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The Potential of Improving Air Quality by Urban Mobility Management: Policy Guidelines and a Case Study

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The Potential of Improving Air Quality by Urban Mobility Management: Policy Guidelines and a Case Study

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Abstract. There is a growing recognition among planners and policy makers that proper transformation of urban mobility systems is crucial to the reduction of air pollution emission. The main objective of the work was to review the current urban mobility strategies in the city of Gdańsk, Poland in terms of their potential for the improvement of urban air quality. Firstly, general policy guidelines for mobility systems were formulated based on a review of recent relevant studies and existing solutions from various European and Asian cities. Then the main spatial characteristics of the transport system and mobility patterns in Gdańsk were determined and visualised by means of GIS-based tools, supported by the analysis of local urban and environmental planning documents. The current air quality status in Gdańsk was also described. Subsequently, the policies proposed in two documents for the urban mobility management in Gdańsk were identified and cross-compared with the previously reviewed solutions from other cities in terms of air quality improvement. The results showed that the strategies for air pollution mitigation are not integrated with the process of urban planning in Gdańsk to a sufficient degree. Finally, some recommendations were also suggested to improve the current strategies.

1. Introduction

Despite the growing efforts to reduce emissions of air pollution, it is estimated that over a half of European residents still live in places where air quality does not meet the World Health Organisation standards, which reduces life expectancy by over two years on average [1,2]. The process of air pollution dispersion can be significantly affected by urban morphology and particular design strategies, which suggests the need to integrate actions aimed at air quality improvement with urban planning [3,4]. There are also numerous studies in which the impact of urban vegetation on the dispersion and deposition of atmospheric pollution is assessed (see, e.g.,: [5,6]). Finally, urban mobility and transport system have a significant impact on the management of air quality and human exposure to pollution [7,8]. Not only the technological advancements to reduce emission in particular vehicles are investigated [9], but also transport infrastructure as well as various urban mobility behaviours [10,11]. The aim of this work was to critically review the current urban mobility strategies in Gdańsk, Poland with respect to air quality improvement. To achieve this goal, the following intermediate objectives were set: **1)** to provide an overview of the best practices for reducing pollution emissions by urban mobility solutions, **2)** to present the main spatial characteristics of the transport system in Gdańsk and, finally, **3)** to analyse and critically evaluate two strategic documents for the re-development of urban mobility system in Gdańsk in terms of air quality improvement.

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2. Urban mobility management for air quality: Best practices in European and Asian cities

The impact of urban mobility management and of some infrastructural transport solutions on urban air quality and traffic emissions was reviewed based on recent relevant studies and selected existing solutions from European and Asian countries. These solutions can be divided into two main approaches **1)** reducing traffic-related emissions or the amount of vehicles and limiting the maximum speed in chosen areas, and **2)** reorganising current traffic arrangements (also in terms of developing alternative transport systems – cycling and pedestrian infrastructure or public transport) – see Table 1.

Table 1. An overview of urban mobility strategies in terms of air quality improvement.

Mobility solution	Explanation and/or expected results	Examples of application	Ref.
traffic-free or zero-emission areas	pedestrianised streets and zones, e.g., allowing only emission free-vehicles in the entire built-up area in Amsterdam by 2030	Europe: e.g., Amsterdam, Copenhagen, Ghent	[12,13]
low emission zones (LEZ)	creating areas with restricted access for vehicles not complying with certain emission standards to reduce air pollution	over 150 cities in Europe	[14]
congestion charging (CC) schemes	road charges applied per vehicle in designated areas to reduce traffic congestion without developing the existing infrastructure	Europe: e.g., Rome, Stockholm, London, Milan; Asia: e.g., Singapore city-state	[14,15]
slow speed zones and traffic-calming devices	reducing the vehicles speed by lowering the speed limit, coupled with introducing infrastructural devices such as speed humps	Europe, e.g., Milan, London, Edinburgh, Asia, discussed for e.g., Hong Kong, Singapore	[16]
low emission neighbourhoods (LEN)	comprehensive measures for emission reduction, including traffic management or facilities for electric vehicles	London	[17]
super-blocks	combining several urban blocks into one cell with inner pedestrian areas and improved traffic flow on the perimeter streets of the block	Barcelona	[18,19]
integrated public transport models	reducing car traffic by prioritising public transport and creating innovative, effective public transport solutions	Europe: e.g., Strasbourg, Madrid; Asia: e.g., Singapore	[13,20]
cycling and pedestrian infrastructure	various infrastructural solutions including fast cycling transit lanes (De Slowlane in Eindhoven) or parallel bike routes (Antwerp)	Europe: e.g., Eindhoven, Antwerp	[21,22]
controlling pollution dispersion	implementing infrastructural and design barriers, e.g., underground road infrastructure or particular traffic arrangements in street canyons	Europe: e.g., Antwerp, Stockholm; Asia, e.g., Shanghai, Guangzhou, Shenzhen	[23–26]

As shown in Table 1, the first group of solutions varies from measures such as the traffic-free areas or access only for emission-free vehicles (an objective for the coming decade in the entire built-up area in Amsterdam), to more relaxed measures like the low emission zones (LEZ), commonly applied in European cities. Different degree of effectiveness was reported for LEZ, even relatively low or limited to specific local pollution issues [14,27,28]. However, other studies showed more promising results or indicated that the real effects may not be easy to distinguish [28,29]. Congestion charging (CC) schemes are common in many cities in Europe, and are also gaining popularity in Asia, e.g., in

Singapore. Their prospective implementation is discussed for several cities in China (Beijing, Suzhou, Zhengzhou, Hong Kong) [30]. However, careful consideration is required, as CC may limit car traffic in the designated zone but lead to its increase beyond the spatial or temporal limits of this zone [31,32]. The effectiveness of traffic-calming measures in improving air quality, either local or area-wide, was reported as rather low or disproportional and difficult to assess due to insufficient evidence [16,33]. Moreover, a recent study showed that the ubiquitous speed humps lead to increased vehicle deceleration and acceleration and, in fact, increased emissions [34]. Promoting low-emission vehicles or reduced use of car transport also require more comprehensive solutions such as the low emission neighbourhoods (LEN) schemes, recently introduced in London, which include various activities such as informed car parking management or social initiatives like the car-free day [17].
Infrastructural arrangements, such as super-blocks – the concept of remodelling the inner city road network of Barcelona, are also applied. It was estimated that the above-mentioned scenario, together with technological improvements of vehicles and the use of high quality fuels, may significantly reduce traffic emissions [18]. Moreover, integrated transport model are sought by promoting improved accessibility and convenient interchanges or innovative regulations [20]. The development of cycling and walking infrastructure is also an important factor. Finally, controlling the dispersion of traffic can also be implemented through many infrastructural projects such as locating major urban highways underground (e.g., planned Ringland tunnel in Antwerp or underground bypass in Stockholm and the existing road tunnels in China [23,25,26]). However, the increased exposure of the tunnel users to vehicular emissions should be also considered [25]. The focus is also places on investigating the combined impact of traffic layout and infrastructural solutions in street canyons – the basic element of the urban structure – on reducing human exposure to traffic traffic-related pollution [35].

3. Urban mobility system and air quality in Gdańsk: Current status and development trends

The municipality of Gdańsk (see Figure 1), located in the north of Poland, is the largest Polish sea port and a part of the Tri-City agglomeration. It covers the area of 262 km^2 with over 460,000 inhabitants. The climate is warm and temperate with predominant southerly, south-westerly and westerly winds (see Figure 2). Gdańsk is located by the Gulf of Gdańsk and on the adjacent moraine hills. The historic centre lies on the lower terrace, whereas the upper terrace accommodates new post-WW2 residential districts and it is now the more dynamically developing part of the municipality, with a higher share of new investments [36]. Due to the lack of effective planning policies, the city is now undergoing suburbanisation and faces an urgent need for the inner centre revitalisation and modernisation of the harbour [37].

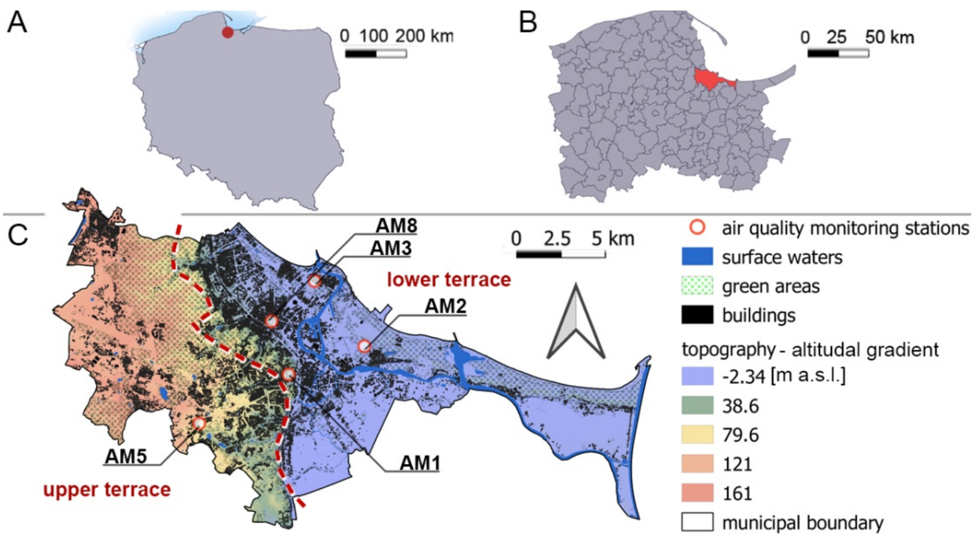

Figure 1. Gdańsk, location: **A-** Poland, **B-** Pomeranian Voivodeship, **C-**topography, built-up areas, greenery and water (based on: the resources of the Head Office of Geodesy and Cartography in Poland [38])

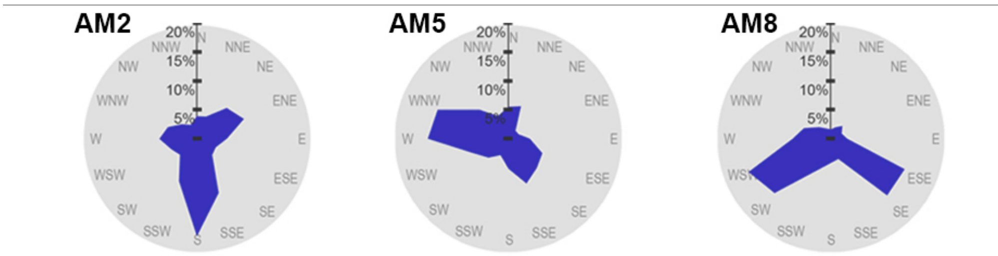

Figure 2. Gdańsk, yearly wind roses for 2018 based on the report from the ARMAAG agency [39])

3.1. Urban mobility system in Gdańsk

Gdańsk is characterised by predominantly linear transport infrastructure and services, aligned with the narrow lower terrace belt (see figure 3) [36]. According to recent traffic counts (2016), Gdańsk has a high share of private car transport in its transport modal shares (41.2%) [40] in comparison with many other European cities (e.g., approx. 33% in Copenhagen, Denmark (2014) or 30% in Zürich, Switzerland (2005) [41]). Moreover, there is a significant difference between the share of car travels in Gdańsk in the lower and the upper terrace (39.4% and 48.6%, respectively), which suggests uneven development of the public transport and cycling network and the need to consider this aspect in the local spatial planning system. The cycling infrastructure density in Gdańsk (quantified as the total length of cycling routes per km^2) is relatively well developed in comparison to other Polish cities, with a 6% share of cycling in the municipal transport modal share (the highest value in Poland). However, a lack of effective city bikes system is still an issue, despite the recent efforts to improve the situation [40,42]. The public transport coverage (quantified as the number of bus and tram stops per 1km^2) in Gdańsk is on average approx. 7 st./km^2 but above 20 in the areas identified as service points (calculated on a predefined hexagonal grid– see figure 2). These values are comparable with some other cities, e.g., approx. 5 st./km^2 in the centre of Brussels, 7 - Barcelona, 10 - Berlin, 12 - Vienna or 15-19 - Singapore, but over 30 st./km^2 in the centre of Rome, over 40 - London or over 50 - Moscow [43]. Moreover, public transport network in Gdańsk covers approx. 40% of the municipality, whereas this value is as high as 66% in Amsterdam, 72% in Hamburg or 77% in Warsaw [43]. However, direct comparison is tentative due to the difference in calculation methods or the spatial structure of the cities. Finally, it is estimated that the railway system in Gdańsk is still insufficiently developed, resulting in low share of journeys by rail, also in the regional scale [44].

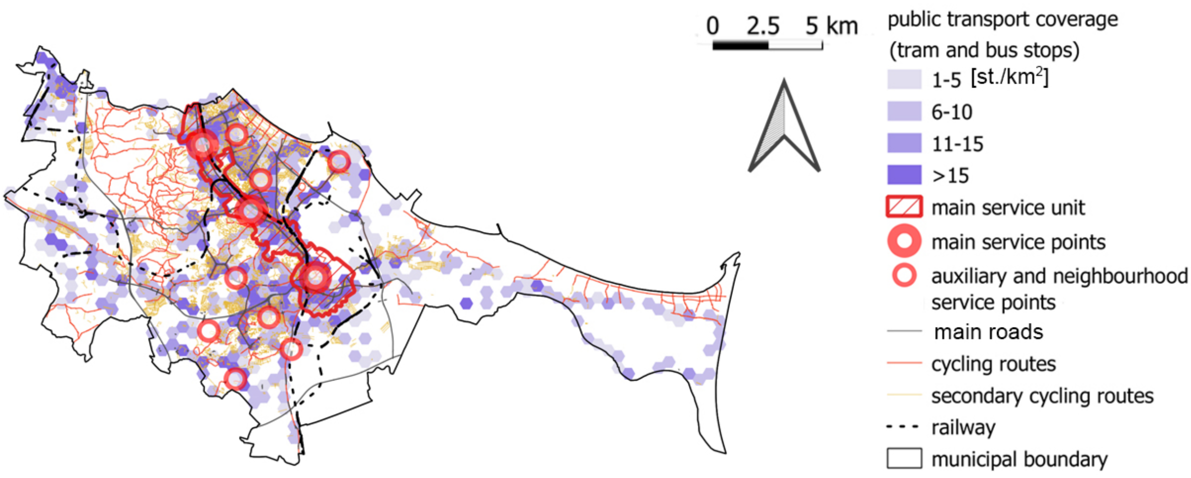

Figure 3. Gdańsk, transport and services (based on: resources of the Head Office of Geodesy and Cartography in Poland [38], the cycling map of Gdańsk [45], the open database of the Gdańsk public transport company [46] and municipal documents [36]).

3.2. Air quality in Gdańsk

According to recent WHO reports, many Polish cities are among the most polluted ones in the European Union [47]. In Gdańsk the issue of air pollution is not as severe as in the central and southern regions of Poland, which may be partly associated with its location by the Gulf of Gdańsk. For example, the yearly average pollution concentration levels for SO_2, NO_2 and PM_{10} are in compliance with the Polish norms for the maximum concentration levels of pollutants in ambient air. Yet, there are many reported episodes of exceedance of the maximum daily or hourly concentration levels [39]. Therefore, further actions are still needed to improve air quality. The main problem is coarse particulate matter (PM_{10}) and benzo(a)pyrene (B(a)P), strongly related to surface emissions, especially in poorly ventilated single-family residential areas where low-quality fossil fuels are used for heating, but also to linear emissions from traffic [48,49]. For example, in 2018 the maximum daily PM_{10} concentration level (50 $\mu g/m^3$) was exceeded on 72 days (where 35 days is the limit value). Moreover, a deterioration in air quality in 2018 in comparison to years 2016-2017 was recorded. However, it was mainly due to meteorological conditions (colder winter and less precipitation). In terms of NO_2 pollution, no yearly exceedances (above 40 $\mu g/m^3$) or hourly exceedances (above200 $\mu g/m^3$) were measured [39]. The daily patterns indicate two peaks in NO_2 concentration levels in the morning and in the afternoon as well as significantly lower measured values of PM and NO_2 concentration levels during the weekends, which is related to traffic emissions and commuting patterns [48].

4. Urban mobility in Gdańsk: Current strategies and solutions for air quality improvement

Two main strategic documents establish the directions for the mobility system development in Gdańsk: **A)** the strategy for transport and mobility for the metropolitan area: Gdańsk, Sopot and Gdynia (abbreviated as STiM 2030) [44], and **B)** sustainable urban mobility plan for the city of Gdańsk 2030 [50]. The aim of the document A was to determine the aims and priority actions for the metropolitan area of the Tri-City until 2030, based on local, regional, national and EU strategic documents, including organisational aspects and financial tasks and various modes of individual and public transport. It also identified the following reasons for low efficiency of urban mobility system: low integration between transport sub-systems, insufficiently developed suburban public transport network, lack of tariff integration and interchanges and, finally, lack of cycling feeder lines and of using the waterways for passengers transport. The aim of the document B was to analyse the current challenges for the transport system in Gdańsk, also in relation to changes in human behaviour patterns, social and spatial context and the available resources. An overview of proposed solutions and supplementing local plans is given in Table 2. The issue of improving air quality by transport planning is generally omitted in both documents, therefore some general recommendations were also given.

Table 2. An overview of sustainable mobility solutions.

Aim	Proposed implementation measures	Opportunities for air quality improvement
modernising and developing the current railway system (A)	-mainly for passengers transport (due to limitations in serving the port) - partly based on the regional sustainable development plan for public passenger transport [51])	- it will improve the current transport modal shares and decrease individual transport but there is a need for detailed solutions in terms of organisational and infrastructural aspects
lowering transport-related emissions (A)	- increasing the amount of electric vehicles and supplementing infrastructural solutions, introducing some emission objectives	- only general targets are set until 2030 – there is a need for introducing immediate solid standards, e.g., by establishing LEZ or CC schemes
the objectives of the “vision 0” (traffic calming) (B)	more areas with speed reductions, infrastructural solutions such as speed bumps or reductions in roads cross-section (based on the existing traffic	- due to limited or unrecognised effects of traffic calming on air quality, it should be mainly regarded in terms of creating safer road conditions and supplemented e.g., by

	calming programme[52])	pedestrianised streets or the reduction of parking spaces
infrastructural changes to encourage cycling and walking (B)	- improving the continuity and design of the pedestrian and cycling intersections with other modes of transport and terrain obstacles, -eliminating mobility barriers	- devices such as traffic bumps should be avoided and the impact of speed reductions or new traffic arrangements on traffic emissions should be estimated in particular cases
developing cycling infrastructure (A), (B)	- creating new lanes and catchment routes towards the centre (partly based on the “STeR” strategy[53]) - creating transit, regional cycling lanes, integrated with public transport	- the target value of cycling in transport modal shares (8-15% by 2030) is rather low - main cycling routes should be separated from busy roads and human exposure to pollution during active travelling should be assessed, e.g., by means of mobile monitoring
improving public transport efficiency (A), (B)	- improving public transport availability, costs and travelling time - providing interchanges, e.g., ‘park&ride facilities’ (partly based on the local and regional public passenger transport strategies [49,51])	- there is a need for detailed solutions in organisational and infrastructural terms - public transport coverage and frequency should be increased especially in suburban areas due to uneven network development

5. Discussion and conclusions

The need for comprehensive evaluation of the correlation between urban transport system and air quality prior to developing mobility plans, especially because of the high heterogeneity of air pollution concentration in complex urban areas [14]. In Gdańsk such studies are limited, with no relevant implications for the development of mobility strategies so far [54]. The understanding of this issue requires more detailed studies to provide a solid background for urban development strategies. Moreover, in the current urban mobility strategies only some consideration for air quality is given, with no reference to many of the currently applied solutions from other cities. An update of the strategic transport development directions, including these novel solutions, such as the LEN, should be considered. Moreover, more ambitious targets should be set in terms of reducing traffic or increasing the share of active modes of travelling.

It is important to note that only general, strategic measures are given in the analysed documents, whereas detailed solutions should be implemented by means of local planning acts. However, these documents do not specify the implementation or decision-making tools and practical guidelines to apply the set objectives at the lower level of the spatial planning system. For example, the unexploited potential of the water transport in Gdańsk was emphasised but no practical suggestions were made in terms of its development. Some additional solid and strict solutions for reducing traffic emissions should be also considered, such as the LEZ or CC schemes, apart from only introducing some general targets. Moreover, there is a need to perform detailed studies and scenario analyses to evaluate the impact of various mobility strategies and transport solutions on pollution emissions. Finally, the further development of the public transport and cycling infrastructure will continue to contribute significantly to the improvement of urban air quality. This must be accompanied by evaluating human exposure to pollution as well as the introduction of effective, real-time system of information about air quality during active travelling.

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