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The application of environmental issues in designing urban structures – a framework for comprehensive local planning policies

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ABSTRACT

The implementation of environmental issues in planning and designing urban structures is becoming a novel approach and a common practice consistent with the paradigm of sustainable development. Maintaining environmental quality in urban areas, managing natural resources and understanding the complexity of urban systems is becoming increasingly challenging. Therefore, it is important to develop strategies for the integration of environmental quality research into urban planning policies and for the development of alternative spatial solutions for the existing urban structure which are aimed at improving environmental quality in urban areas. The aim of the article is to review contemporary theoretical and practical approaches towards the implementation of environmental issues within the process of urban planning in order to present a framework for local planning policies. Described is the research into spatial and design solutions which can efficiently reduce noise levels, mitigate atmospheric pollution and odour nuisance or prevent the negative effects of local microclimate effect. The possibility of application of design guidelines aimed at achieving environmental objectives in local planning documents is also assessed.

Keywords: Environmental evaluation, urban areas, sustainable development, integrated urban planning, quality of the built environment, design guidelines

1. INTRODUCTION

The world is becoming increasingly urbanised. It is estimated that by the year 2050 urban population will reach 70% of the total population in the world [1]. This leads to environmental stress, uncontrolled urban sprawl and increased in the use of resources and landscape degradation. When global environmental issues such as the greenhouse gas emissions and the loss of biodiversity have been acknowledged, a more sustainable planning agenda started to be widely advocated for [2,3]. Nowadays it implies new challenges connected with the development of urban areas as it is emphasised by the governments that inhabitants should be provided with a good quality of life in cities [1]. This concept, however, varies between different countries and its implication for urban planning will be different for poor developing countries and for the wealthy regions of the worlds. For instance, in the former, the priority is to ensure basic hygienic and residential standards whereas in the latter the stress can be placed on the expenditure of natural and environmental resources [4]. However, in all countries the quality of life is inseparably connected with the quality of the built environment.

Sustainable development of urban areas is not easily achieved as often environmental quality norms does not allow for dynamic urban growth, whereas the improvement of environmental quality is not integrated with the spatial policies [5]. Economic and social aspects may often dominate over environmental objectives in urban planning and decision making although planners are becoming increasingly aware of the need to respect environmental quality. Therefore, nowadays some environmental issues are already accounted for in the planning processes, for example as in the case of urban climate and its interrelations with urban structures as it was describes by Scherer et al. [6]. However, the growing need to comprehensively integrate all fields of environmental research with urban planning is often advocated for in the subject literature [7-10]. It is suggested that the results of environmental evaluation should be used in the master planning process by integrating various models into a common platform [11-13].

Yet, the complexity of various environmental quality determination makes it difficult to obtain a coherent vision of spatial development and ecological protection for urban areas [14]. It is important to note that two different approaches can be meant when referring to the integration of environmental quality evaluation with the practice of urban planning: environmentally conscious design in which the impact of urbanisation on the environment is taken into consideration or the implementation of environmental quality evaluation in urban policies and planning outlines. In the article, the latter will be discussed.

The environmental issues related to the development and spatial planning of urban areas include air pollution, odour nuisance, noise pollution, urban microclimate or the heat islands effect. They are all related to decreased quality of life and health-related risks to the urban inhabitants. One of the most concerning of them is atmospheric pollution. As estimated by the experts at the World Health Organization, in 2016 over 4 million cases of premature deaths were due to the exposure to outdoor air pollution. For example, the long-term and short-term exposure to fine and coarse particulate matter is considered a major risk factor in many respiratory and cardiovascular diseases, lung cancer, asthma and pulmonary conditions [15]. Odour nuisance can be also discussed in the context of air pollution. According to World Health Organisation substances can be classified as odours only at concentrations below toxic effects. It is underlined in the subject literature that only in extreme exposure conditions

odours can cause serious health-related symptoms [16]. However, frequent and intensive odour incidents have been reported to cause annoyance among its recipients [17]. Noise pollution can also be accounted for another form of air pollution which, already severe in urban areas, will continue to increase along with the growth of population and the process of urbanisation [18]. Moreover, the issue of urban microclimate should be also taken into consideration in urban planning on regular basis. This include temperature fields in cities, especially the urban heat island effect which is regarded as a climate modification resulting form from anthropogenic activity [19].

A considerable part of research regarding the environmental quality includes some consideration of the urban structure and possible design guidelines aimed at mitigating environmental problems. These design guidelines should be taken into consideration in planning and land use decision making. The aim of the article is to present environmental quality issues occurring in urban. The challenges connected with their integration and implementation into the practice of urban planning are also discussed. Moreover, some recent research on the impact of urban structure on environmental quality is reviewed together with the proposed design guidelines.

2. THE APPLICATION OF ENVIRONMENTAL QUALITY RESEARCH IN THE DEVELOPMENT OF DESIGN AND PLANNING GUIDELINES

A strong field of environmental quality research concerns the impact of urban spatial structures on the dispersion of atmospheric pollution. Researchers are convinced that air quality evaluation performed at monitoring points dispersed within the area of the city does not reflect the spatio-temporal complexity of the pollutants dispersion [20,21]. Therefore, modelling of the pollution dispersion is a useful tool in determining areas where the maximum pollution concentration levels are exceeded but also in developing and evaluating strategies for its mitigation. To investigate dispersion of atmospheric pollutants and the effect of breathability in urban areas, a wide range of research is being conducted using various methods including CFD simulations [22-24] or CFD simulations coupled with wind tunnel experiments [25-27].

The research is performed at different urban scales; different urban geometries are also considered. For example, Borrego et al. investigated what kind of urban structure typology is most effective form the urban quality perspective. Three typologies were investigated: low density disperse structure with segregated land use, high density compact structure with mixed land use or a network structure with several nodes connected to a dense centre by an intensive transport structure. According to this study, compact urban structure is the most advantageous [28]. There were also some studies performed at a local urban scale (street or neighbourhood), using models of urban blocks or building complexes, single street canyons or isolated buildings [29]. For example, Yuan et al. investigated the impact of urban morphology on the dispersion of pollutants for the high-density street canyons typical for the urban areas of Hong Kong. With the use of parametric models of the existing structures and their modifications, they developed spatial strategies which are helpful in improving air quality at the level of the pedestrians (see Table 1) [22]. Despite the hitherto achievements in this field, there is a need to further develop methods for the evaluation of pollution dispersion for

different spatial structures and design strategies and to incorporate them into the process of spatial planning.

Odour nuisance mitigation strategies are also not sufficiently accounted for in urban planning although odours are nowadays subject to control and regulation in many countries [30]. Evaluating odour nuisance is a challenging issue due to certain subjectivity in its measurement. Therefore, there is a variety of methods which can be applied for this purpose which include indirect methods of instrumental detection and direct methods in which human nose is used as a sensor (for example the most commonly used sensorial technique of dynamic olfactometry) [31,32]. Although odour measurement at the emission source is a relatively simple task, field measurements are more complex so an approach based on odour dispersion modelling is commonly applied for the purpose of odour nuisance [33].

The aforementioned complexity and subjectivity of this air quality issue implies the need to incorporate many different research tools towards its evaluation. For example, the issue of odour nuisance in the vicinity of a municipal landfill in Gdańsk, Poland, was researched in an interdisciplinary approach in order to evaluate its range based on the results of field olfactometry measurements and gas dispersion modelling. The results in the form of spatial representation of odour nuisance were used to analyse them in the context of local planning systems and to propose spatial solutions aimed at odour mitigation [14] (see Table 1). Other studies regarding odour nuisance were also with the incorporation of social research methods. For example, the results of olfactometric measurements and dispersion modelling conducted by Sironi et al. in northern Italy were validated by means of a social survey in which the perceived odour episodes were reported which showed a correspondence of 86.5% between the odour perceptions and the modelled immision levels [34]. Moreover, Invernizzi et al. propose a model to be used for the purpose of qualification of environmental odour nuisance, based on its frequency, intensity, duration, hedonic tone and location, which can be used as a useful urban planning tool [35].

In case of noise pollution, its perception is also subjective. The way noise is perceived by humans depends on the emotional interpretation of sounds and the relation of the recipients to the emitting sources. This is included in the concept of soundscape (first introduced by M. R. Schaffer in 1969 in a book entitled *The new soundscape*) in which it is perceived as the auditory component of urban landscape. Therefore, the management of noise in urban areas should account for the human experience of noise instead of focusing only on the physical measurements [36]. ArizaVillaverde et al. are convinced that since noise pollution depends on different urban features such as the spatial form of the buildings, their layout and the construction density. They propose a novel approach in which they investigate the correlation between noise level and the width and height of urban street canyons by means of joint multifractal spectrum [37]. However, more research is also needed into the impact of urban structure on the distribution of noise within urban areas with the use of various methods of research, also accounting for the human experience factor. For example, Zannin et al. used sound pressure level measurements and noise mapping coupled with a social questionnaire to investigate the environmental noise on the campus of the Polytechnic Center of the Federal University of Paraná, Brazil [38].

Urban planning is also increasingly confronted with the issue of climate and its relation land-use transformations [6]. As the climate change has become a global and widely discussed concern, various aspects of urban climatic parameters are considered and incorporated as design parameters in urban planning with the cooperation of designers and

urban climate scientists [11]. The perception of environmental quality is especially affected by local climatic conditions and the urban heat island effect which is described as an area where the temperatures are relatively higher than in the adjacent areas due to specific conditions such as human activities and generated waste heat. This effect is also associated with increased atmospheric pollution levels [39]. However, the climatic issues are not sufficiently accounted for in existing urban planning regulations

Some of the research regarding the impact of urban spatial structure on the various aspects of environmental quality were listed in Table 1. Exemplary design guidelines which result from the findings of the conducted investigations are also presented.

Table 1. Examples of environmental quality research in the context of urban structure

Environmental issue/ study area	Methods	Most important design and planning guidelines	Ref.
Investigation of the relationship between air pollutant dispersion and urban morphologies/ high density Hong-Kong street canyons	parametric modelling, CFD simulation	[1] the applied CFD model can serve as an architectural and urban planning design tool due to its high accuracy and low computational cost [2] evaluation of pollution dispersion is especially important in high-density urban areas [3] the study suggested the following strategies which promote convection effects and therefore are most effective in mitigating air pollution: building separations and voids, porosity [4] strategies such as building setback casing larger turbulence diffusion are less effective	[22]
Evaluation of the impact of trees on the dispersion of CO (carbon monoxide) pollution near road traffic infrastructure/ street canyons in Lisobon and Aveiro (Portugal)	Two different CFD models, CO concentration site measurements	[1] depending on the wind configuration an average increase or decrease in CO concentration was observed in the urban street canyons geometries which suggest that the optimisation of air quality in urban areas should be based on specialised research [2] using two different CFD tools can increase the accuracy of simulations [3] the following aspects should be taken into consideration in planning for a better air quality in urban areas: meteorological conditions, 3D configurations of buildings and the presence of vegetation [4] the use of CFD models is a useful tools in urban planning and optimising the	[40]

		impact of vegetation on human health and well-being	
Odour nuisance evaluation/ residential areas adjacent to a municipal landfill in Gdańsk	field olfactometry and weather monitoring, dispersion modelling, urban analysis	[1] the study suggested the implementation of tree buffers and vegetation with high adsorption [2] the facility should be provided with biofilters and other technological solutions to reduce emission [3] based on the odour nuisance dispersion modelling, residential use should be excluded in areas with high odour concentration [4] odour sources should be located away from residential areas	[14]
Environmental noise assessment/ urban areas the campus of the Polytechnic Center of the Federal University of Paraná, Brazil.	sound pressure level measurements, noise mapping, questionnaire	[1] there is a need for effective traffic and land-use planning [2] technical measures should be applied at noise sources [3] the reduction of noise transmission can be achieved by trees and other vegetation	[38]
Evaluation of the impact of urban geometry on outdoor thermal comfort and air quality/ downtown area in Curitiba, Brazil	on-site climatic monitoring, microclimate simulation, SVF (Sky View Factor) Analysis	[1] avoiding a dense matrix of buildings and canyon geometry (high street height vs width ratio) is advantageous from the thermal comfort perspective [2] a large proportion of the ground surface to be covered with impervious surfaces – concrete, asphalt etc. should be avoided [3] there is a need for the presence of vegetation [4] solar gain should be controlled, e.g. by introducing solar reflective surfaces	[39]
Evaluation of the effects of vegetation on the urban heat islands/ four areas in New York City	Analysis of field data and weather parameters, evaluation of heat fluxes, climatological model	[1] according to the study, densely vegetated areas are more successful at reducing heat fluxes and high surface temperatures than impervious surfaces [2] multi-storey buildings and narrow street geometry should be avoided as they reduce the wind permeability and, consequently, the heat dispersion [3] green roofs and their both thermal resistance and evapo-transpiration reduce the flux of heat through the roof	[41]
Investigation of the influence of urban planning regulations	ENVI-met microclimate simulations	[1] the type of buildings geometry in urban streets canyons has a significant impact on the thermal comfort in urban areas	[42]

<p>on the local climate effects in a hot dry climate conditions/ the city of Damascus, Syria</p>		<p>[2] other factors can also influence surface temperatures and thermal comfort in street canyons: aspect ratio, orientation of the street or the presence of vegetation [3] the planning regulations should be modified according to the research of urban climatic conditions, e.g. in case of Damascus smaller setbacks, narrower streets and higher buildings should be allowed in new areas as in more dispersed urban structures larger parts of buildings and streets are exposed to solar radiation</p>	
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3. THE IMPLEMENTATION OF LOCAL POLICIES IN LOCAL PLANNING – PRESENT CHALLENGES AND FUTURE PROSPECTS

Current practice of urban planning is aimed not only at designing spatial structures but also at promoting sustainability of urban areas and ensuring public health and well-being as well as the best quality of the built environment. The issue on integrating the issue of sustainability with the planning agendas has been tackled with by urban planners and environmentalists since the 1990s [43] but the outcomes are still not fully satisfactory. The effective integration and implementation of planning policies in which many factors of environmental quality are coordinated have been advocated over the past decades [see for example: [37] as well as the integration of environmental issues with the development planning [45].

Therefore, there is a need to develop a novel framework for environmental decision-making and local planning policies in which environmental issues are integrated with spatial, economic and social objectives. Such an approach can be found in concepts such as integrated planning or comprehensive planning [5,14,46,47]. Such a framework would allow for more conscious spatial decisions based on scientific evidence and multidimensional aspects of urban environmental quality. The assessment of the quality of the urban environment should be used to formulate implications for planning policies [48]. This may be exemplified by the design guidelines developed in the environmental quality research which were reviewed in the article, concerning issues such as atmospheric pollution, odour nuisance, noise pollution or climatic aspects. It is important to note that more issues can be taken into consideration in this respect such as the efficient use of daylight in designing urban forms. Comprehensive planning is also an important in maintaining biodiversity in urbanised areas and providing a variety of green spaces within the city [46].

The environmental sustainability is also very often linked with the economic development and the prosperity of urban areas. The three components – environmental, social and economic objectives – are mutually interdependent [49]. Therefore, the concept of social-ecological urbanism also needs to be mentioned. According to its authors, spatial paradigms should be reconciled with social and ecological sustainability at both global and local scale [50]. This also implies an important role of public participation in environmental planning which also a complex and unsettled process in which innovative tools are also needed [51].

4. CONCLUSIONS

New challenges of the comprehensive urban planning are connected with the integration of spatial development with the evaluation and improvement of environmental quality. For this end, cooperation between different sectors and fields of research is needed. New environmental quality evaluation tools should be constantly developed and improved with the Specific spatial strategies and design guidelines should be sought in environmental research aimed at mitigating many negative effects of the environmental issues on the quality of life of urban residents. Moreover, different environmental issues in urban areas require an individual approach and research. Yet, attempts should be made to integrate different aspects of environmental research and design into the practice of urban planning. Although the integration of various factors of environmental quality and their implementation into the process of urban planning have been advocated for over three decades, a comprehensive and effective framework for achieving this objective is still to be achieved.

The conceptual framework for the integration of urban planning agenda and environmental quality objectives should get across the disciplinary differences, difficulties may appear resulting from, for example, contradictory design guidelines or from the incompatibility of the results of environmental quality research. Therefore, modes of cooperation between different fields of research should be developed in order to create a common, interdisciplinary platform. However, each time local conditions as well as social and economic aspects should be taken into consideration so the effectiveness of the current practise of social participation in the process of environmental management should be evaluated and various social stakeholders should become involved. Moreover, social participation can be also successfully used as one of validation tools in environmental quality evaluation research.

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