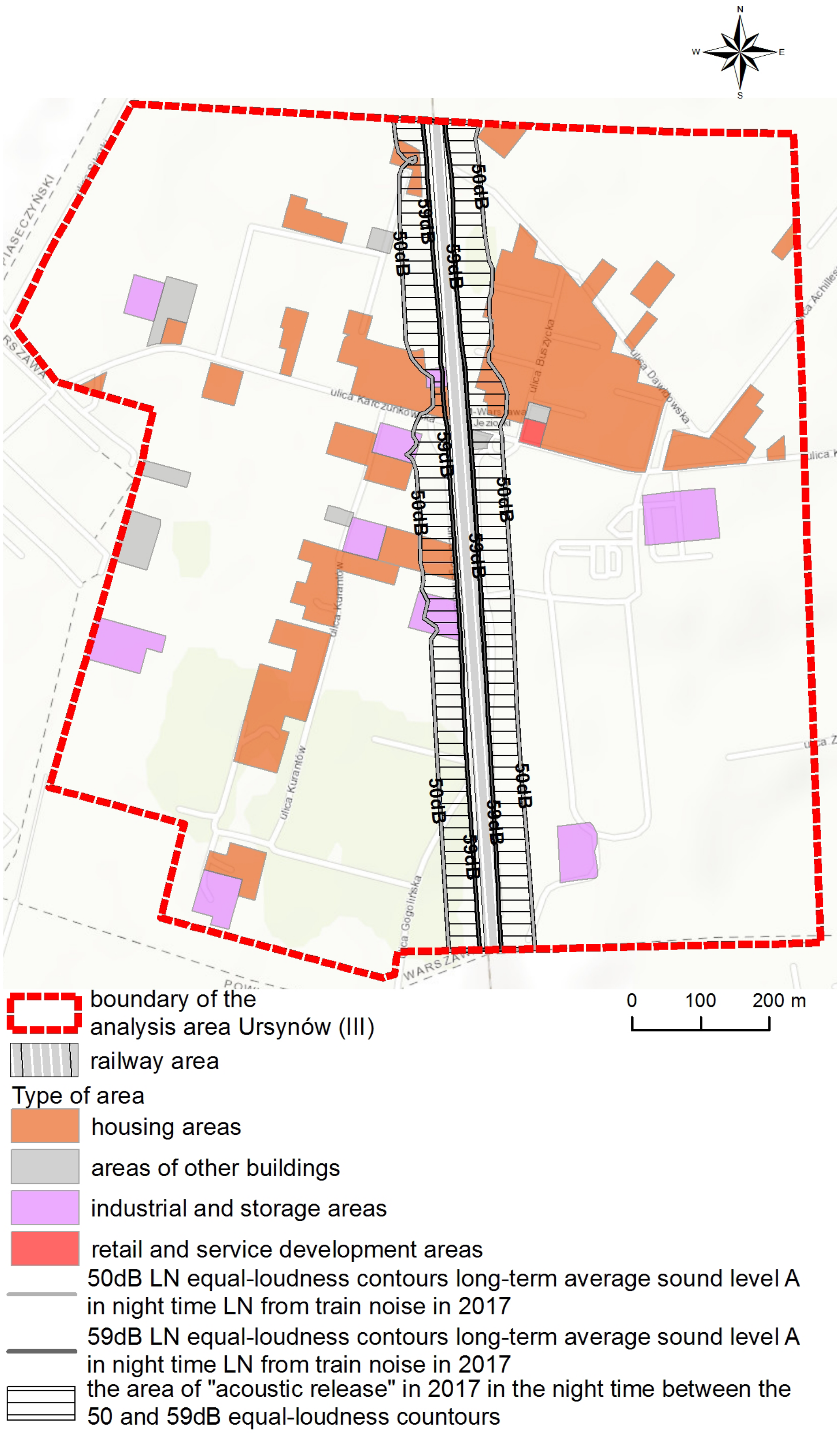

Figure 6. The area of “acoustic release” after changing the permissible sound levels in the night time in the area under analysis, Area III (Ursynów)
Source: own elaboration

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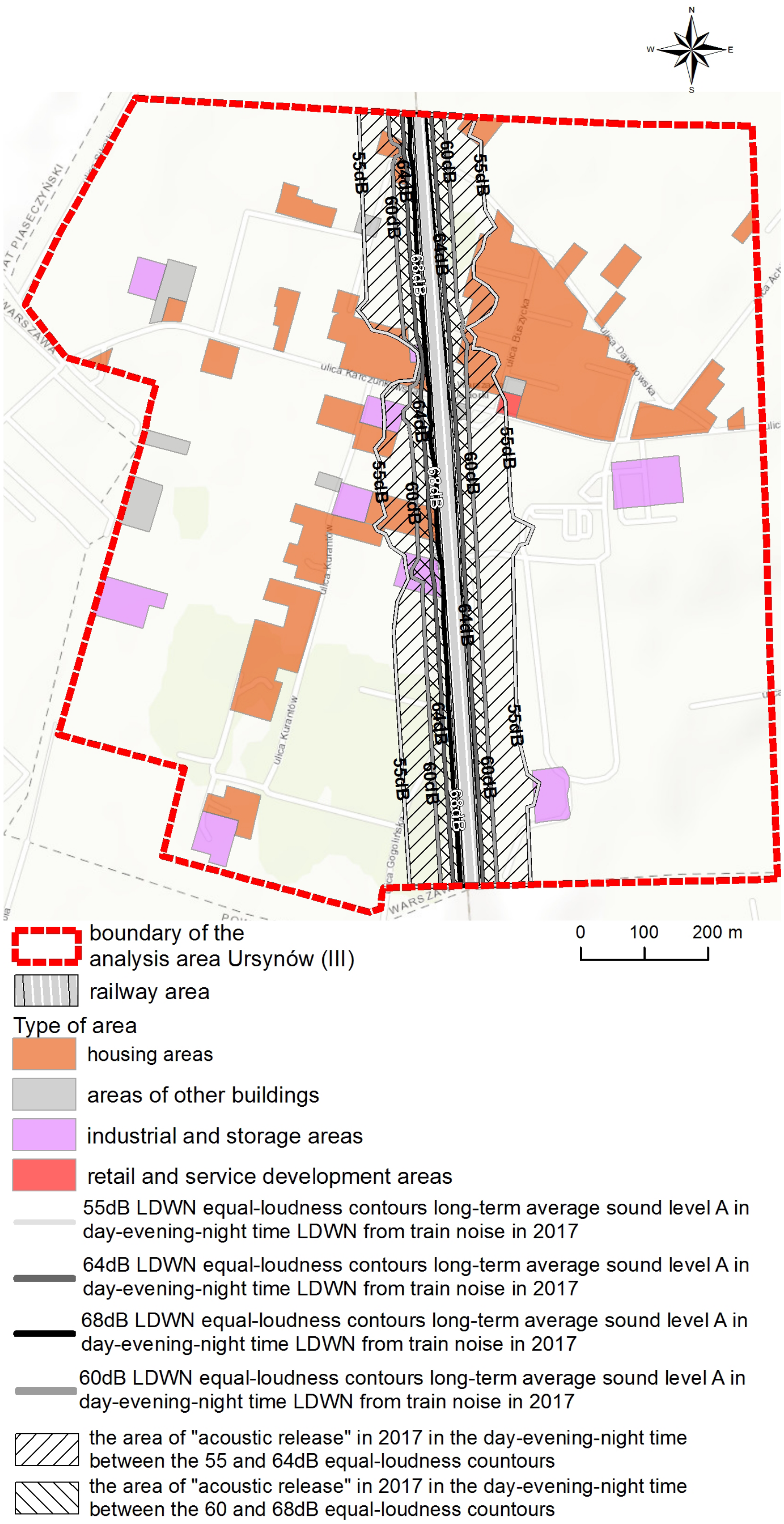

Figure 7. The area of "acoustic release" when changing the permissible sound levels in the day-evening-night time in the area under analysis, Area III (Ursynów)
Source: own elaboration

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2017. Meanwhile, the acoustic climate in Area III (Ursynów) remained relatively stable.

The introduction of amendments to the legal regulation on permissible noise levels has led to significant release of land dedicated to future investments without requiring additional expenditure to reduce excessive noise. Increasing the allowable railway noise indicators LN and LDWN has meant that, in areas with high and medium degrees of urbanisation, the amount of land with functions sensitive to noise fell by between 40% to 70% and, in less urbanised areas, by as much as 90-100% (RT2). It follows that the calculations for distances to buildings considered to be exposed to noise do not entirely result from acoustic hazard, but are rather defined by the regulations of the Act on the Railway Transport (2003).

Increasing the LN from 50dB to 59dB and the LDWN from 55dB to 64dB (night time) and from 60dB to 68dB (day-night) is beneficial for investors and contractors who can develop areas close to railways without investing in additional noise reduction measures. On the other hand, increasing permissible noise levels by as much as 9dB should be considered very shocking and negative for the health of future residents. They will probably not be satisfied with the acoustic climate despite the fact that the applicable standards theoretically do not exceed permissible noise levels in areas near railway lines (RT3).

This conclusion clearly shows that the increase in permissible noise levels was driven more by industrial and economic factors than health and social concerns. By deciding to increase permissible noise levels in the environment, it is a challenge to ensure appropriate, balanced spatial planning of urban areas in the proximity of railway lines. Although these analyses are based on the example of Warsaw, the situation could be generalised and applied to similar places where land is developed in the proximity of railways.

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