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The Impact of Transport Infrastructure Modernisations on Acoustic Climate on the Example of the City of Szczecin (Poland) Intersections Redevelopment Effects

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Abstract

The source of most noise worldwide is mainly caused by machines and transportation means, including motor vehicles such as cars, buses, trains, aircrafts and so on.

The excessive noise, called noise pollution, may harm the activity or balance of human or animal life. Noise pollution can cause annoyance, aggression and sleep disturbances. Chronic exposure to noise may cause noise-induced hearing loss, tinnitus and contribute to cardiovascular problems such as hypertension as well as increased incidence of coronary artery disease. Such may bring about deterioration in the wellbeing of people and increase the number of days of incapacity for work.

This paper is an attempt to analyze the impact of transport infrastructure modernisations on the noise pollution in the city of Szczecin. The main objective of this paper was to compare the level of traffic noise in the areas surrounding streets: *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów Streets* and crossroads of the streets: *Taczaka-Łukasińskiego* as well as *Taczaka-Derdowskiego* before and after the modernizations.
The comparison of obtained results suggest that in some cases the modernization hasn't influenced on noise levels. In some, it improved the acoustic situation but hasn't reduced the noise to keep acceptable levels.

The results emphasizethe thesis that some accepted methods of streets and crosswords modernization are sometimes ineffective in the fight against noise pollution.

Conclusions: Modernization of intersections in Szczecin improved traffic flow but had a little impact on the noise levels. Modernisations that improve the traffic flow can cause even increment in noise pollution. It should be taken into consideration possible benefits of used methods of city traffic modernization related not only to traffic improvements but also to noise pollution reduction. We suggest computer aided stimulations and acoustic specialist advices prior to any restructures of city traffic. To minimize the noise pollution, comprehensive solutions are needed.

Keywords: noise pollution, pollution monitoring, city traffic, modernization, health

1. Introduction

Noise (acoustic noise) is any unwanted, unpleasant, annoying and even harmful sound.

It accompanies human beings all over the world. A certain level of background sound, depending on the time and place of human life is even necessary for the well-being and welfare of man. The complete silence is irritating and influences on human psyche in unwanted way, on the other hand random and loud sounds disturb people, can cause permanent irreversible hearing damage as well as manyother biological as well as psychical harmful effects.

The sounds that are too loud, unpleasant, unexpected, or undesired are called noise. The noise, regardless of its origin, the intensity and duration is a bothersome factor for humans and for the environment (Brzeźnicki, Bonczarowska, & Gromiec, 2009; Iwanek, Kobus, & Mitosek, 2007) including animals (Jaeger et al., 2008; Moura et al., 2008; Zhang, Chen, Gao, Pu, & Sun, 2008), plants (Watts, Chinn, & Godfrey, 1999) and buildings (Akdag, 2004; Naticchia & Carbonari, 2007).

Studies of noise exposure suggest some associations with hypertension and cardiovascular diseases (Kempen, 2011; Bluhm & Eriksson, 2011). There was described association of aircraft and road traffic noise with psychological symptoms such as depressiveness and nervousness and some psychiatric disorders (at much higher noise levels) (Stansfeld & Matheson, 2003).

It is very difficult to measure parameters of any noise that are described by the such words as "unpleasant" or "annoying" - they are subjective. To compare and define the noise, the parameters: sound level and frequency of sounds are used. Usually the noise if defined as sounds with the range of frequencies between 16 Hz and 16 000 Hz (Dz. U, 2001). Often noises are described only by the most characteristic parameter - sound level expressed in decibels (dB). The dB is a logarithmic unit used to describe a ratio. The threshold of hearing is assigned a sound level of 0 decibels (abbreviated 0 dB); this sound corresponds to an intensity of $1*10^{-12}$ W/m^2. If one sound is 10^n times more intense than a sound that corresponds to the threshold of hearing, then it has a sound level equal to 10 x n decibels. For example military jet take-off which is 10^{14} times greater than the threshold of hearing has the intensity of $1*10^2$ W/m^2 and the level: 10 x 14=140 dB. Threshold of pain means the level 130 dB, instant perforation of eardrum may be caused by the sound level close to 160 dB.

The noise is all around us, it accompanies us during our work and rest, it is in our houses, at streets, in means of communication, restaurants, gardens, parks, shops and so on. The structure of the noise that reaches us consists of many components including traffic noise, rail noise, industrial noise, aircraft noise as well domestic noise.

The most common types of noise that affect people living in modern cities are: traffic noise as well as industrial, residential and housing noises (Kucharski, 1996).

The most troublesome and the most common, especially in the urban environment, are noises coming from motor vehicles and other modern sources of locomotion and transportation. In advanced as well developed countries, roadway noise contributes a proportionately large share of the total societal noise pollution. In some of them (such as many European countries and the USA (Miedema, 2001) traffic noise contributes more to environmental noise exposure than any other noise sources.

Industrial noise refers to noise that is created in the factories. Such noise adversely affects not only the workers but also people living close to industrial plants.

Domestic noise (residential) refers to noise nuisance coming from the following sources: playing of amplified music, playing of musical instruments, loud TV and video, parties and barbecues, barking dogs, neighbours activity and possible their anti-social behaviours,ventilation systems, kitchen utensils, other home appliances as well as intruder alarms.

Community noise (also called environmental noise, residential noise) is defined by The World Health Organization as noise emitted from all sources except noise at the industrial workplace. This term includes: domestic noise and traffic noise (traffic noise is a combination of the noises produced by vehicle engines, exhaust, and tires).

The most troublesome and the most common, especially in the urban environment, is noise from motor vehicles (traffic noise, roadway nose).

Traffic noise has become a serious problem nowadays because of inadequate urban planning of the city in the past. Homes, schools, offices, hospitals, commercial business centres, and other community buildings have been routinely built close to the main roads of the municipality without buffer zones or adequate sound proofing - such neglect of the past make life in many cities really difficult. The problem has been compounded by increases in traffic volumes.

All over the civilized worlds, the traffic noise is the most annoying kind of noise.

In most developed countries, sound-pressure levels of road communications are high, ranging from 60-90 dB. It is accepted that sound levels in cities should not exceed the range between 60-70 dB (A), with suburban levels between 50-60 dB(A). The World Health Organisation has set guideline levels for annoyance at 55 dB(A) representing daytime levels.

In the 1999, in European Union countries, about 40% of the population were exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB (Berglund, Lindvall, & Schwela, 1999) during the daytime and 20% - to levels exceeding 65 dB, at night, more than 30% were exposed to equivalent sound pressure levels exceeding 55 dB (Berglund et al., 1999).

In 2009, the problem of noise pollution in residential areas concerned 30% of people in Romania and Cyprus, 52.8% in Germany, 25.3% in Netherlands 17.7% in Poland and 11.8% in Norvay as well as 12% in Esonia (Rybkowska & Schneider, 2011).

Noise was became irritating and increasing problem in big cities, especially in dwellings located close to busy streets, airports, railway linesand big factories.

In 2012, 24% of the population of Dublin region were exposed to undesirable night time sound levels and 5% were exposed to day time sound levels exceeding 70dB(A) (Noise Maps, 2012). In Paris (in 2007) 59% of the population were plagued by noise, more than 7% of the inhabitants of the French capital were exposed to noise levels exceeding 71 dB (traffic noise measured year-round between 6 a.m. and 10 p.m.) (Bruitparif, 2013).

The Environmental Noise Directive of the European Parliament and Council (EN Directive, 2002) suggests EU Member States to produce strategic noise maps in their main cities and in vicinity of transport infrastructures as well as and near industrial sites. Mentioned actions may enable making a diagnosis of noise pollution in Europe and give suggestions that can be implemented in terms traffic modernization planning and other actions called acoustical planning.

Awareness of the unfavourable health effects of noise pollution forces local authorities to take into consideration the influence of any modernizations of traffic routes on human environment. It is recommended to make efforts to control environmental noise in cities by using computational models for urban planning and traffic modernization. These models are considered as extremely helpful for environmental management and decision-making for solutions to potential environmental risks, including urban noise (Zannin & de Sant'Ana, 2011).

Currently many realized projects of modernizations of the streets and intersections are aided by experimental measurements and software simulations, especially in cases when the prediction cannot be performed in simple way (Zurita, Parrondo, Díaz, & Corrales, 2005; Guarnaccia, 2010a, 2010b).

2. Aim

The fight against noise pollution and its negative effects is a priority in the policy in the European Union, which resulted in the adoption in 2002 the Noise Directive (EN Directive, 2002). Requirements for acceptable noise in Poland are set out in the Regulations of the Minister of Environment of 29th July 2004 and 14th June 2007 on permissible levels of environmental noise (Dz. U., 2004; Minister of Environmental Protection, 2007). Because of the fact that in many Polish cities noise levels exceed the permissible noise limit values, it is the urgent need to make efforts to change the *status quo*.

To do this, the following means and procedures are necessary: actual noise levels maps, changes in priorities in traffic modernisations procedures and permanent supervision of influences of any changes in traffic characteristics (including fluctuations of traffic volume, vehicles movement velocity and flow of the traffic) on noise pollution.

Our paper deals with such aspect of noise pollution supervision.

The main objective of this study was to assess the impact of restructuring and modernization of communication systems (intersections) in Szczecin on traffic-related acoustic noise pollution.

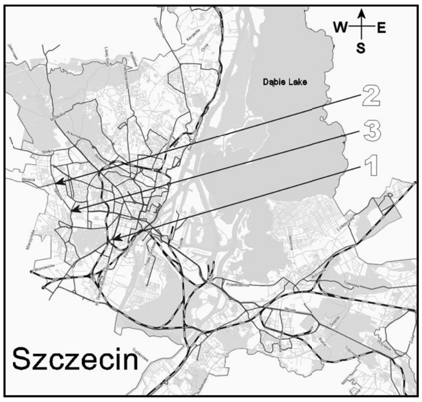
For this purpose, the traffic noise levels were estimated - prior and after the modernisations of three intersections in Szczecin: 1) *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów*, 2) *Łukasińskiego-Taczaka* and 3) *Taczaka-Derdowskiego*.

Such observations concerned intersections, typical elements of city traffic system, being sources of noise pollution.

All the intersections, mentioned above, have been the sources of noise exceeding the acceptable levels.

3. Material and Methods

The noise levels were analysed before and after the modernisation of three busy intersections in Szczecin (Figures 1-4).



(1) the intersection: *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów Streets*

(2) the intersection: *Łukasińskiego-Taczaka Streets*

(3) the intersection: *Taczaka-Derdowskiego Streets.*

Figure 1. Szczecin. Location of intersections where the noise measurement points have been settled

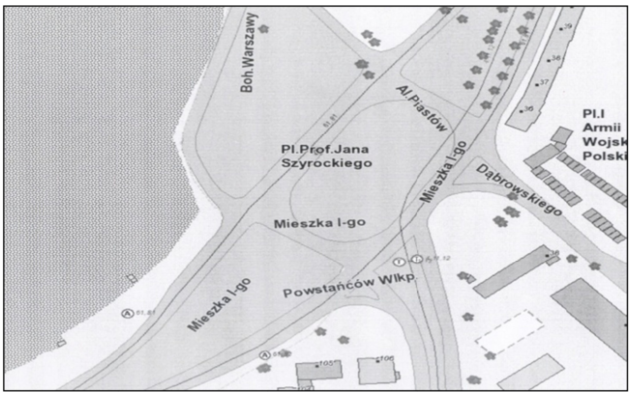


Figure 2. Noise measuring points (grey asterisks) around the intersection: *PowstańcówWielkopolskich, Mieszka I and Aleja Piastów.* Topographical map presenting the *status quo* before the modernisation

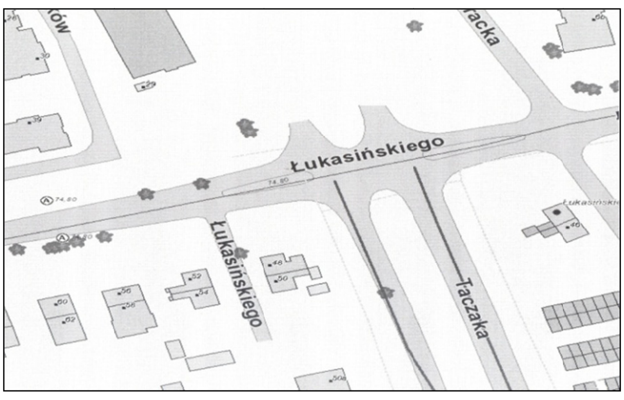


Figure 3. Szczecin. The intersection: *Łukasińskiego-Taczaka*. Topographical map presenting the *status quo* before the modernisation. Localisation of noise measurement points (grey stars)

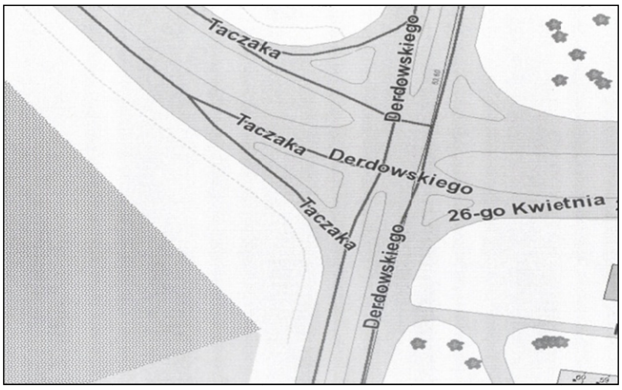


Figure 4. Szczecin. The intersection: *Taczaka-Derdowskiego*. Topographical map presenting the *status quo* before the modernisation. Localisation of noise measurement points (grey stars)

Szczecin is the capital city of the West Pomeranian Voivodeship in Poland situated in the vicinity of the Baltic Sea, being the country's seventh-largest city and a major seaport in Poland. In 2011 its population was close to 408,000. The traffic noise problems described in Szczecin are typical also for other major cities in Poland.

The intersection *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów* is located near the centre of Szczecin, in high-density residential area. It conducts a road traffic coming from the city centre of Szczecin to the western district of this city (‘*Pomorzany*’) inhabited by more or less 22 000 people and then to Germany (Motorvay A6).

The intersection *Taczaka-Derdowskiego* is located near a large housing estate ‘*Kalina*’ and is the beginning of the bypass route of Szczecin and leads the road traffic to Police (city, 42 000 inhabitants). In the immediate vicinity of the intersection there is a residential area with single family housing.

The third intersection: *Łukasińskiego-Taczaka* is a part mentioned above bypass route of Szczecin leading the road traffic to Police. It is located near a residential area with single family housing, too.

The topographies of all three intersections are shown as the Figures 1-4.

All the intersection are equipped with traffic lights. All the measurements were made during the daytime, so at the time the road traffic was most intense.

The noise measurement was performed by the use of automatic sonometers SON - 50 and IM - 02 measuring equivalent noise levels. The characteristics of mentioned sonometers are as follows:

- SON - 50 (Integrating SOUND LEVEL METER SON - 50; Producer: Sonopan) is an integrating sound level meter that measures levels of 3 types of signals: stable, unstable and pulse ones. The meter enables two independent measurement: RMS for measuring Leq, LMX, LMN, and second - to measure the peak. Accuracy class: 1; Measuring range: 15- 135 dB; range of RMS detector: 60 dB; dynamic characteristics: SLOW, FAST.
- IM - 02(Integrating SOUND LEVEL METER IM-02; Producer: Sonopan) - an integrating sound level meter that measures levels of 3 types of signals: stable, unstable and pulse ones. Accuracy class: 2; Measuring range: 20-135 dB; range of RMS detector: 63 dB; frequency characteristics: A, C, Lin.

The noise measurements were realized in sampling points marked by asterisks on the attached maps (Figures 2-4). Measurements were taken at 1.0 m distance from curbs or elevations of residential buildings. The microphones were placed 1.2 ± 0.1 m above the ground surface.

The measured noise level was the result of noise levels coming various sources related to the use of vehicles; in the vicinity of measuring points there were no other (than traffic) sources of noise.

There were measured levels of only nonstable noise.

The measurements were provided during the following weather conditions: no precipitations, puffs of wind not exceeding 2m/s.

4. Results and Discussion

The results of measurements are shown as Graphs -Figures 5-13.

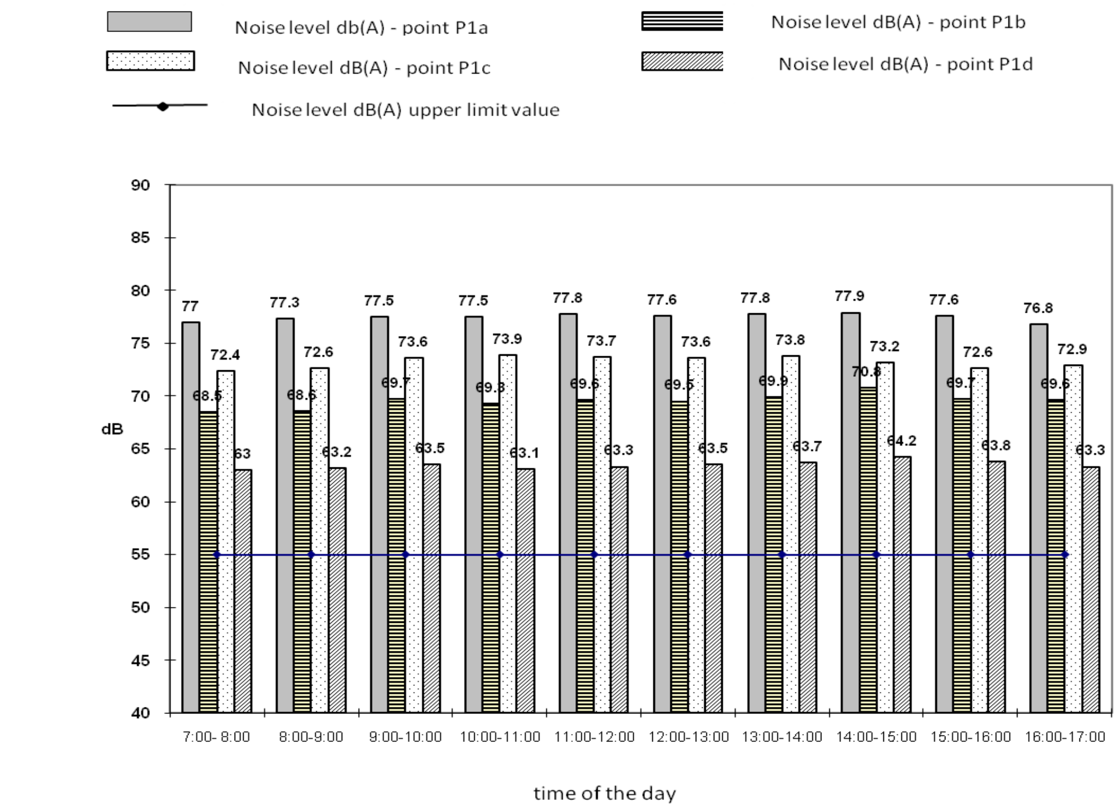


Figure 5. Noise level, depending on the time of day in the area of streets *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów* measured before modernization the intersection (data from four measuring points: P1a, P1b, P1c, P1d)

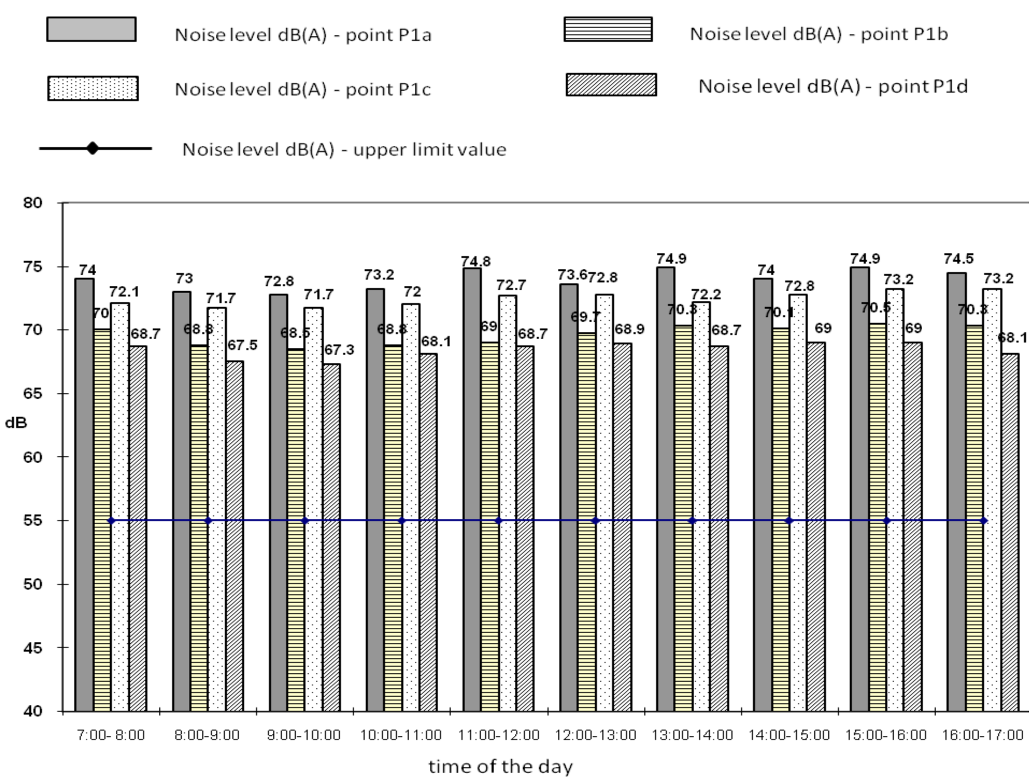


Figure 6. Noise level, depending on the time of day in the area of streets *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów* measured after the intersection modernization (data from four measuring points: P1a-P1d)

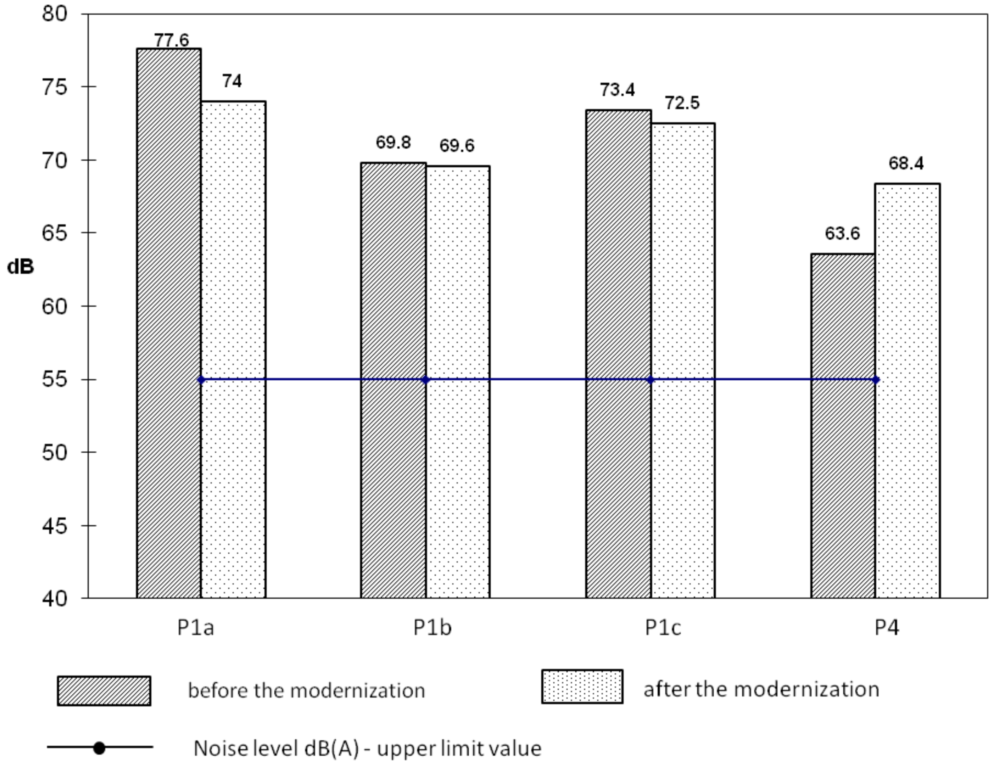


Figure 7. Average noise levels close to four measuring points (P1a-P1d) before and after the modernisation of the intersection: *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów*

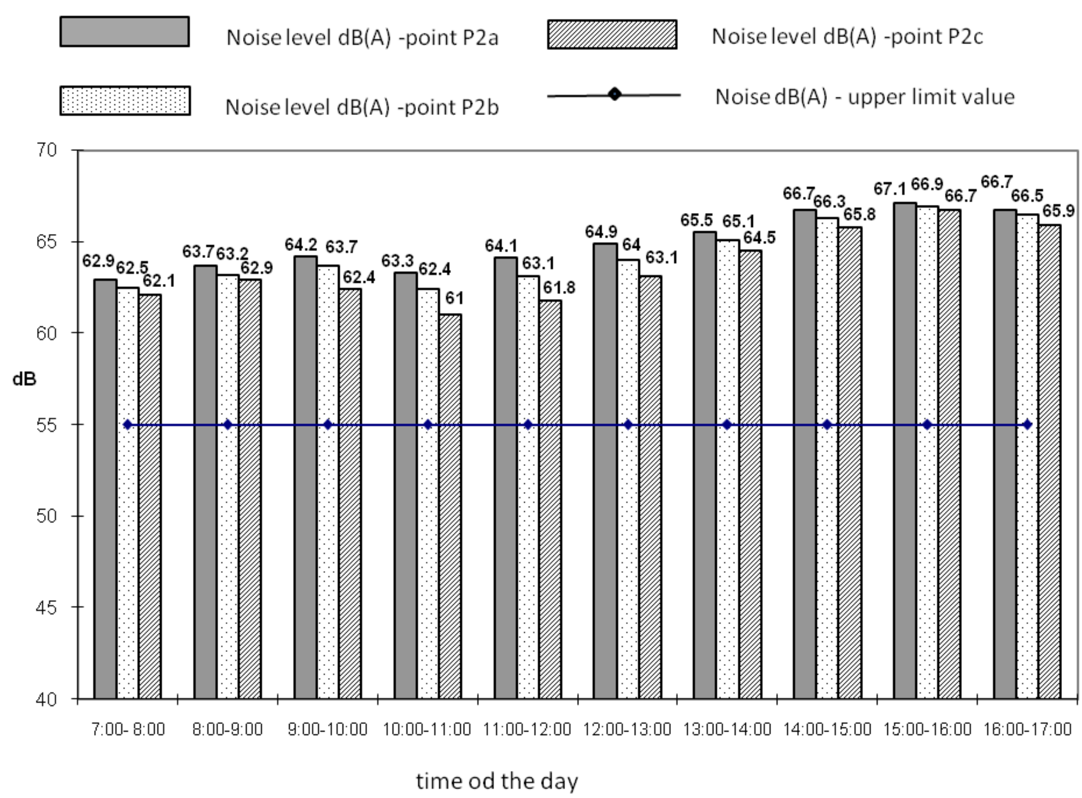


Figure 8. Noise level, depending on the time of day in the area of streets *Łukasińskiego-Taczaka* measured before the intersection modernization (data from three measuring points: P2a-P2c)

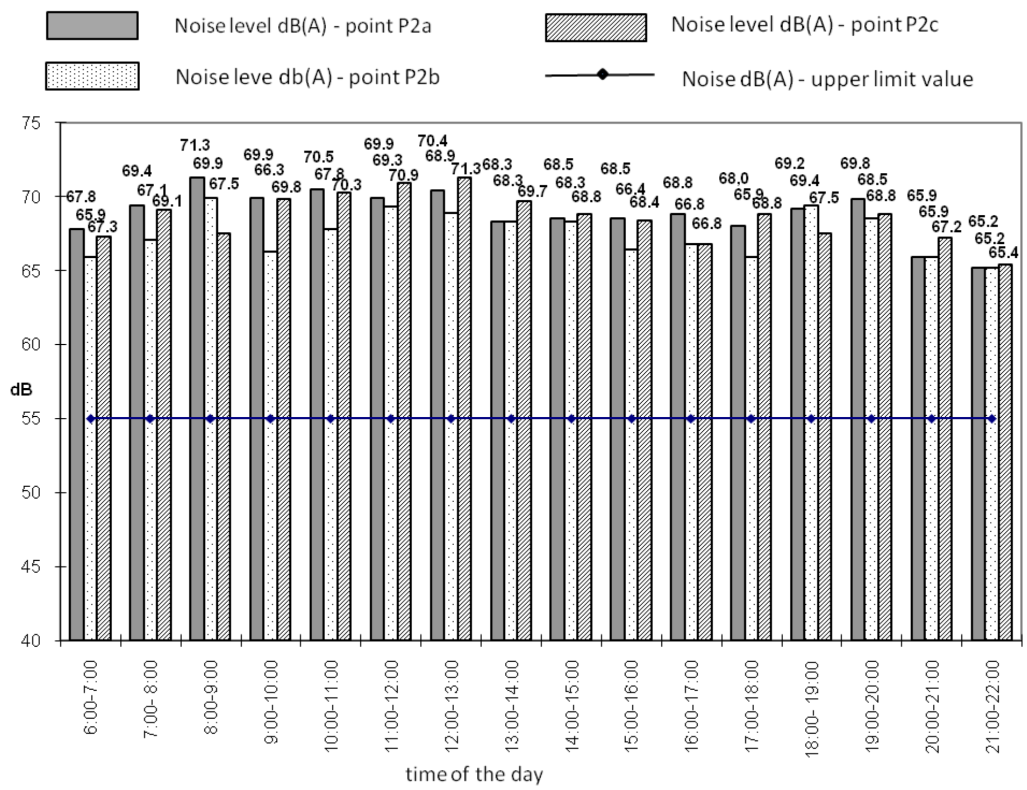


Figure 9. Noise level, depending on the time of day in the area of streets *Łukasińskiego-Taczaka* measured before the intersection modernization (data from three measuring points: P2a-P2c)

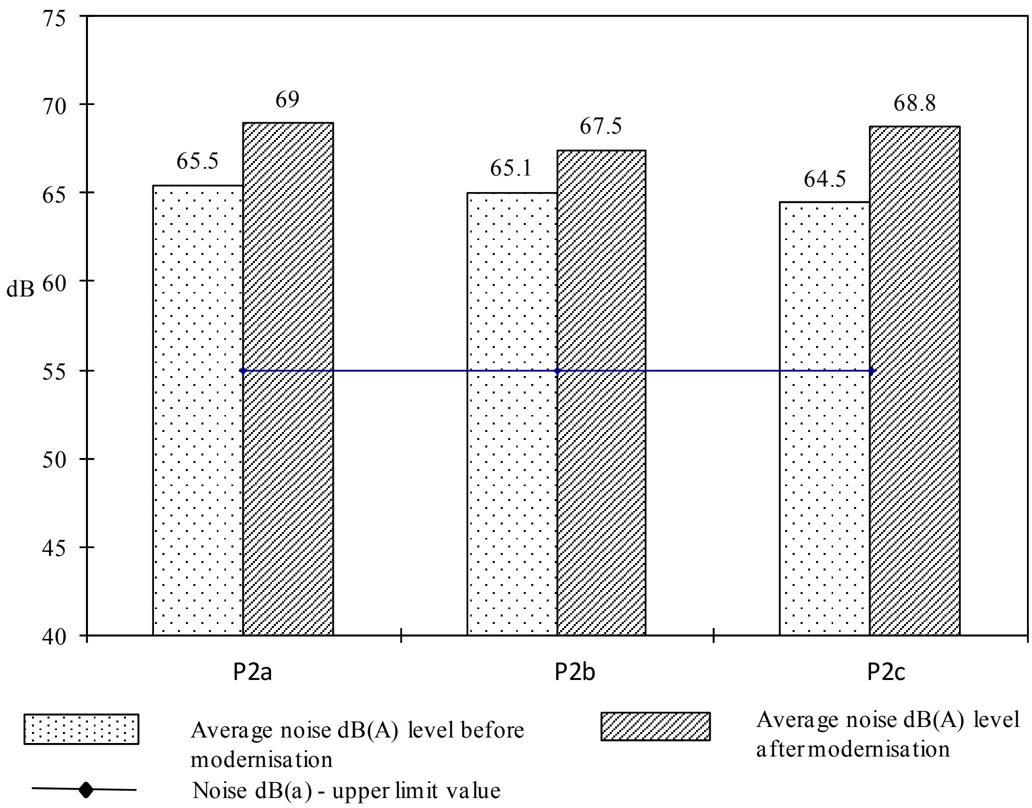


Figure 10. Average noise levels before and after modernization of the intersection: *Łukasińskiego-Taczaka* - data from the measurement pointsP2a-P2c

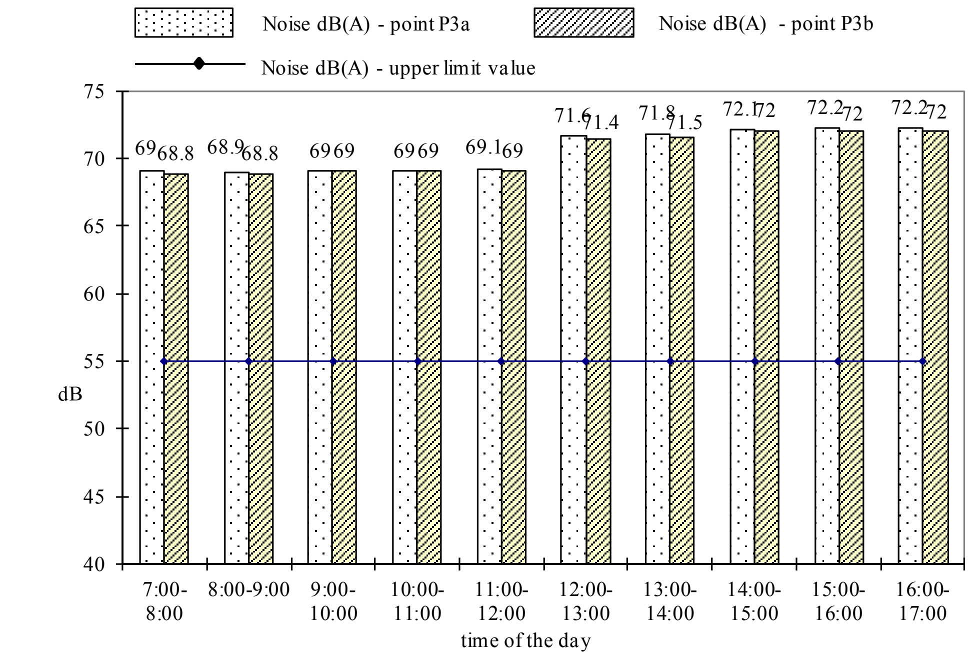


Figure 11. Noise level, depending on the time of day in the area of streets *Taczaka-Derdowskiego* - measured before the intersection modernization (data from two measuring points: P3a and -P3b)

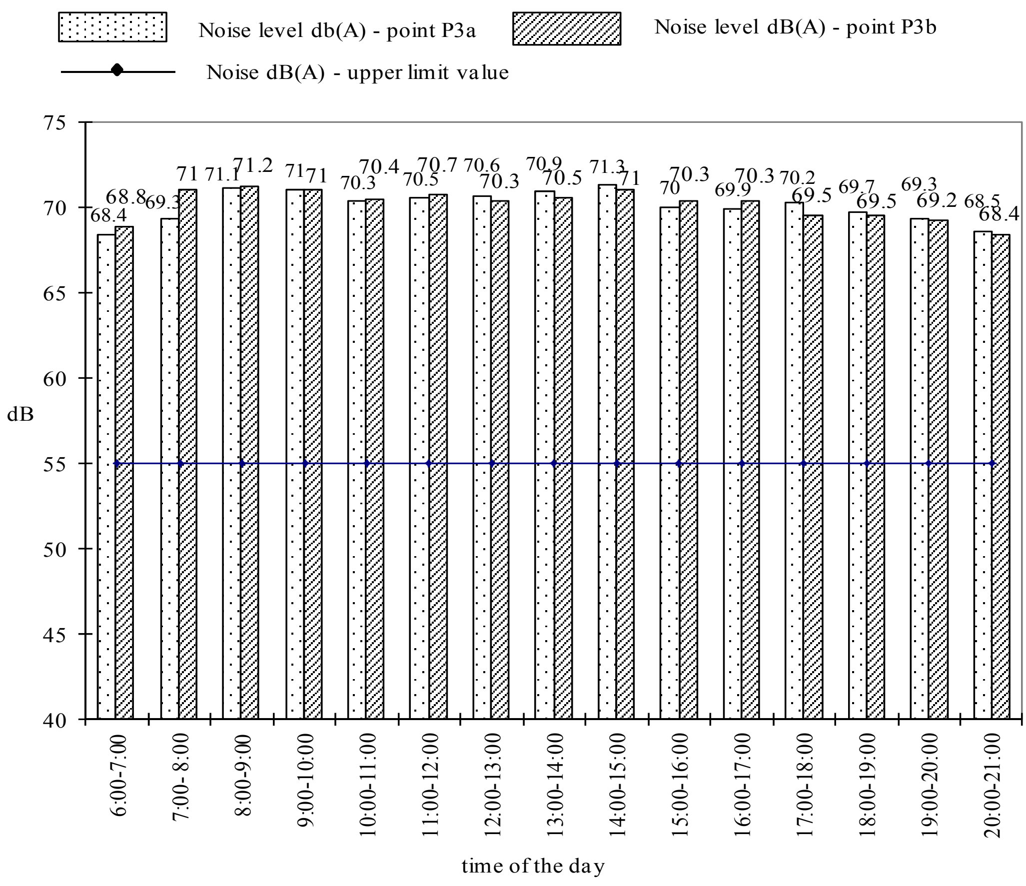


Figure 12. Noise level, depending on the time of day in the area of streets *Taczaka-Derdowskiego* measured after the intersection modernization (data from two measuring points: P3a and–P3b)

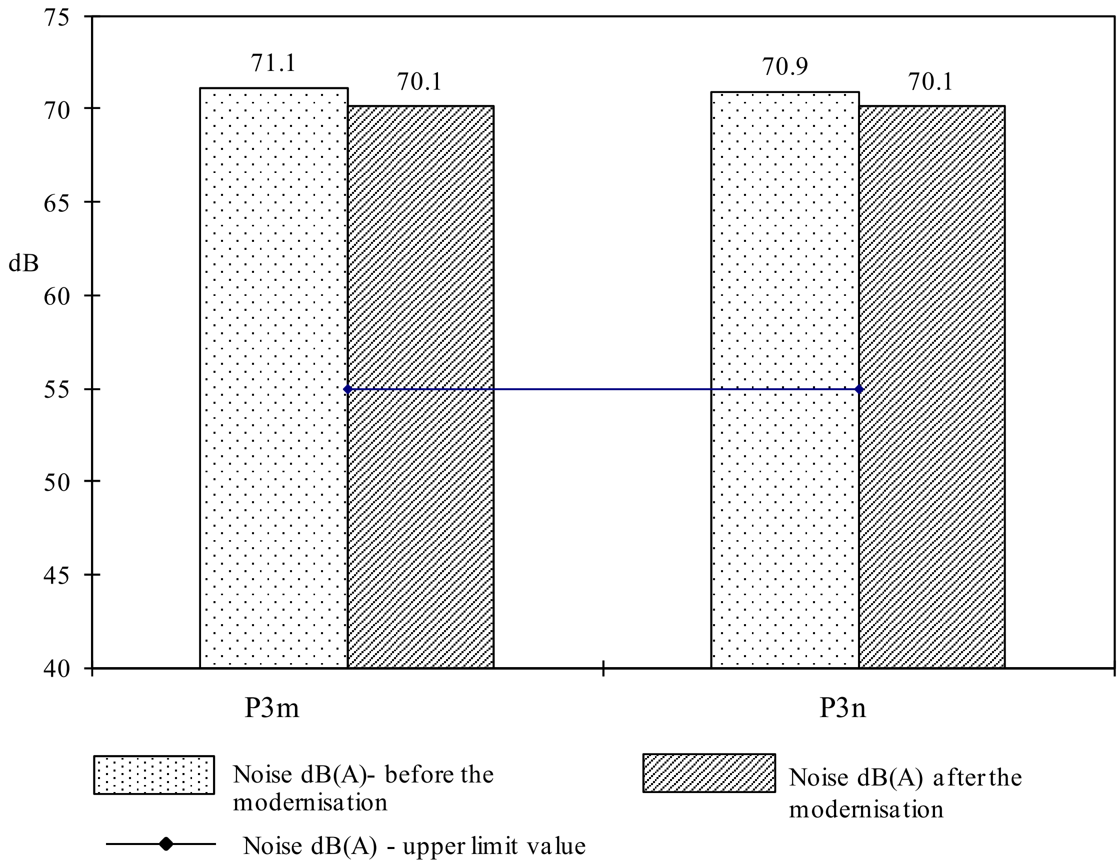


Figure 13. Average noise levels in two measuring points (P3m, P3n) exposed to highest noise levels. Data obtained before and after the modernisation of the intersection: *Taczaka-Derdowskiego*

Table 1. Permissible noise levelsin the environment according to the Regulation of the Minister of Environmental Protection, Natural Resources and Forestry (Dz. U, 2004)

Item in the Regulation	Areas	permissible noise levelsdB(A)	
		daytime	night
(1)	a) health-resorts b) hospital areas if located outside cities	45	40
(2)	a) single-family housing areas b) land buildings where children or young people live or stay for many hours c) areas of nursing homes d) hospitals in urban areas	50	40
(3)	a) multi-family housing and collective housing areas b) single-family housing areas with craft services c) recreational areas outside the city d) farms	55	45
(4)	downtown areas and cities with over100 thousands of residents with dense residential development and high concentration of administrative, commercial and service buildings	55	45

The results were compared to noise levels norms accepted by the Polish Ministry of the Environment in July of 2004 (Regulation of the Polish Minister of Environmental Protection, Natural Resources and Forestry on the permissible noise levels in the environment - 29.07.2004) (Dz. U., 2004) - Table 1. Location of measurement points (city > 100 000 inhabitants) and type of residential areas (high density housing) surrounded intersections gives the impression that the upper limits of permissible noise levels are defined by items 3 and 4 present in mentioned Regulation of the Polish Minister of Environmental Protection, Natural Resources and Forestry on the permissible noise levels in the environment (Table 1).

As is clear from the collected and shown as figures data (Figures 5-13), all the registered noise levels (both prior and after modernisations) exceed the upper limits of the applicable standards.

Comparison of differences in noise levels recorded before and after the modernizations of intersections made possible the evaluation of environmental profits obtained by carried out modifications.

The basic assumptions of modernization were: improvements in safety and traffic flow as well as in reducing the noise levels and then - improvement the acoustic conditions for people temporarily staying in the intersections areas, as well as living in the surrounding buildings.

The modernization of *Taczaka-Derdowskiego* intersection reduced the average noise level by 1 dB, the modernization of *Powstańców Wielkopolskich, Mieszka I and Aleja Piastów* intersection reduced the average noise level by 0-3.6 dB (different data in different measurement points), although in one measurement point there was noticed an increase in the noise level (about 5 dB). The modernization of *Łukasińskiego-Taczaka* intersection made the acoustic situation worse (an increase in the noise level by about 4 dB in almost all measurement points).

Therefore, in conclusion, it can be said that one of the most important goal (improvement in the acoustic conditions) has not been met. As a result, costly modernizations has given the effect: minimal improvement or even deterioration in the acoustic situation.

Noticed unfavourable effect can be explained in many different ways:

- the modernization of intersections improved the traffic flow, so the number of vehicles increased and (instead of some improvements) the noise volume increased (proportionally to increment in traffic density)
- the better traffic capacity influenced on drivers. Many of them have chosen better traffic routes (with improved intersections) instead of other streets jam-packed with vehicles
- modernisation of intersections improved traffic and enabled faster movement. Higher speed of vehicles means increment in noise volume.

The past decade is the period of sudden increment in traffic volume in all civilized countries. Such conclusion concerns Poland too. There is no doubt that the infrastructure of current and future large cities is a critical issue in our society. Streets and highways will remain critical transportation conduits, so their maintenance and improvement will remain an important challenge.

The rapid development of many civilised countries and increasing wealth of society led to a rapid increment in number of means of communication and transportation. Such increment - on one side and troubles with rebuilding communication routes (reconstruction are costly and time-consuming, in large cities is not enough space for tracing any new routes or broadening old ones) - on the other side, made that in many cities transportation is still ineffective, time-consuming and producinga lot of noise.

The modernisations, although, are necessary may brig only some, sometimes almost imperceptible effects - especially when it comes to the fight against noise. Such conclusion may be draw when one analyses effects of modernisation of mentioned three busy intersections in Szczecin.

The similar conclusion were drawn in other countries, where roads and cross-sections modernisations were considered as necessary but not sufficient efforts to achieve the objective of significantly reducing public exposure to traffic noise (Bing & Popp, 2011). One of the best solutions is: improving traffic flows without traffic growth (Rauterberg-Wulff, 2010) but typical modernisation increases traffic volume.

It seems to be necessary to look for other conceptions of fighting against noise pollution in big cities (Secretary of State for Transport UK, 2013).

Among them, nine (mentioned beneath) seem to be the most interesting (Jakovljevic, Paunovic, & Belojevic, 2009; Pilkington, 2000; Lee, 2013; Laoghaire, 2013; Secretary of State for Transport UK, 2013; Siemens, 2010; Węcławowicz-Bilska, 2012; Giuliano, O'Brien, Dablanc, & Holliday, 2013):

- ring roads
- underground roads/tunnels
- zones restricted to pedestrians only
- zones with public transportation means only
- zones with no transit traffic
- zones with no truck traffic
- zones with vehicles maximum speed limit lowered 50, 40 or even 30 km/h
- zones for electric or hybrid vehicles only
- intelligent systems controlling traffic lighting schemes (intelligent traffic regulation) to reduce the average speed and improve the flow of the traffic.

The most radical are concepts suggesting total ban on vehicles movement or reducing the traffic flow velocity to 30 km/h. Such radical ideas give the best results but disrupt normal city life and provoke many controversies over such points of view. In Europe, there are areas where the 30 km/h (19 mph) speed limit is in force. Such areas are present in some cities as Dublin (GB), Vienna (Austria) and Graz (Austria).

Mentioned regulations are forced both to reduce traffic noise and to improve safety for pedestrians (road traffic safety project started in Sweden in 1997 - "Vision Zero" (Fahlquist, 2006) - policy that requires that fatalities and serious injurious will be reduced to zero by 2020).

Mentioned modifications make some problems. Some drivers follow the lower speed limit while others ignore it, disrupting traffic and increasing the potential for collisions between slower and faster drivers. There are suggestions that speed limits that are inconsistent with driver expectations will not be kept (Skerritt, 2013). The reducing the traffic flow velocity has implications being in conflicts with the ideas of modern society - a large workers' mobility, flexible working hours and frequent changes of employment.

Reduced traffic flow makes trouble with worker's mobility and by influencing on the increase in the time spent on traveling to and from the work, reduces the amount of time that employees can spend on rest or devote for the families.

Almost all concepts of big cities have taken place in times when factories, offices and other places of employment were close to houses or residential areas inhabited by workers. So, the traffic was small and adequate to necessities and to the technical development was not so enjoying and the problem of noise was not so irritating.

Nowadays we have old concepts of cities (and their functions) and new concepts of life and working. They are simply not compatible.

It is an urgent need for changes in the functioning of societies, forcing reduced demand for the use of individual means of transportation (cars). It is quite possible that a change in the concept of work - work at home for remote companies and facilities (operating via the Internet) would be a reasonable way out of the current stalemate.

5. Conclusions

(1) Modernization of intersections in Szczecin improved traffic flow but had a little impact on the traffic noise levels.

(2) Modernisations that improve the traffic flow can cause even increment in noise pollution.

(3) It should be taken into consideration possible benefits of used methods of city traffic modernization related not only to traffic improvements but also to noise pollution reduction.

(4) We suggest computer aided stimulations and acoustic specialist advices prior to any restructures of city traffic.

(5) To minimize the noise pollution, comprehensive solutions are needed.

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