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Research Paper

A Proposal Concerning Assessment of Alternative Cityscape Designs with Audiovisual Comfort and Health of Inhabitants

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The research concerning the future of sound in towns and cities is focused on two main issues: studies are conducted separately on the comfort, i.e., assessment of visual scenery and sound levels in a cityscape and separately, on the health protection issues. The policy of the acoustic environment control with regard to the health of its inhabitants is traditionally connected with measurements of noise levels presented with the help of the coefficients L_{den} and L_{night} noise indicators, while the models based on tranquillity rating (TR) with the help of the coefficients L_{Amax}, L_{Amin}, L_{Aeq}, L_{A10}. None of these coefficients refers to the soundscape. In this paper, we present a justification of the necessity to enter into discussion on the need to combine these research areas. The authorities managing towns and cities of the future should be provided with tools enabling them to assess modernisation projects from the point of view of both health and comfort of inhabitants. We present our ideas treating them as an invitation to a scientific discourse, in the form of analysis of actual projects concerning modification of existing cityscapes. The modifications are aimed at returning some unfavourably developed spaces to the inhabitants. When analysing the changes proposed in the projects, we take into account two models of the revitalised area quality assessment. The first model is used to assess the effect of noise on health. The second model, based on the indicator known as the TR, serves simultaneous assessment of an area from both visual and acoustical aspects. The models used contemporarily by scientists show multiple flaws, therefore, for the TR indicator we propose a modification taking the sound structure into account. The modification embodies the idea of masking unpleasant sounds with friendly ones. The changes to the model are presented, in this paper, in the context of two projects which were worked out in the framework of 12th edition of the intercollegiate workshop cycle The New Cityscapes. In the course of each workshop of the cycle, we combined art, science, and technology in order to seek solutions creating a better future. In view of the importance of this issue and the need to introduce a certain level of universalism, the authors offer an invitation to join a discussion on the future of sound in urban agglomerations.

Keywords: noise maps; tranquillity rating; enclaves of silence; alternative urban spaces; sound masking.

1. Introduction

Along with development of urban agglomerations, the effect of noise on health of residents becomes more and more noticeable. According to World Health Organization [WHO] (2018) document one European out of five is regularly exposed at night to sound levels posing a significant risk to health. For many years now, initiatives have been undertaken to enforce noise reduction through legislation. An example of such a legislative initiative is Directive 2002/49/EC (Commission of the European Communities, 2002) in which main sources of noise were identified (road, railway, and air transport, industry), regular measurements of related noise levels were made obligatory together with the requirement to draw up noise maps and noise action plans for agglomerations with more than 100 000 inhabitants. The aforementioned WHO document contains a systematised survey of proofs evidencing relationship between exposure to noise, both in the daytime and at night-time, and risk of adverse health effects in humans.

The mentioned documents are focused mainly on the issue of noise levels. In many cases, however, in view of necessary financial outlays (construction of screens, replacement of windows, road surface refurbishment) or time-scale (conversion to electric drive in vehicles), achieving required results is impracticable. It is, however, still possible, especially in cases of minor exceedances of the recommended levels, to reduce the discomfort of living in urban environments by modification of nature and contents of sounds (by sound masking) and provision of quiet places available, for instance, within public transport routes (bus/tram stops). Such activities exceed the scope of the acoustics alone and become an inherent part of interdisciplinary urban studies (Kang, 2006; Raimbault, Dubois, 2005; Chojnacki *et al.*, 2018). This approach to the science, characterised by seeking universalism, represents an attempt to define the presence of a human both in a cityscape and in a specific location (Ozga, 2017), where the research work is joined by sociologists (Bukowski *et al.*, 2018; Giddens, 1987), architects (Kapecki, 2020), artists (Gibała-Kapecka, Kapecki, 2014; 2016; Koolhas, Mau, 1998), acousticians (Kukulski *et al.*, 2018), and geographers (Murzyn-Kupisz, Działek, 2017; Redaelli, 2019). This paper presents the point of view of acousticians hammered out after discussions held with artists, architects, and sociologists on the occasion of intercollegiate workshop Alternative Cityscapes which was held in Cracow in 2018 (Gibała-Kapecka *et al.*, 2019). Discussions with representatives of other disciplines of science have indicated clearly that the research concerning the future of sound in the cityscape was carried out in two different directions: separately on comfort of living among local residents and separately on health protection issues.

This paper presents two models allowing to assess urban space modernisation projects worked out in the course of the mentioned 2018' workshop. In the first model, sound levels only are taken into account (and therefore it concerns only the health of people present in the area of interest), while the second model is an extension of the first one with the sound structure analysis (and thus concerns the comfort of residents). The work on cityscape acoustic assessment models and cooperation of various disciplines of science was initiated in order to create cityscapes in which the visual scenery and the audio landscape scenery (soundscape) are fully adequate. On the acoustic side of the problem, we combine the two trends in research on the acoustics of urban agglomerations to make achieving the set goals more realistic.

The analysis carried out in the scope of the health protection issue was performed with the use of SoundPLAN software implementing unified measurement and calculation methods known as CNOSSOS-EU (European Commission, 2012), the application of which became mandatory to all European Union Member States from January 1, 2019. The method includes algorithms used for predicting levels of road, railway, and air transport noise as well as the industry-generated sounds. In the present paper, the method is used to determine changes that would occur in the soundscape after implementing solutions proposed in cityscape modification projects. The second model defines the cityscape in terms of architecture, nature-related elements integrated into the architecture, and the soundscape. The model is a proposal concerning assessment of urban space designs based on the analysis of the visual scenery and the soundscape by means of the quantity known as the tranquillity rating (RT).

We are aware of difficulties involved in comparison of results obtained with the use of the above-presented models (based on L_{den}, L_{Aeq}) but we still hope that this paper will draw attention to the necessity to take into account not only the health but also the comfort of life in towns and cities and the need to work out new methods of assessing the latter.

2. Methods used to achieve acoustically alternative cityscapes

2.1. Health – protecting cityscape users from noise

Problems in contemporary urban agglomerations are growing much faster than our ability to solve them. Air pollution, ubiquitous noise, and climate warming require a change in our thinking about the cities and towns of the future. In our case, new ideas were first formulated in connection with a workshop named The New Cityscape. This intercollegiate event, combining art, science, and technology, was carried out from 26 to 29 November, 2018 in Cracow as the 12th subsequent edition of the workshop cycle known as Alternative Public Spaces. The challenge posed to the participants was to develop a proposal to modify a piece of urban space without taking into account the constraints of current legislations or economics. Students from four universities in Cracow were involved in the projects: Academy of Fine Arts (Faculty of Interior Design); Cracow University of Technology (Faculty of Architecture); Jagiellonian University (Institute of Sociology); and AGH University of Krakow (Faculty of Mechanical Engineering and Robotics, Field of Acoustic Engineering). The students were offered support from their lecturers and tutors as well as doctoral students and representatives of the Urban Greenery Management in Cracow.

In the urban area dealt with in the workshop framework, the main noise source is the sound generated by road traffic. There are also a tram route and a railway line running along the street; however, the noise generated by them is definitely lower than the motor vehicle traffic. Additionally, the space is characterised by small share of green areas and very dense building development. Between buildings and the roadway, a footpath and tram routes are situated. The overall picture is typical of many cityscapes worldwide where people live and function.

The acceptable levels of noise in the environment, as applied in the long-term policy regarding protection from noise and while drawing acoustic maps, are determined by yearly indicators L_{den} and L_{night}. WHO recommends (2018) reducing noise levels produced by road traffic below 53 dB L_{den}, because noise above this level is associated with adverse health effects including ischemic heart disease (IHD), high annoyance (HA). For night noise exposure they recommend reducing the noise below 45 dB L_{night}, as night-time road traffic noise above this level is associated with adverse effects on sleep including high sleep disturbance (HSD). Below these levels, none of the listed negative effects will occur. However, the values set by the WHO are only recommendations, but in the case of road traffic noise they are strong recommendations, that according to WHO can be adopted as policy in most situations. Regardless, each European country has its own policies to control noise, including road traffic noise. This also involves self-determination of permissible environmental noise levels, which in each European country are higher than those recommended by the WHO. In Poland, since 2012 the acceptable noise levels have been determined by the Regulation of the Minister of Environment (2014). It has turned out, however, that the levels for "A" spa resorts and hospital areas beyond towns are the only ones that satisfy the WHO criteria. The acceptable noise level is higher in all the remaining areas referred to in the Regulation. In the case of the land considered in this work, the areas situated to the west of the Zakopianka motorway are subject to acoustic protection (as residential quarters), and the norms are respectively 68 dB (L_{den}) and 59 dB (L_{night}). The area east of the motorway is the home for workshops and stores for which no noise limits have been specified.

In the area of interest, measurements of noise levels were taken together with records concerning traffic intensity and structure. The obtained results were then used to develop and verify a calculation model in SoundPLAN 8.2 software environment. The model used to calculate noise levels in road traffic implemented in the software performs calculations according to the CNOSSOS-EU methodology.

Results of calculation for the current state are presented in Figs. 1 and 2.

Measurements taken in the current state indicate that thresholds recommended by WHO are exceeded both in the daytime and at night-time. The objective set for each of the projects developed in the workshop

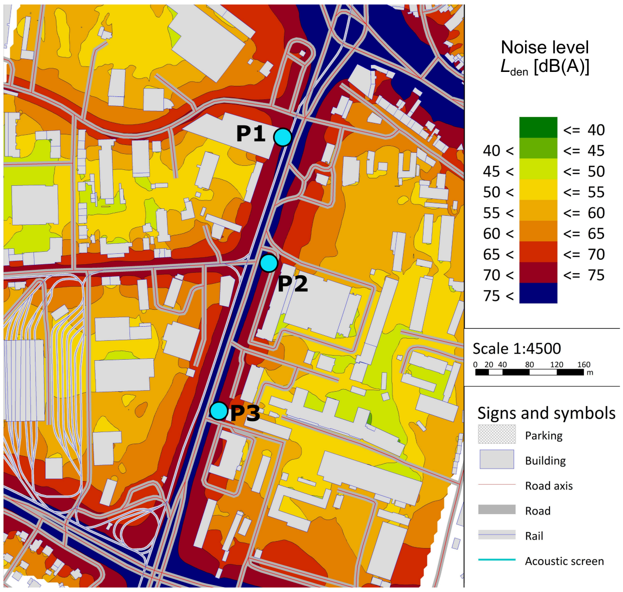

Fig. 1. Day-evening-night noise level (L_{den}) for the current state, calculated in the SoundPLAN 8.2 software.

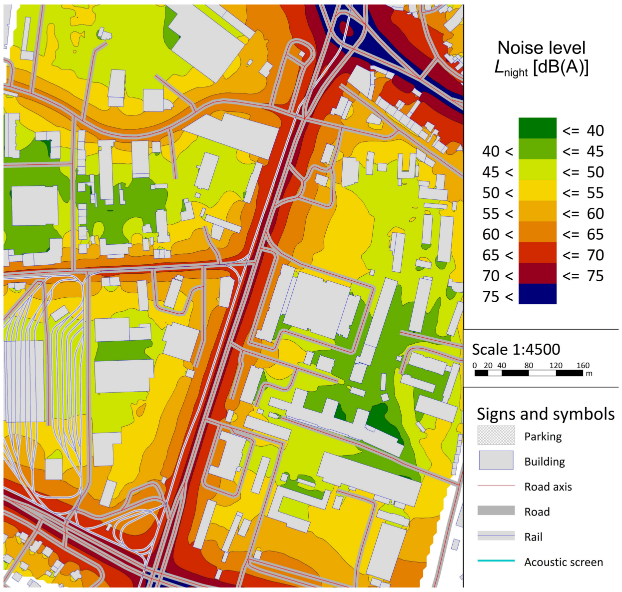

Fig. 2. Night noise level (L_{night}) for the current state, calculated in the SoundPLAN 8.2 software.

entitled Alternative Cityscapes was to reduce traffic noise along the examined road section down to the level L_{den} recommended by WHO. Several project teams decided to transfer the mainstream traffic to an underground tunnel – that was the first of innovative changes necessary to return the area to the residents. Results of sound level calculations indicate that with:

– reduction of the traffic on the road segment under consideration to 20 vehicles per hour guaranteeing the inhabitants the access to their property or apartments;
– reducing the permitted speed to 30 km/h;
– introduction of quiet means of public transport;

one obtains reduction of L_{den} down to the value of 55–62 dB and L_{night} to 50–55 dB (Figs. 3 and 4 – the day-evening-night noise level and the night noise level, respectively).

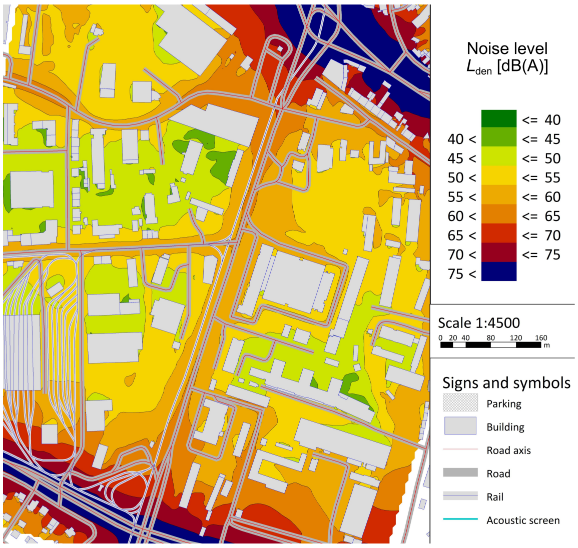

Fig. 3. Day-evening-night noise level (L_{den}) after traffic volume reduction to 20 passenger cars per hour, calculated in the SoundPLAN 8.2 software.

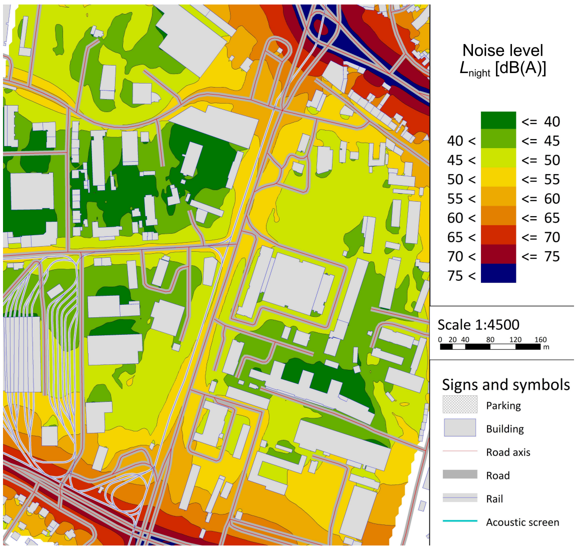

Fig. 4. Night noise level (L_{night}) after traffic volume reduction to 20 passenger cars per hour, calculated in the SoundPLAN 8.2 software.

Without using acoustic models of the space under consideration we would hardly know that the deployed measures were insufficient to solve the problem. To make such drastic limitations in vehicle traffic credible and possibly able to bring notable benefits in the form of noise level reduction over the whole street segment under consideration, it was necessary to introduce the means of acoustic protection aimed at reduction of the possibility of penetration of noise from neighbouring arterial traffic routes on which no such restrictions will be introduced in the examined area. Therefore, 5-metres-high acoustic screens were provided in the project. Such a solution results in noise level reduction, especially in the direct vicinity of the screens. It should be indicated that the proposed acoustic screens are not situated directly in the area under consideration, but at its borders, in order to block the noise from reaching the main city roads. Moreover, the design includes the "green wall" type of screen, which is to be covered by climbing plants, thus becoming a biologically active element that will not decrease the aesthetic values of the surroundings. The results of noise level calculations are presented in Figs. 5 and 6, for the day-evening-night level and the night level, respectively.

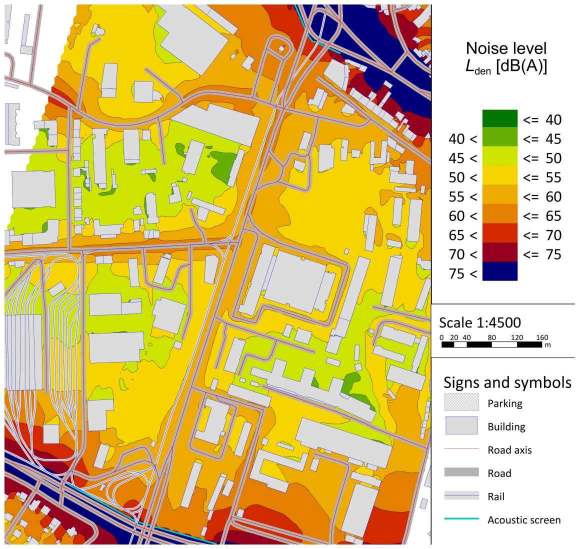

Fig. 5. Day-evening-night noise level (L_{den}) after traffic volume reduction to 20 passenger cars per hour and installing acoustic screens, calculated in the SoundPLAN 8.2 software.

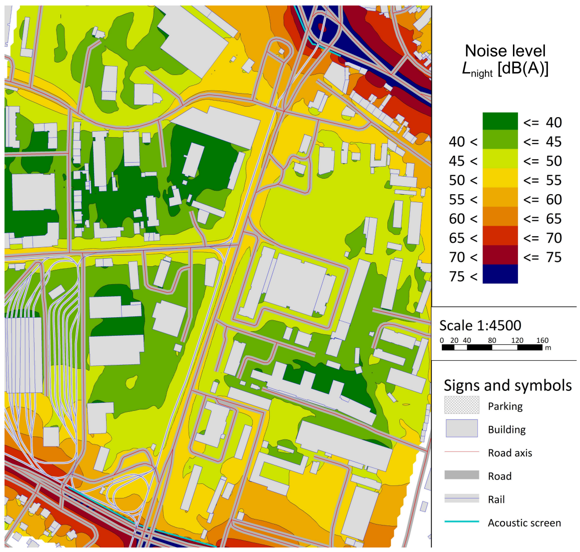

Fig. 6. Night noise level (L_{night}) after traffic volume reduction to 20 passenger cars per hour and installing acoustic screens, calculated in the SoundPLAN 8.2 software.

For the purpose of quantitative comparison of the effect induced by the introduced changes, sound level calculations were carried out for measurement points P1, P2, and P3. The situation of the points is shown in Fig. 1 and calculation results in Tables 1 and 2.

Table 1. Calculation results for the day-evening-night noise level (L_{den}).

	Current state [dB]	Traffic volume reduction [dB]	Traffic volume reduction + acoustic screen [dB]
Point 1	73.5	61.6	58.7
Point 2	74.2	58.0	57.5
Point 3	72.5	56.7	54.6

Table 2. Calculation results for the night noise level (L_{night}).

	Current state [dB]	Traffic volume reduction [dB]	Traffic volume reduction + acoustic screen [dB]
Point 1	66.8	54.7	51.8
Point 2	67.5	51.2	50.6
Point 3	65.8	50.0	47.9

The existing models for predicting noise levels in an environment may be used to determine changes which must be implemented in towns and cities to protect their inhabitants from harmful effects of noise. On the other hand, proper development of a cityscape aimed at "giving it back" to local residents involves further introduction of some changes in the visual sphere which can also be verified with the use of mathematical models. These noise reduction methods are applied in the so-called Action Plan when cities are modernised as a result of an analysis of noise maps.

2.2. Comfort – an application of the tranquillity rating to assessment of urban space modernisation projects

Studies carried out in various research centres show interdependence between tranquil urban areas and stress reduction (Ulrich *et al.*, 1991; Takano *et al.*, 2002). These works are focused only on the assessment of sound stimuli or the impact of visual and audial stimuli on a given space (Preis *et al.*, 2015; Nilsson *et al.*, 2007). Several attempts have been made to describe the interdependence between the assessment of acoustic and visual quality of a space with the help of mathematical models. However, in the aspect of the evaluation of city space modernization projects, tranquility rating seems the most promising tool to be used.

Assessment of usefulness of the area determined with the use of the tranquillity rating is defined by means of the equation:

$$\mathrm{TR} = X \pm \alpha \cdot A_1 \pm \beta \cdot A_2 \pm ... \pm \omega \cdot A_n, \qquad (1)$$

where X is a constant which, like other quantities appearing in the formula, is determined based on psychoacoustic tests. To determine the actual form of the function, the regression analysis is used. $A_1, A_2, ..., A_n$ represent sociologically conditioned elements shaping the perception of tranquillity, whereas $\alpha, \beta, ..., \omega$ are weights characterising the effect of each of the above elements.

The tranquillity rating may comprise a number of indicators, whereas positively perceived visual and sound elements increase, and negative ones decrease the parameter value.

A number of models for TR are discussed in the literature of the subject.

The tranquillity rating prediction tool (TRAPT) provides that the formula for TR value may take a number of forms determined with the use of the regression analysis, two of which are (Pheasant *et al.*, 2009):

$$\mathrm{TR} = 13.93 - 0.165\,[L_{\mathrm{Amax}}] + 0.024\,\mathrm{NCF}, \qquad (2)$$

$$\mathrm{TR} = 8.57 - 0.11\,[L_{\mathrm{Aeq}}] + 0.036\,\mathrm{NCF}, \qquad (3)$$

where L_{Amax} is the maximum sound pressure level and L_{Aeq} is the equivalent continuous sound pressure level expressed in dB. The square brackets denote the numerical value of a given quantity, so for, e.g., $L_{\mathrm{Amax}} = 50$ dB, $[L_{\mathrm{Amax}}] = 50$. The quantity NCF (natural and contextual features) ranges from 0 to 100 and corresponds with the share p (expressed in percent) of natural features, i.e., flora, water, etc., in the environment, so NCF = $[p]$.

In each of the quoted forms, the TR can assume values from the minimum equalling 0 to the maximum of 10. If TR > 10 or TR < 0, its values of 10 and 0 are adopted, respectively. Assessment of the examined area is verbalised according to the scale: below 5 – unacceptable; [5, 6) – just acceptable; [6, 7) – fairly good; [7, 8) – good; 8 and above – excellent. The Eq. (3) was proposed for both urban and rural areas, which was a fundamental impediment to application of the model for the purposes of assessment of typically urban space modernisation projects. That gave rise to further research (Watts, 2017; Watts, Marafa, 2017) as a result of which a new model was developed expressed by means of the equation:

$$\mathrm{TR} = 10.55 - 0.146\,[L_{\mathrm{Aeq}}] + 0.041\,\mathrm{NCF} + \mathrm{MF}, \qquad (4)$$

where MF is a moderating factor offering the option of taking into account various factors having either positive or negative effect on perception of the space in question. Its effect is estimated to be ±1 scale points. The approach in which researchers break down MF into factors characteristic for the location of interest and specific for users of the space in question, cannot be generalised to cover other spots. The research is of local nature. Additionally, impressions of subjects taking part in the research depend on such factors as gender, age, or physical and mental state, therefore any change of one variable in the regression analysis (Pheasant *et al.*, 2009) is explained by means of changes in the second variable at the determination level of $R^2 = 0.59$ (in the audio experimental conditions) and $R^2 = 0.5$ (for purely visual stimuli). Any psychoacoustic assessment obtained on the grounds of laboratory tests instead of on-site examination is also biased with a certain error resulting at least from the fact that the subjects are immersed in an environment illuminated with artificial lighting (and not the natural light). The sound reaching a user of a specific city spot and the view of the location make up a multi-dimensional spatial and sound scenery. In a laboratory, the perception is in a way reduced to two dimensions regardless of whether the subjects are presented a video or still photos of the location in question.

From the first portion of this paper we have learned that the sound level would fluctuate around 50 dB which means that for the model (3), the obtained TR value will be unacceptable, whereas for the model (4), it will be acceptable at 50% NCF. The research concerning the model (4) improves the presented situation significantly by reflecting perception of cityscapes more accurately, although it is far from solving all the involved problems. In urban conditions, it is difficult to obtain TR values better than the acceptable ones (TR < 7), which seems to be in contradiction with the reality. If a zone comfortable for people was characterised with TR values above 7, then according to the model (4), it would be necessary to introduce at least 92% of natural elements and nature-harmonised architectural features into the scene. In case of city modernisation projects taking into account the masking of unfriendly soundscape with sounds which can be considered friendly or neutral by the users of the space in question, none of the above-discussed models seems to be applicable. That is why in the next section, we propose a change to the TR model.

3. Modification of the tranquillity rating carried out for the purpose of assessing urban space modernisation projects

Cooperation with artists, sociologists, and architects in the framework of intercollegiate workshops has made us aware that there was a lack of tools for objective assessment of urban space modernisation projects. The problems have been identified:

1) Health (L_{den} and L_{night}) and tranquillity (Pheasant *et al.*, 2008), as well as comfort or wildness, are described with the use of different acoustic indicators. The health is defined in terms of L_{den}, whereas the tranquillity is determined based on L_{Amax}, L_{Amin}, L_{Aeq}, and L_{A10}. In a method developed in England (Kephalopoulos, Paviotti, 2008; DEFRA, 2006) and used to determine the road traffic noise, formulae for converting individual indicators into other ones obtained by estimation result in differences of the order of 2%, which gives an insignificant change for sound levels in the range 50–55 dB compared to the uncertainty taken into account when predicting sound levels in SoundPLAN software environment.
2) In case of modernising a cityscape, it is equally important what the appearance of the space in question is both in daytime and at night-time and what the related soundscape is at each time of the day.
3) The following can be noted about the TR in the currently used form:
   - the TR concerns perception of a space on a sunny day and only during the daytime;
   - the coefficients estimated in the course of the regression analysis suggest that any zone comfortable for people characterised with values of TR indicator above 7 is very difficult to obtain in city conditions, which seems to contradict the reality. Additionally, in the available literature, only point estimators of the regression line are used, suggesting that interval estimation analysis of the indicators is of no significance whatsoever. Such an approach to the topic seems to be erroneous;
   - the basic model is hardly universal – it applies to specific locations only and additionally, the coefficient of determination shows significant dispersion in reception of a given space by individual volunteers;
   - the model is designed for application to both urban and rural areas and is likely to upset perception of urban spaces in which the users seek tranquillity rather than silence which exists in the nature;
   - the structure of sound is not taken into account, so it is impossible to extend the research towards the use of sound masking.

We invite other scientific centres to join the work on putting forward and solving individual problems. Years of intensive work and discussion are still before us. In this article, we start with putting forward a proposal of changing the TR model through taking the structure of sound into account. We search for a solution universal enough to be suitable for application in different cultural environments on different continents.

3.1. Theory of complexity for the analysis of acoustic quality

Studies on soundscape indicate a far less dominating role of physical parameters of sound and a much more significant role of individuals and their perception (Brown, 2010). It is not only the ability to identify sources of sounds that is important, but also the proportion of time when the sound is perceptible. Designing of a coefficient model univocally describing the soundscape is still an open problem. We suggest that this model should include the SCF indicator (proposed by authors, first time introduced in this work, short for sound and contextual features) that represents a friendly soundscape taking into account the role of human perception included in the theory of complexity for the analysis of acoustic quality.

Now, let us refer to the theory of complexity for the analysis of acoustic quality (Ipsen, 2002; Elmqvist, Pontén, 2013) based on differentiation of the soundscape. There is a relationship between the perception quality and complexity of the perceived sound. The interest in the soundscape decreases for a low level of sound complexity. The same occurs when complexity of a soundscape is very high as in such a case legibility of each sonic component making out the soundscape deteriorates. Low and high sound levels of complexity have never been clearly defined by the authors of the theory. As the authors of this paper understand it, a low sound level of complexity is a single acoustic event. The opposite of this phenomenon is the high level of complexity, that is, multiple events occurring frequently.

We propose that sound complexity is described using a second-order polynomial obtained by interpolation. Zeros of the function are assumed to fall at 30 and 70 dB. Bearing in mind that a normal conversation of two people corresponds to sounds with the level of 55–60 dB and thus not always contributes to friendly soundscape for other users of the same space, the maximum value of the function was assumed to be 50 dB. Masking the sounds with levels below 30 or exceeding 70 dB is pointless; the lower-limit values are possible to register only in parks late at night (Wiciak *et al.*, 2015), whereas upper limit levels are perceived as disturbing in the context of seeking tranquillity, regardless of the sound structure:

$$\mathrm{TR} = 10.55 - 0.146\,[L_{\mathrm{Aeq}} - L^*] + 0.041\,\mathrm{NCF}, \qquad (5)$$

where L^* is the quantity corresponding to the theory of complexity for the analysis of acoustic quality expressed in the form of a second-degree polynomial and assumes values from 0 to 1.08 dB,

$$L^* = \mathrm{SCF}(-0.000186\,[L_{\mathrm{Aeq}}]^2 + 0.018571\,[L_{\mathrm{Aeq}}] - 0.39)\ \mathrm{dB}, \qquad (6)$$

where SCF is the indicator assuming values from the range (0, 100) corresponding to the percentage share of friendly sounds in the soundscape.

Referring to the theory of complexity for the analysis of acoustic quality we assume that for 30 dB the complexity of sounds in the soundscape is probably minor, and therefore the soundscape is dull. When the soundscape includes friendly sound sources (actual or disguising sounds of nature, like the sound of running or falling water), the complexity increasing the attraction of the soundscape will increase, reaching the maximum at 50 dB. At higher levels of noise, the attractiveness of the soundscape will slowly decrease. Taking into account that the soundscape might include unfriendly or neutral sound sources (a tram passing by or cyclists riding), the equation includes SCF index describing the proportion of friendly sounds in the soundscape. Since the model has been adjusted to urban space modification projects, SCF index is determined on the basis of a prognosis.

As for the proposed changes, the effect of friendly soundscape equalling approximately ±1 scale point (Fig. 7) was assumed, which corresponds to the factor MF (4). In our model, the factor has been integrated

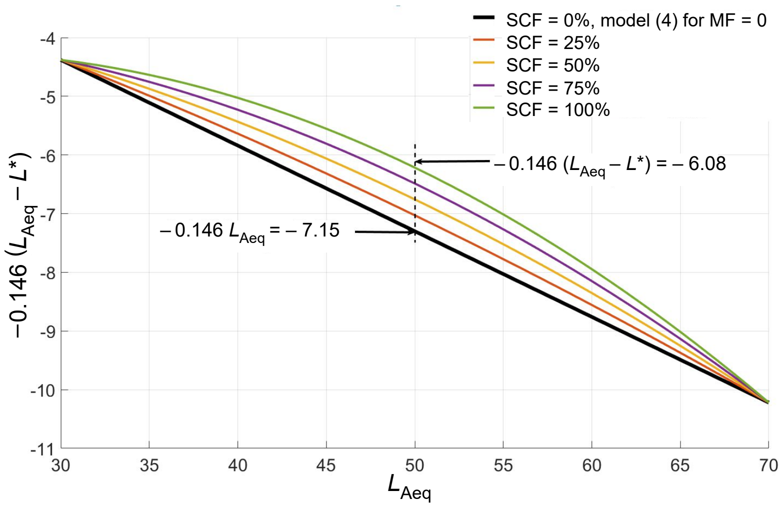

Fig. 7. Modification of tranquillity rating proposed specifically for the purpose of assessment of cityscape modernisation projects. Equation (6), calculated with interpolation for the 100% favourable soundscape, between 45 and 55 dB does not increase the TR by more than 1 point, which is in accordance with the studies presented with the help of the model (4).

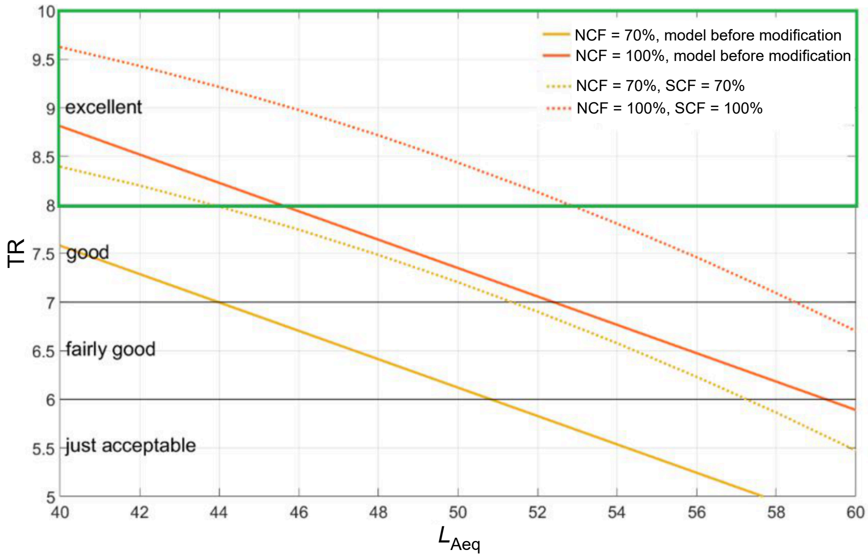

Fig. 8. TR before and after modification taking into account the sound structure and the theory of complexity for the analysis of acoustic quality.

into L_{Aeq}. The proposed change introduces some universalism to the model – there is no need to carry out any research on the issue which sounds and in what way contribute to increase of TR in a given location. This depends on the community members who use the space in question. We rely on a model assessing the comfort only provisionally, until new models based on the indicator L_{den} are developed taking into account the analysis of both point and interval estimators with a significantly higher coefficient of determination. At the moment, we would like to reliably assess the projects developed in the course of intercollegiate workshops. The proposed modification pertains only to city modernisation projects and does not affect conclusions drawn from the research carried out in other scientific centres.

By introducing the factor following from the acoustic theory of complexity for the analysis of acoustic quality (6), we have reproduced the perception of a cityscape more realistically – the concept of a comfort zone now includes also provision of sound levels in the range of 55–58 dB which are normally observed in an office space or a coffee shop (Fig. 8) and which have no negative impact on human health.

3.2. Projects developed in the course of the workshop and their assessment with the use of the modified model

In the following, two projects out of the total number of nine which were worked out in the course of the Alternative Public Spaces workshop are presented and assessed. They are projects of modernization of the space presented in Sec. 2. The selected projects are those within the framework of which their authors predicted values of the indicators SCF and NCF. In the first project named the *Alsos Avenue* (where *Alsos* is a Greek word meaning *Grove*), bicycle lanes and pedestrian pavements were designed along the whole section of its route through the area (Fig. 9). Between

Fig. 9. The Alsos Avenue project. Authors: Karolina Motak, Paulina Habura, Marta Bil, Sanara Słojewska, Julia Idczak, Karol Piotrowski. Original pictures of the designs are accessible in (Ozga *et al.*, 2019).

these bicycle and pedestrian paths, green areas are planned to be created and – as a reference to the history of the location and the *Mateczny Spa* – construction of a ditch is being designed to form a channel for the creek. A ribbon-shaped metal structure filled up with a membrane was integrated into the cityscape. The function of the ribbon feature included the roofing of shelters, public transport stops or rest spots. An additional benefit of the ribbon was the possibility of using it as a mounting frame for sound shower type loudspeakers which enabled introduction of masking sounds to the soundscape. By assumption, the whole area was meant as a space encouraging inhabitants to arrange meetings in the open air and having a beneficial effect on physical and mental state of the people present. The NCF value predicted for the space is 70%, SCF is also forecasted to be on the level of 70%.

In the case of designs, it is impossible to calculate NCF – the percentage value of each natural element of the landscape in accordance with the rules given in (Pheasant *et al.*, 2010). The authors of the project are obliged to create a space that is 70% biologically active, and on this basis NCF is accepted. It is far more difficult to forecast the SCF coefficient for the space in which quiet trams and car passage to the owner's property at the speed limit of 30 kmph have been allowed. Parking spaces for properties at Alsos Avenue were designed beyond the discussed area, pedestrian and bicycle lanes are lined up with specially designed pavements. A tram passage at the rush hour is forecasted at every ten minutes. The soundscape in such a space is like patchwork – filled with humans talking, sounds of water flowing in a stream and sounds of nature – which are either actual or meant to disguise something else. It cannot be precisely calculated since in spite of a finite number of sound sources that are forecasted, the number of combinations of acoustic events and their duration is infinite. The risk analysis shows that the most difficult situation will occur when the inhabitants commute to and from work. For these rush hours, the acoustic restrictions presented above allow a forecast of no less than 70% level. Most frequently, a person staying at Alsos Avenue will hear the sounds of nature, water and conversations. The duration of unfriendly events will be short, like the passage of a quiet tram, departures or arrivals of individual cars at distant parking sites.

The function assumed for the second project named Zakopane Road Spa (Zakopianka Zdrój, Fig. 10) was the promotion of health. The project assumed creation of enclaves of silence. Revitalisation of the public space was aimed at reconstruction of identity of the existing location called Mateczny Roundabout, a site with some spa traditions. In 1898, drillings carried out by a town councillor Antoni Mateczny led to discovery of a source of sulphur mineral water with unusual healthful properties. The layout ended near the Shrine of the Divine Mercy, a religious cult centre, where water symbolises revival and exculpation. The curative water will be offered for tasting and purchase in the quiet areas. The NCF predicted for this space is 100%, with SCF also forecasted to be at the level of 100%. In the case of Zakopane Road Spa, space management and sound are 100% connected with water, which, according to the propagator of the concept of soundscape (Schafer, 1993) is the most beneficial of the attainable environments.

According to the model (4), for sound levels in the range 48–52 dB, the Alsos Avenue project would be assessed on the "fairly good/just acceptable" level (Fig. 8), whereas the presented solution after application of the proposed modification, was assessed as "good". This makes assessment of perception of the space in question more realistic. The Zakopane Road Spa project, which was developed to protect health and promote a healthy way of life; without modification of the model, could be assessed as only "good", whereas its perception and the modified indicator TR result in the assessment on the "excellent" level.

The presented alternative cityscape projects prove that it is possible to establish a reliable assessment system in which the visual scenery and soundscape are fully adequate both in the daytime and at nighttime.

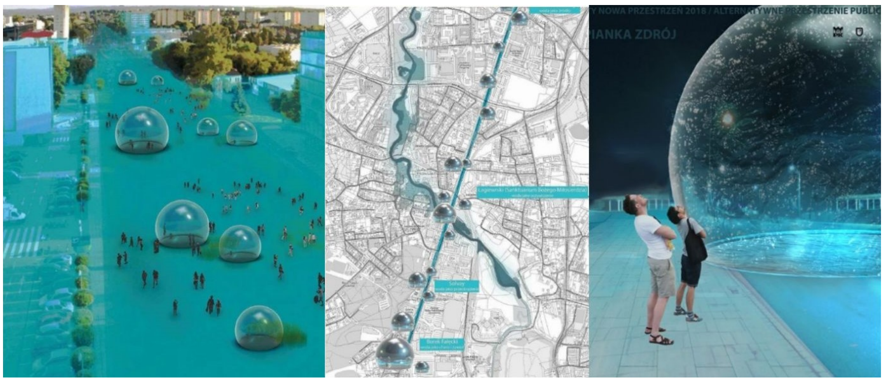

Fig. 10. The Zakopianka Avenue project. Authors: Dominika Kuczera, Kinga Duda, Aleksandra Rogowiec, Janusz Rożdżyński.

4. Summary

The projects created in the framework of Alternative Public Spaces workshops cycle's 2018' edition were supposed to be free from either political or economic barriers which, in many cases, hinder the necessary changes. The students were made aware of the fact that although the information about the environment is perceived, first of all, via the sense of sight, and their projects would be assessed, as a rule, from the visual point of view in the first place, they should nevertheless draw their attention also to other stimuli. The existing strong interdependence between senses by which the environment is perceived (sight, hearing, smell, touch) is defined as the perception ecology.

The presented research results indicate that in many cases, it is virtually impracticable to achieve compliance with the required permissible sound levels in a cityscape. However, it is still possible to change the character of noise (by masking) which may result in an increase of the comfort of life. In view of the aforementioned, a modification of the TR indicator was proposed consisting in making it dependent on both sound nature and level. The proposal should be considered an idea aimed at extending the currently used environment status assessment coefficients rather than an alternative for the presently applied ones.

In view of conclusions from the research carried out by WHO, according to which one European out of five is regularly exposed at night-time to sound levels posing a significant risk to health, it is necessary to make out noise maps and use them for the purpose of noise reduction. In the daytime, on the other hand, despite technical impracticability to lower the sound level in large urban areas, attempts should be made to change the character of the sound and create acoustically alternative cityscapes, the so-called enclaves of silence or quiet areas. It is also necessary to work out methods and indicators for assessing their effect on people – the presently used set of sound-level-based indicators seems to be insufficient.

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