

ID 1646 | ANALYSIS OF THE AIR FLOW PERFORMANCE IN WARSAW IN YEARS 2002-2016

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1 INTRODUCTION

1.1 WHY AIRFLOW IS IMPORTANT

Nowadays, more than a half of the world's population lives in urban areas. By 2045 this number is expected to surpass six billion, reaching 66 percent by 2050 (United Nations, 2014). People decide to choose cities as their living place for various reasons, such as developed labour market or wide range of services. Unfortunately, highly urbanised areas, despite their understandable economic and living-standard advantages, suffer from serious environmental and development problems caused by erroneous planning decisions.

City climate is clearly related to general climatic conditions occurring in a selected geographic region, however, it is also dependent on factors such as land use, building geometry or street canyon design. Luke Howard in his renowned work "Climate of London" 200 years ago proved that urban climate differs from the rural one and noticed the urban heat island (UHI) occurrence. Indeed, the city of Warsaw, an object of this study, is distinguished by a lower access of solar power, higher air temperature and shorter period of frost incidence as well as lower relative humidity, bigger cloud cover, higher rates of rainfall and lower wind speed (Stopa-Boryczka, Kopacz-Lembowicz, Wawer, 2001).

Rapid changes of temperature, wind and humidity also affect comfort and health of the people as well as energy consumption and air quality (Elliason, 1999). Thus it is important to enable achieving conditions of thermal comfort especially in a hot and humid climate, through increasing wind velocity (Kato & Hiyama, 2012). Ensuring proper airflow in urban areas should be one of the key environmental issues tackled by governments and city mayors. However, T. R. Oke points out that it implies a critical choice between four goals: to maximize shelter for pedestrians by not exposing them to strong winds, to maximize dispersion of pollutants and minimize their impact on inhabitants and vegetation, to maximize urban warmth and to take full advantage of solar energy. We have to take into consideration that large amount of harmful compounds detected in the air of urban areas where human activity is intensified is not only a result of increased emission but also an effect of the strong surface drag in rough structures and limited effectiveness of dispersion of pollutants (Suder & Szymanowski, 2014).

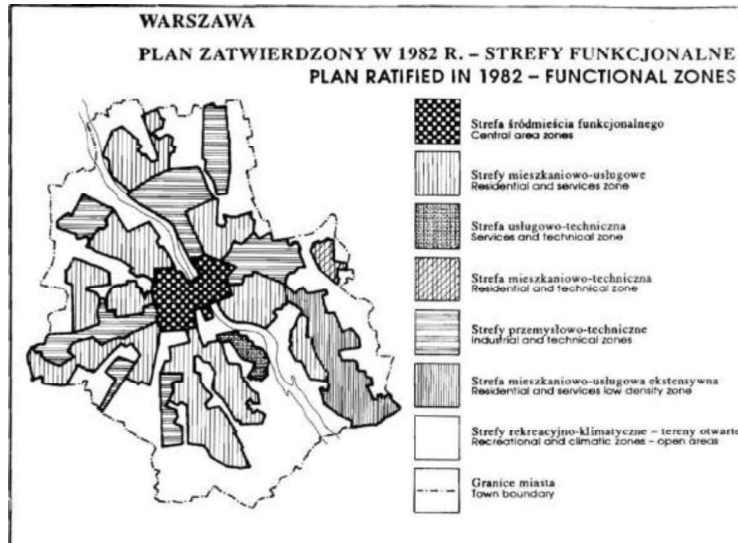
Therefore this study was set to analyse changes in morphology and terrain roughness in Warsaw in years 2002 – 2016 and related changes in city's aerodynamic properties, including ventilation corridors.

1.2 AIR FLOW CORRIDORS IN WARSAW'S PLANNING DOCUMENTS

The issue of air flow corridors and regeneration of air has been present in Warsaw's planning documents since 1916, when "The Initial Draft of the City of Warsaw Regulations", also known as "Tolwiński's Plan", named after the author, has been published. Tolwiński stated that: "the ease and recklessness which the builders of the city apply to taking away lands from its inhabitants (also citizens) is startling (Tolwiński, 1948). In order to prevent this issue from occurring he set down 6 air flow corridors consisting of continuous green areas, areas at the banks of Vistula river, as well as cemetery areas, all creating a sun-shaped system. On those territories total prohibition of building construction was enforced. Each of the following Warsaw's planning documents published before 1939 respected those guidelines.

During Second World War 84% of buildings located by the left side of the river were demolished. Such serious material losses lead to the creation of the Plan of Reconstruction and Restoration of Warsaw. That document, written in 1946, implied preservation of pre-existing air flow corridors and the emergence of the

new ones which were to be created by railway lines as well as lines of big city transportation. That plan



marked 9 corridors in total; 6 green corridors and 3 transportation ones. In 1956 The General Plan for the years of 1955-1965 was created, preserving the sun-shaped system of air flow (Government office, 1956). Between 1965 and 1982, as the result of lack of one planning document for the whole Warsaw, one could observe gradual build-up of the corridors.

Figure 1. Air flow corridors in 1982 (white colour). Source: National Council of Warsaw, 1982.

In 1982 the Prospective Plan of General Spatial Development for the city of Warsaw was created, which changed the definition of air flow corridors in the city. Above all, it included short buildings territories as well as green areas, sport areas, and land lot areas. The plan named them "recreation and climatic spheres – open areas" (Rada Narodowa m.st. Warszawy (National Council of Warsaw), 1982).

Finally in 1992, Local Spatial Development Plan of the city of Warsaw marked 8 significantly smaller corridors than those proposed by the Plan of Reconstruction and Restoration of Warsaw

(Rada Warszawy (City Council of Warsaw), 1992).



1.3 ISSUES CONCERNING AIR QUALITY IN WARSAW

Air quality in Poland has significantly improved since 90'. This was a period of rapid transformation of national politics and economy in post-soviet countries, including Poland. Over the years Poland as a signatory of international, and later European, conventions and programmes had to fulfil its obligations in terms of reducing emissions of pollutants, moreover it forced technological development in energy and industrial sector. Amount of annual emission of greenhouse gases in 2012 has decreased by almost 30% in comparison with 1988 (Krajowy Ośrodek Bilansowania i Zarządzania Emisjami (The National Centre For Emissions Management), 2014). However, Supreme Audit Office in 2014 claimed that norms of air quality established in European Union's regulations and implemented in Poland had not been completely carried out by Polish government.

Figure 2. Air flow corridors in 1992 (arrows). Source: City Council of Warsaw, 1992.

Particles which are emitted into our atmosphere can cause adverse effects on human health and the condition of ecosystems. Human activity leads to the emission of gases such as sulphur dioxide, carbon monoxide, ammonia and volatile organic compounds, which subsequently can react and form new pollutants. Air can also be polluted by toxic metals or methane and benzene. However, the most harmful for our health are particulate matters with diameters of 2.5 and 10 micrometres (PM_{2.5}, PM₁₀), nitrogen oxides (NO_x), tropospheric ozone and cancerogenic benzo-alpha-pyrene (B(a)P) (WHO, 2017). In 2013 PM_{2.5} pollution caused over 48 000 premature deaths in Poland. (European Environmental Agency, 2017)

Emissions of CO are still high, emission of B(a)P— even the highest in Europe (European Environmental Agency, 2016). World Health Organisation in 2016 revealed that 33 out of the 50 most polluted cities in Europe are in Poland. Results of annual valuations conducted by Inspectorate of Environmental Protection unequivocally indicate that low emission phenomenon deriving from commercial, institutional and household fuel combustion together with transport sector are the most responsible for inadequate air quality condition in Poland. In 2012 over 88% of total PM₁₀ concentration limit exceedances were contributed by emissions connected with individual house heating. Poles use low quality fuels and combust waste in unsuitable installations as an effect of unsatisfactory social awareness, but also because of economic reasons (Ministerstwo Środowiska, 2015). Voivodeship Inspectorate of Environmental Protection reports that causes of line emissions of air pollutants exceedance in Masovia, where Warsaw is located, are lack of city bypasses, technically obsolete vehicles and bad condition of road surfaces. What is important, substantial influence on air quality has also the inflow of pollutants from outside of voivodeship as well as secondary emissions of gases (W.I.O.Ś (Voivodeship Inspectorate of Environmental Protection), 2016).

People in Masovian Voivodeship and Warsaw are mostly struggling with problem of air pollution caused by particulates such as TSP (Total Suspended Particles), PM₁₀ and PM_{2.5} (IOŚ-PIB, 2016). In 2016 daily limit value of PM₁₀ (50 µg/m³) concentration established by EU Ambient Air Quality Directive was exceeded in every zone of voivodeship. On Niepodległości avenue station, in a centre of Warsaw, this norm was surpassed 85 times, while the limit is set at 35 days a year (Figure 3). The average concentration of PM₁₀ particulate was around norm (40 µg/m³ a year) yet maximum value of PM₁₀ concentration noted in the central station equalled 552.7 µg/m³, exceeding a daily norm 10 times. To compare, in 2002 it was 215,8 µg/m³ while average year concentration was similar. There is a noticeable downward trend in the number of exceedances in years 2005 - 2016, however annual pollution values had not significantly dropped over that time and since 2012 they slightly fluctuate about acceptable limit (Figure 3).

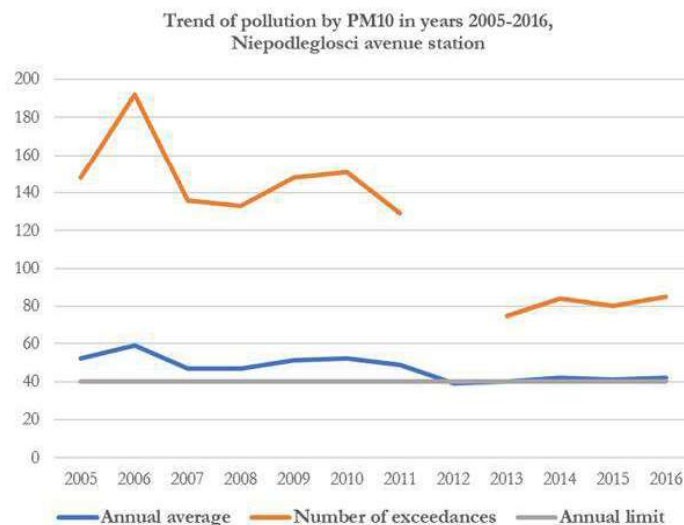


Figure 3. Trend of pollution by PM₁₀ in years 2005-2016 on Niepodległości avenue station. There was no data about number of exceedances for year 2012. Source: own study based on data from Voivodeship Inspectorate of Environmental Protection.

Spatial dispersion of concentration of substances such as: particulates, nitrogen and sulphur dioxides, carbon oxide and benzo-alpha-pyrene indicates that highest levels of air pollution occur in central districts of Warsaw, especially in Śródmieście. That situation motivated us to analyse how topography of the city can affect the airflow performance and to make an attempt of identifying barriers formed in urban and planning processes over time.

2 DATA

Data for the study were derived from Land and Property Register from Geodesy and Cadastral Office (Ewidencja Gruntów i Budynków EGiB), on the basis of an agreement between Warsaw University of Technology and the Office. Acquired Land and Property Register consists of buildings geometry, number of storeys in the buildings and the year of construction. 0,3% of the total number of records did not contain number of storeys and were excluded from the the first phase of the study (terrain roughness analysis).

More detailed data were prepared for the air flow analysis. Building characteristics were obtained from Topographic Objects Database (Baza Danych Obiektów Topograficznych BDOT) for year 2014. Geometry and location of the buildings were validated using aerial photographs. Data concerning number of storeys for each building were complemented using aerial photographs and other sources. In both cases height of buildings was calculated using number of storeys multiplied by estimated height (3 m).

Meteorological data for the study was obtained from website Weather Online, generating forecast on the basis of international databases (WeatherOnline).

3 METHODOLOGY

Indicators and urban parameters were determined in order to obtain appropriate spatial development effects (spatial order). Basic urban indicators include intensity, density of buildings and weighted average building height, which provide information on the extent of usage of construction sites. These indicators should be interpreted together as they can provide sufficient information about the characteristics of the built environment and assess the quality of the place as a place for living. Moreover, in our study we choose these few urban indicators to see how urban morphology impacts air flow in the city. Our choice was mainly based on the study "Correlation between Urban Morphology and Wind Environment in Digital City using GIS and CFD Simulations" (Yin J., Zhan Q., Xiao Y., Wang T., Che E., Meng F., Qian Y., 2014) in which the relationship between specific indicators and city ventilation was investigated. It has been found that there is a correlation between urban indicators and wind conditions in the city - a strong linear correlation between building density and average wind speed at pedestrian level, while the intensity and average building height show a weak, but existing correlation.

In this paper the intensity of development (I_n , equation (1)) is calculated as the ratio of the total building area (PC) to the surface of the site (PT , and the site is a mesh net):

$$I_n = PCPT \quad (1)$$

The intensity of terrain development is complemented by information such as:

- building density (G_{zab} , equation (2),) is the index of the sum of the cubature of the building (K) to the site area (PT):

$$G_{zab} = KPT \quad (2)$$

- weighted average number of storeys (LK , equation (3),), is the ratio of the total area of the buildings (PC) to the built area (PZ) (the area occupied by the buildings):

$$LK = PCPZ \quad (3)$$

To fully understand mentioned formulas, it is necessary to clarify some terms (explained in standard PN-ISO 9836:1997):

- total area of the building - the sum of the area of all storeys of buildings in a given area, calculated in the outer contour of the wall / walls,
- built area - the sum of the floor area of all buildings in a given area, calculated in the external wall / wall contour,
- cubature of a building (cubic volume of a building (gross)) - the sum of the product of the total floor area and its height.

Urban standards/norms take the form of regulations defining the relationships between urban indicators and the appropriate capacity of communication service and the size / availability of service areas (shops, education, health, culture, recreation, etc.).

In Poland, urban norms functioned during the Polish People's Republic. But after 1990, as a result of system changes (as well as demographic determinants, the growth of the automotive industry and the conditions of housing investments and land prices), most of the assumptions became obsolete and the application of norms ceased to be justified. When formal limitations ceased, the practice immediately surpassed the normative framework.

In Poland for almost 30 years no central urban standards have been applied (under the Land Spatial Planning Act 1994 the competence to set local urban development standards was passed to municipalities). The lack of mandatory regulations establishing spatial health and social minima causes numerous abuses: the implementation of housing complexes with too dense development, lacking basic social infrastructure, public access to sports and recreation areas and access to public transport (Dąbrowska - Milewska, 2010).

Calculations of the indicators (Fig. 5 - 13) within the study were made in a cartographic grid 100m x 100m covering the whole area of the city. The net mesh area (10000 m² / 1 ha) is the area for which the indicators were calculated.

In order to reflect the location of buildings in the meshes properly, the layer of buildings was cut through the mesh. So when the building is in two mesh nets, it will be counted in both of the meshes according to what surface it occupies in each, not just one. Height of the building was calculated on the basis of number of storeys. Average height of storey was assumed 3m.

All calculations were made using ESRI's ArcGIS software.

The main aim of the project was to analyse changes in the morphology of Warsaw in 2002 – 2016 period and related changes in its aerodynamic properties. Methodology of the survey was based on methodology proposed by M. S. Wong et al. (Wong, Nichol, To, & Wang, 2010). Terrain roughness was analysed on the basis of the Frontal Area Index (FAI), a parameter for estimating aerodynamic resistance of the urban surface. FAI is the total area of the facets of buildings in an area, where windward facets cover these located behind them, divided by surface of the area (equation (4)).

$$\lambda_f = \frac{A_{facets}}{A_{plane}} \quad (4)$$

Test plot given in the study was defined by the square 500m x 500m grid net. Frontal area of objects depends on the direction of airflow. Moreover, each wind direction was weighted accordingly to the frequency of its occurrence in the analysed period: (N - 7%, NE - 6%, E - 15%, SE - 15%, S - 12%, SW - 9%, W - 27%, NW - 9%).

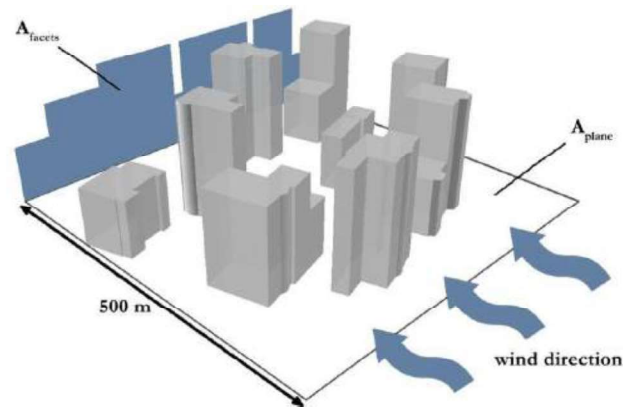


Figure 4. Data for frontal area index calculation. Source: own study.

Roughness index values gave basis to the wind corridor identification. For this purpose, 50m x 50m net grid was created and used for frontal area index (FAI) calculation, aiming to obtain results precise enough for a city scale study (Hsieh & Huang, 2016). Later, for each of four cardinal wind directions (W-E, NW-SE, N-S, SW-NE) was generated a grid classifying FAI for respective direction into ten classes. Then they were used as a distance weight grids for Least Cost Path (ESRI) analysis method generating a corridor between each pair from 144 barrier points chosen around the city's administrative border. Each pair was classified into the closest basic direction to a geographic azimuth between these points and a path between them was calculated on respective grid. That all identified wind corridors between sampled barrier points and throughout the city. In the following paper results for two most frequently observed winds are presented: W-E and NW-SE (Figure 18, Figure 19).

Airflow performance was visualized using computational fluid dynamics methods in Air Flow Analyst software. Elevation model was established using Airborne Laser Scanning data from 2011. Due to limited available computing power and marginal impact of the Warsaw landform on the results, elevation data was later ignored in the study.

4 RESULTS

4.1 URBAN INDICATORS CHANGE ANALISYS

Urban indicators calculations resulted in maps showing city-wide urban indicators for the years 2002, 2009 and 2016 (Fig. 5, 6, 8, 9, 11, 12). Moreover, it was possible to determine the change in these indicators in years 2002-2016 (Fig. 7, 10, 13). Analysis of the results allows us to designate areas of intensive urbanization in Warsaw and areas under-invested in recent years.

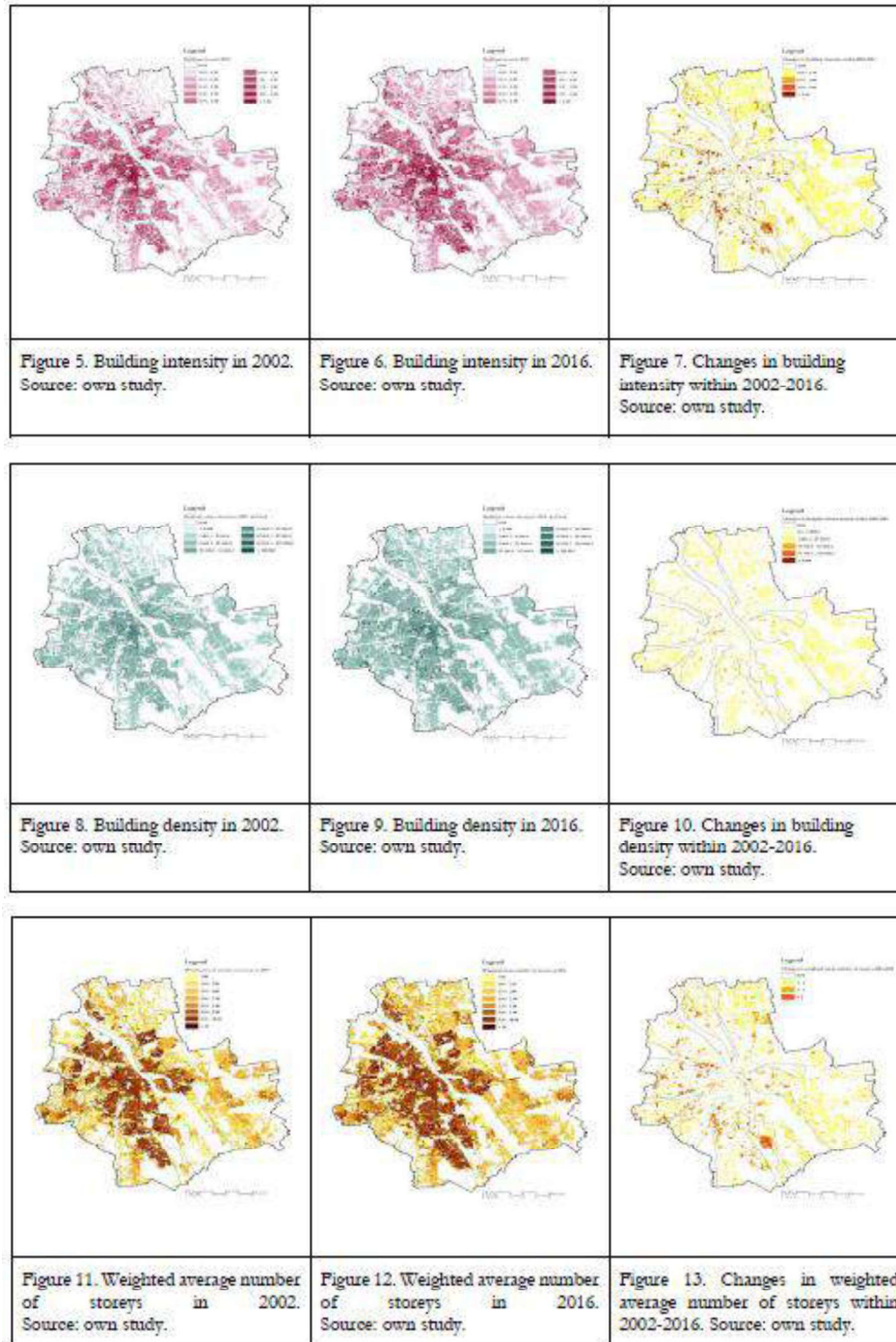
Increase in value of the indicators over the years could be observed, especially in Wilanów district, Ekopark estate, located in ventilation corridors Skorosze estate (very intensive multi-family housing without public space), Górcze estate (along Obrońców Grodna avenue) and Młynów estate.

It is possible to observe the development of new buildings on the eastern side of the Vistula River - yet building intensity is relatively small and the predominant number of storeys does not exceed three storeys. The biggest changes are located on Praga Poludnie district.

On the west side of the Vistula, the intensity of development is intensified in the following districts: Żoliborz, Wola, Ochota, Ursynów, Mokotów and Włochy.

From the performed analysis an overall trend of supplementary development and diffused urbanisation can be observed. New developments adapt undeveloped terrains on the city outskirts, as well as along thoroughfares and railroads. Furthermore, a disproportion occurs between eastern and western part of the city. The north-eastern part of Warsaw characterizes less densely built up area than the rest of the city. This, combined with an insufficient coverage of planning document, results in spread of development of highly urbanised settlements.

In the context of the city ventilation project, this analysis allows to designate investments that are located within the city ventilation corridors.

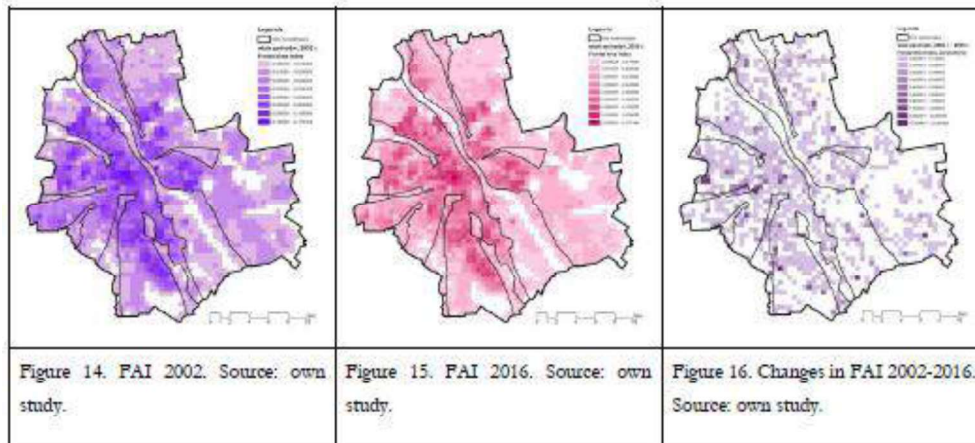


There is a noticeable increase in the intensity of development in corridors ventilating the city, which disrupts its natural ventilation. This leads to the formation of negative phenomena such as smog or urban heat island (Stopa-Boryczka, Kopacz-Lembowicz & Wawer, 2001).

The above maps do not show which buildings were built on areas covered by local planning documents and which are not. This aspect is worth later investigation.

4.2 ROUGHNESS TERRAIN ANALISYS

As a result, we achieved FAI values in 2002, 2014 and 2016 (Figure 14, Figure 15); FAI percentage increase in 2002-2016 enables to identify areas where new investments have a particularly negative impact on the air exchange and air regeneration system in Warsaw (Figure 16).



The highest value of the Frontal Area Index was noted in 2016. The greatest changes in the indicator value during period 2002 - 2016 could be seen in the corridor of river Vistula and in the corridor of Bemowo district. The greatest changes in surface facades of buildings frontal to the west wind can be observed in the Western Railway corridor and in the Bemowo corridor. This is related to the passage of corridors, parallel to the direction of the west wind. Definitely a negative phenomenon that can be observed is the increase of the building density at the end of the Bemowo corridor and the narrowing of the western, Mokotów and embankment corridors (Figure 17), which may significantly reduce effectiveness of these ventilation areas.

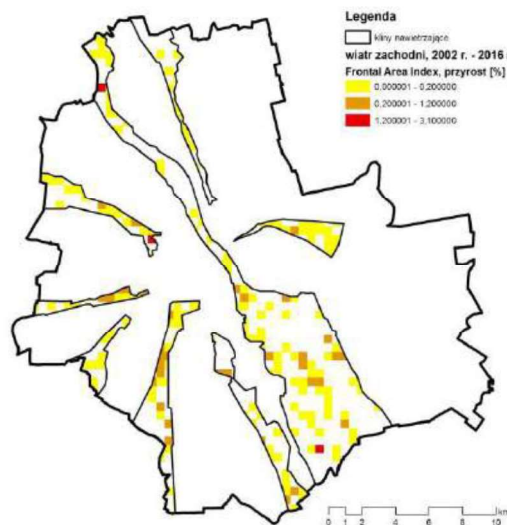


Figure 17. Changes in Frontal Area Index in Warsaw in 2002-2016 within ventilation corridors. Source: own study.

4.3 AIR CORRIDORS IDENTIFICATION

Least Cost Path analysis for two, most frequently observed winds (W-E and NW-SE) were generated (Figure 18, Figure 19). Analysis, basing on the terrain roughness indicator, used 50m x 50m grid and resulted in potential frequency of occurrence (standardized) of the air flow in given net.

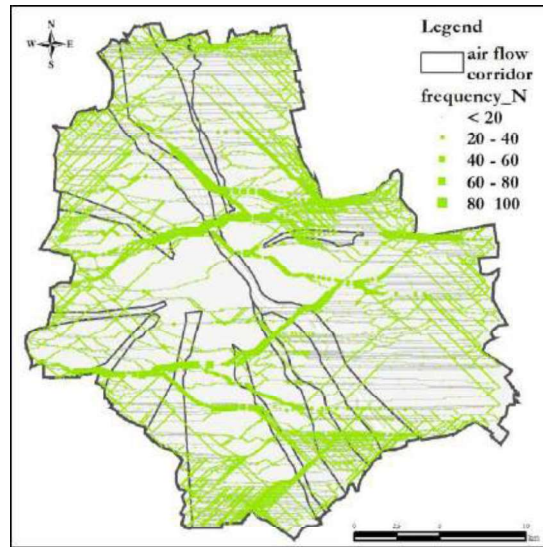


Figure 18. Least Cost Past analysis results, wind W-E, 2014. Source: own study

Airflow from western and eastern direction is highly evident. Its path goes through principal communication arteries. High probability of wind occurrence is visible on the dominant transportation corridors. Main paths can be seen along the railways, mostly along surroundings of Gdański bridge, Okęcie airport, allotments in Mokotów district and Arkadia Park, also at industrial plants near Grot-Rowecki Bridge and near the city boundaries (which might be a result of the methodology imperfection). What can be obviously seen from the model is that the city center is excluded from the ventilation system. Moreover, our predicted wind paths for the western wind do not coincide with the corridors designated in the Strategic Concepts of Conditions and Directions for the Spatial Development of Warsaw.

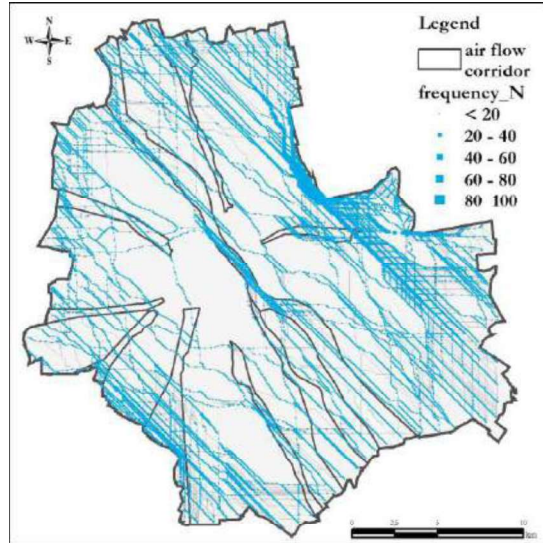


Figure 19. Least Cost Past analysis results, wind WN-ES, 2014. Source: own study.

Results of the Least Cost Path analysis for the oblique wind, northwestern-southeastern, approximately overlap with contours of eastern Bemowo, embankment and Vistula corridor. Winds representation here also misses the city centre; it dominates in the Vistula area, while the west wind is present in the communication arteries. In the south eastern part of Warsaw there is no definite course of the ventilation corridors (e.g. Wesola district), which is in line with the model results for the oblique wind. The greatest value for the LCP is found at the eastern border of the city, but due to its location it is not clear for interpretation. Vistula river, as well as airport and railway areas, play a significant role for both wind directions.

5 DISCUSSION

Scope of our analysis was limited due to lack of reliable data concerning building geometry and cubature. Data derived from Geodesy and Cadastral Office had a limited number of records concerning year of construction of each building. Also, height of building was not always complete in the obtained database. Therefore, for air corridors modelling, data was manually complemented, which entails risk of errors. What is more, two sources concerning height of buildings were used. One was number of storeys provided by Geodesy and Cadastral Office and the other was our interpretation of aerial photographs, which could result in imprecise input of data for further study. In the future research height data should be obtained from airborne laser scanning.

Next generalization in the study was forced by no meteorological data available during the main phase of our research. The data was generated by using a model collecting information from international sources in Europe.

The other limitation was caused by the simplified methodology used in the study. Assumption that the height of the building is equal to the multiplication of number of storeys and their dimensions was necessary, however, it simplifies the building's bulk to a great extent. Moreover, adopted methodology does not take into account turbulence in airflow in a rough area and other movements related to fluids. We assumed a linear air flow through the city and the absolute limitation of its motion when encountering a barrier (building). It does not fully reflect the real movement, however, our goal is to develop a simplified model, while maintaining the required accuracy of the results. In the city scale research, taking into account the available computational power, such an approach may be sufficient. However, the results obtained should be verified in reality or in a different calculation method. Computational Fluid Dynamics software could be used only on a small part of the investigated area, which was caused by lack of available computing power for such analyzes and no funding of our research - which was a great limitation.

Misinterpretation of the results of the study could be caused by adopted grid division. While the urban indicators analysis and terrain roughness calculation were aimed at obtaining more general, viewable results; the Least Cost Path analysis gave more precise results (based on the 50m x 50m grid). Adopted mesh division could be misleading, especially when concerning thoroughfares: wide streets, potential air flow corridors, could be omitted in the analysis when divided between grid areas. In conclusion, it is highly advisable to use the smallest grid possible, although computing time and cost need to be considered.

Adopted methodology assumed arbitrary designation of points generating air streams, in equal intervals, along the city borders. This implies the occurrence of errors at the boundary of the study. In order to optimize analysis for the peripheral districts, the scope of the study should be extended, taking into account the adjacent municipalities.

Additionally, influence of the green areas was not included in the survey. Greenery is a factor of a great value, nevertheless not yet adopted in our methodology, due to its differentiated impact on the city climate. Green areas increase roughness of terrain and consequently reduce the speed of wind and simultaneously cool air and increase its humidity, which as a result stimulates air movement. Defining impact of the greenery requires further analysis and subsequently is to be included in our model.

6 CONCLUSIONS

Before World War II Warsaw was provided with airflow corridors full of greenery. Over the years, green wedges were degraded to marginal role in city-development politics. Consequently, green corridors was replaced by communicational arteries. Today, they mostly stretch alongside railways. Undoubtedly, these terrains are very attractive for new investment plans, therefore they should have proper protection.

Unfortunately, building in airflow corridors is possible due to decisions of building conditions (Decyzja o Warunkach Zabudowy i Zagospodarowania Przestrzennego). This document establishes ways of management and conditions of development of terrains not included in local zoning plan and in case it is not public purpose investment. However, this conditions do not have to be compliant with Strategic Concepts of Conditions and Directions for the Spatial Development of Warsaw (SUiKZP) regulation according to which terrains of airflow corridors ought to be protected. Generally, it is deficiency of

development strategies in Warsaw which makes new investments a kind of chaotic filling of empty, frequently green, spaces within a city.

Housing in Warsaw is concentrated on a left side of Warsaw, however changes in building intensity can be also observed on the other side of the Vistula River. Hence, there is a noticeable increase in the intensity of development in the corridors ventilating the city. Lack of municipal planning politics led to uncontrolled development of the airflow corridors. Moreover, not including proper protection of the airflow corridors in planning documents had an impact on aerodynamic properties of the city and its ability to ventilate. It also negatively affected green areas which play crucial role in air regeneration process.

Results of the study revealed that city centre, as the most densely developed area, has impaired airflow performance. Simultaneously, it is the area of the highest pollution levels, where accumulated pollution has no possibility to be dispersed. Therefore it is crucial to induce the air movement in the downtown area. Whereas it is unlikely it this district for buildings to be demolished and the development area to become less intensive, it is crucial to stimulate the flow and ventilation capabilities by other methods. This can be achieved through introducing high greenery that cools the temperature and increases its humidity, thereby stimulates its vertical motion (convection).

Contamination of air alongside with smog episodes are still a substantial problem in Warsaw and a real threat to its inhabitants' health or even live. There is no fully effective remedy, however authorities ought to use all possible political, strategic and financial tools to protect green terrains and make the city more sustainable. The key point is to reinforce planning politics and to include these assumptions in Strategic Concepts of Conditions and Directions for the Spatial Development of Warsaw study and to prioritise its regulations. It is also important to promote proecological behaviors among inhabitants to reduce pollution from individual sources. Furthermore, as it is line sources which are the main cause of these condition, it is recommended to reduce traffic in a city centre by all means.

The aim of the study was to analyse changes in the morphology of Warsaw and relate changes in its aerodynamic properties. It could not be done without ensured access to full, qualitatively good and available data from Land and Property Register, containing year of construction and height of the objects, as well as from Voivodeship Inspectorate of Environmental Protection, which could be analysed to illustrate real condition of air in chosen corridor. However, it is possible to calculate urban indicators using the actual height of buildings obtained by photogrammetric method, which would increase the accuracy of the analysis. Credibility of the results might also be increased by consideration of landform and land cover in future analysis. Moreover, the aspect of new buildings developed on the areas covered by local planning documents is worth later investigation. It means that standards and suggestions how to design housing to not disturb airflow are ought to be set. Also, according to our study, placement of airflow corridors does not coincide with paths of corridors obtained from modeling, which implies a need to carry out observations in situ to confirm our results.

In conclusion, proposed methodology for analysis of airflow conditions of a city to evaluate and create planning documents could be taken into consideration. It might appear to be a cheap but still effective tool for these purposes.

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ID 1654 | GEOGRAPHY OF "SUSTAINABILITY WITHIN URBAN FOOD STRATEGIES

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ABSTRACT: The whirling population growth that is affecting global cities is causing an enormous challenge to conventional resource-intensive food production and supply and the urgent need to face food security and sustainability concerns. Cities can be the starting points of these strategies and they need to strike a balance between the localization of their food chains, reconnecting food with its place of provenience, and the globalization and market pushes. Urban Food Policies or Food Strategies can provide an interesting path for the development of this new agenda within the imperative principle of sustainability. But which are the main components of these policies? Most the food plans include actions related to three main dimensions that falls within the umbrella of what the food planners call "food