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SEARCHING FOR ALTERNATIVE POSSIBILITIES FOR IMPROVING THE LIVING CONDITIONS OF CITY RESIDENTS THROUGH MODIFICATIONS TO TRAFFIC FLOW

POSZUKIWANIE ALTERNATYWNYCH MOŻLIWOŚCI POPRAWY WARUNKÓW ŻYCIA MIESZKAŃCÓW MIAST POPRZEZ MODYFIKACJE PRZEPŁYWU RUCHU DROGOWEGO

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Abstract: The identification of best practices in traffic organization and road infrastructure in urban agglomerations indicates their low effectiveness in terms of traffic flow. Through the acquisition and synthesis of available knowledge, this article aims to foreground effective organizational and technical concepts that will help efficiently reduce traffic congestion in urban agglomerations. A modern city or urban area is a system of interconnected elements that influence people's quality of life; influenced, among other things, by the accessibility of amenities or urban space related to the effort required for mobility, often involving emotional, temporal, and financial costs. People's movement encounters many limitations related to urban area management. The conducted theoretical research indicates that any effective reduction of traffic congestion in urban agglomerations would require a combination of different organizational and technical solutions. Best practices in traffic organization and road infrastructure include the development of public transport networks, the implementation of intelligent transport systems, variable road pricing, and urban planning that considers traffic flow. Of course, radical restrictions on road traffic in cities are also possible through the utilization of various technical and organizational solutions, such as promoting alternative means of transportation.
Keywords: road traffic, urban agglomeration, urban logistics, transport infrastructure, smog

Abstrakt: Zidentyfikowanie najlepszych praktyk w zakresie organizacji ruchu i infrastruktury drogowej w aglomeracjach miejskich wskazuje na niską ich efektywność w zakresie przepływów w ruchu drogowym. Pozyskanie i synteza dostępnej wiedzy ma na celu opracowanie efektywnych koncepcji organizacyjnych i technicznych rozwiązań, które pomogą w zmniejszeniu występowania korków drogowych w aglomeracjach miejskich. Nowoczesne miasto lub obszar zurbanizowany jest systemem "połączonych naczyń", które wpływają na komfort życia ludzi. Jeden z głównych czynników determinujących satysfakcję z życia w miastach to jakość życia. Podlega on wpływom m.in. dostępności udogodnień lub przestrzeni miejskiej związanej z podejmowaniem wysiłku w celu przemieszczenia się, co często wiąże się z wysiłkiem emocjonalnym, czasowym i kosztowym. Przemieszczanie się ludzi napotyka wiele ograniczeń wynikających z zarządzania obszarem zurbanizowanym. Przeprowadzone badania teoretyczne wskazują, że skuteczne zmniejszenie korków drogowych w aglomeracjach miejskich wymaga kombinacji różnych koncepcji organizacyjnych i technicznych rozwiązań. Najlepsze praktyki w zakresie organizacji ruchu i infrastruktury drogowej obejmują między innymi rozwijanie sieci transportu publicznego, wdrożenie systemów inteligentnego transportu, stosowanie opłat drogowych zmiennych w czasie i planowanie przestrzenne uwzględniające ruch drogowy. Oczywiście autorzy zdają sobie sprawę, że radykalne ograniczenie ruchu drogowego w miastach jest możliwe dzięki wykorzystaniu różnych rozwiązań technicznych i organizacyjnych, takich jak: promowanie alternatywnych środków transportu.
Słowa kluczowe: korki drogowe, aglomeracje miejskie, logistyka miejska, infrastruktura transportowa, smog

Introduction

A modern city or urban agglomeration is a system of "connected vessels" that affect the comfort of people's lives. One of the main factors determining the satisfaction with living in cities is quality of life. This is often a subjective parameter. It is influenced, among others, by the availability of amenities or city space related to making an effort to move,

and this is often an effort from the emotional, time and cost side. The movement of people encounters a number of restrictions in cities resulting from the management of an urbanized area.

In the urbanized areas of the Republic of Poland, passenger cars are still the main means of transport. This necessitates adequate infrastructure solutions, including the provision of a certain number of parking spaces. Parking spaces take up large areas of urban land, although many city authorities are taking steps to increase the use of public transport.

Modern cities are constantly developing in terms of infrastructure. Many innovations concern transport infrastructure and means of transport. The aim of the actions taken is to increase the comfort of living in cities by improving flows. The development of an effective concept in relation to urban traffic seems to be necessary due to the factors causing negative health effects and the burdening of city budgets. The analysis and synthesis of knowledge in the substantive thematic scope indicates the search for adequate solutions in technical and organizational areas. At the same time, the priority is to address the threats affecting the functioning of society. This will allow for the appropriate hierarchy of algorithms. Of course, the authors are aware that a radical reduction in road traffic in cities is possible through the use of various technical and organizational solutions, such as: promoting alternative means of transport, such as bicycles, electric scooters, as well as public transport; introducing charges for entering city centers that reduce car traffic; the use of intelligent transport systems that will enable the smooth flow of road traffic; such as autonomous vehicles that are able to transport passengers without the participation of a driver. However, due to the urgency of the problem, a different concept is presented here.

Literature review

Currently, it can be observed that two concepts clash with each other when it comes to mobility in cities. One of the concepts emphasizes the development of collective transport (and all sharing solutions) and infrastructure adequate in this respect. The second one develops facilities for individual transport, which are primarily passenger cars. However, if we really want to improve the quality of life in cities, solve the problems of flows, we should reach for radical and unconventional solutions. Exposure to road noise can have negative effects on health. Prolonged exposure to high levels of road noise has been linked to a number of health problems, including hearing loss, sleep disturbance, hypertension, cardiovascular disease, and impaired cognitive function. The World Health Organization (WHO) has identified environmental noise, including road traffic noise, as a significant public health concern. Measures to reduce road noise, such as noise barriers, speed limits, and traffic management strategies, can help mitigate these negative health impacts (Szymczyk, Kadłubek, 2019; Heumann, 2021, Kwok-Suen, 2002).

Traffic jams can have negative effects on health. Prolonged exposure to traffic congestion can lead to increased levels of air pollution, which can cause respiratory problems, cardiovascular disease, and other health issues. Additionally, sitting in traffic for long periods of time can contribute to stress, anxiety, and other mental health problems. Urban planners and policymakers can help mitigate these negative impacts by implementing strategies to reduce traffic congestion, such as improving public transportation options, promoting active transportation like cycling and walking, and implementing smart traffic management systems (Nürnberg, 2019; Savchenko, 2021; Yang 2017; Sanjoy 2023; Thomas 2021).

Optimism bias is a cognitive bias that causes people to underestimate the likelihood of negative events happening to them. This bias can lead to individuals perceiving themselves as less vulnerable to traffic accidents than they actually are, which in turn can lead to risky behavior on the road. Research has shown that individuals who are more optimistic about their driving abilities and less concerned about the risk of traffic accidents are more likely to engage in risky driving behaviors such as speeding, driving under the influence of drugs or alcohol, and not wearing a seatbelt. This can increase their risk of being involved in a traffic accident. Communication campaigns that focus on raising awareness about the real risks of traffic accidents and the consequences of risky driving behaviors can help counteract the effects of the optimism bias. By increasing risk perception and encouraging safer driving habits, these campaigns can help reduce the number of traffic accidents on the road (Dejoy 1989, Kwok-Suen 2002, Baensch-Baltruschat 2020).

Exposure to smog can have negative effects on health. Smog is a type of air pollution that is composed of a mixture of particulate matter, nitrogen oxides, and volatile organic compounds. Prolonged exposure to smog has been linked to a number of health problems, including respiratory illnesses such as asthma and bronchitis, cardiovascular disease, and even premature death (Leśnikowska,

2014; Pan, 2020; Adipah, 2019; Jasiński, 2020; Brook, 2010; Kramer, 2023; Chłopek, 2014; Latza, 2008).

Drones are increasingly being used in urban logistics as a way to transport goods quickly and efficiently in congested urban areas. Drones can bypass traffic and reach their destination more quickly than traditional delivery vehicles, making them a useful tool for last-mile delivery (Semjon 2023; Silarski, 2022).

Factors affecting the reduction of the quality of life in cities

Road noise

Along with the progressing development of cities, an increasing threat to residents from the factor of road noise can be observed. The importance of this factor has been noted in the European Union. Also, since 2012, new standards for permissible traffic noise have been in force in Poland. In 2012, the Minister of the Environment introduced new standards for daily and long-term traffic noise. Overnight, it turned out that residents of large cities must by law tolerate noise levels as high as 70 dB during the day and 65 dB at night. That's more than the World Health Organization (WHO) recommends. According to the WHO, annoying sounds above 55 dB have an adverse effect on human health – fatigue, irritability, headaches, abdominal pain, muscle pain appear (Najwyższa Izba Kontroli, 2019)

New directives have forced solutions in the appropriate infrastructure, which allowed to significantly reduce noise in large cities, however, many areas are still at risk of this factor. According to the author, investing in a new anti-noise infrastructure is not an optimal direction due to the space being disturbed by artificial objects and the costs. The presented innovations are intended to reduce noise without such complex and invasive investments in the city.

Road transport causes noise levels ranging from 75 dB (car) to even 95 dB (bus). In large cities during the day the noise level is 70-80 dB. The most famous cities in Europe are: Bratislava (1st place), Warsaw (2nd place) and Paris (3rd place)) (Szołtysek, 2012).

Due to the different impacts of noise on the human body, and thus the different harmfulness to health, audible noise can be divided into the following five groups, depending on their level:

- below 35 dB(A) – harmless to health, may be annoying or interfere with work that requires concentration,
- 35–70 dB(A) – affect the human nervous system, hinder speech intelligibility and sleep patterns,
- 70–85 dB(A) – significantly reduce work efficiency, may be harmful to health and cause hearing damage,
- 85–130 dB(A) – cause numerous diseases of the human body, preventing speech intelligibility even from a distance of 0,5 m,
- above 130 dB(A) – cause permanent hearing damage, vibrations of human internal organs causing damage (Leśnikowska-Matusiak, 2014).

Excessive noise always causes more or less serious hearing damage. Noise can also cause many other disorders in the human body, including internal diseases. Disturbances of the body's work under the influence of noise mainly concern the cardiovascular system (increased blood pressure, palpitations and beating of the heart, weakening of the condition, flushing of blood to the head). At the intensity of 60-75 dB (standard noise level in cities) there are noticeable changes in heart rate, blood pressure and breathing rhythm. Other symptoms of an "overdose" of noise are shortness of breath, nausea, dizziness and headaches, as well as pain in muscles, joints and many metabolic diseases. A road noise study conducted in Germany analyzed the effect of 65 dB on systolic blood pressure and blood clotting time,; and it was also shown to reduce cortisol and platelet counts. Similar studies conducted in England have shown that exposure to traffic noise of 66-70 dB may cause a small increase in the relative risk of ischemic heart disease.

Studies carried out for a medium-sized city (75000 inhabitants) showed an excess of 70 dB for all major communication arteries. In the case of larger cities, there is a much higher traffic intensity, a greater variety of means of transport, higher speeds (arteries with a maximum speed of 80 km/h). So the health risk is greater (Tong, 2023).

Traffic jams

Another huge threat to city dwellers is traffic jams. On the one hand, it is about time inefficiency, on the other hand, it is about the generation of pollution and noise.

In accordance with the research methodology adopted in the report on traffic jams developed by the consulting company Deloitte, it was assumed that the alternative cost to the time lost in traffic jams is performing paid work. It was also assumed that drivers use a statistical car (Fiat Panda with

a 1.1-liter petrol engine), which results in conservative calculations of lower consumption and lower fuel costs than, for example, vehicles with a larger engine. The price of gasoline used in the model is an annual average for the entire country. The time of delays for the 7 largest Polish cities was extended by 2 hours. 10 minutes per driver per month and as much as 25 hours 42 minutes a year (Rzepnikowska, 2016).

As stated in the report, the cost of traffic jams for a statistical inhabitant-driver from 7 cities was PLN 3,350 per year on average. The highest nominal annual cost of traffic jams in the amount of PLN 3,976 per year was incurred by drivers from Warsaw. And the time spent in traffic jams was 22 minutes and 14 seconds per day.

Exhaust gases from internal combustion engines

Traffic Jams are directly related to high emissions of exhaust gases from the engines of cars and trucks. The main components of these emissions are: carbon dioxide (CO_2), carbon monoxide (CO), total hydrocarbons (THC), Particulate Matter (PM) incl. soot and Nitrogen Oxides (NOx). The first component of exhaust gases is non-toxic for human health in low concentration (under 3% of volume) (Environmental Protection Agency, 2015) [accessed 20.03.2023]. Long-term human exposure (above 1 hour and more) for higher concentrations of CO_2 (beyond 5% of volume) may cause several negative consequences ex. tremors, headache etc. Locally higher concentration of CO_2 may occur in city center during peak traffic, however the concentration of mentioned gas in this places never reaches a level above 2% volume. This fact indicates that the emission of carbon dioxide from exhaust gases does not significantly impact human health in cities.

Vehicular emissions are a major concern as these are ground-level sources. Vehicles in major metropolitan cities are estimated to account for 70% of carbon monoxide (CO), 50% of hydrocarbon (HC), 30% to 40% of oxides of nitrogen (NOx), and 30% of particulate matter (PM) of the total pollution load (Central Pollution Control Board - CPCB, 2010) (Sanjoy, 2023). In the context of emissions, the first steps should be aimed at a better verification of the technical condition of vehicles moving within an urban space. Particularly during technical inspections, the correct functioning of an automotive together with the fuel supply system components should be carefully checked.

Traffic accidents

A significant problem in cities are the low levels of security and safety. Pedestrians and cyclists are a particularly vulnerable group of road users. In the last ten years, the number of pedestrian fatalities has decreased by only 39%, compared to a 49% decrease for motor vehicle fatalities. In 2015, 32,967 accidents and 362,265 road collisions were reported to the Police. 42,716 people were injured in road accidents, of which 2,938 died and 39,778 were injured. Road accidents and collisions have a measurable cost to society. The unit cost of a fatality (an accident involving a fatality) is PLN 2,052,518. The unit cost of a road accident is PLN 1,018,160. The unit cost of a road collision is PLN 40,458. (Nürnberg, 2019).

The impact of smog

Air pollution affects both humans and the entire natural environment: soil, water, earth, animals and plants. One component of air pollution is particulate matter (PM). Studies of concentrations of PM10, PM2.5, PM1.0 fractions from linear communication sources were planned and carried out in Wola, one of the districts of Warsaw. Exceeded norm values were noted primarily at major intersections and communication routes. Very high and at the same time constant concentrations of particulate matter in the urban air occur during congestion. The obtained studies show that the concentrations reach significantly higher values if motor vehicles stop before traffic lights and when they start off.

Heavy metals

Cars in urban traffic are also a source of pollution in the form of dust containing heavy metals. It is estimated that dust weighing up to 0.5 kg may be emitted from the braking system of a passenger car within 1 year. In addition, solid particles from the braking system are classified as very fine dusts, mostly with equivalent dimensions of the order of single micrometers and smaller than 1 μm. The dominant component of particulate matter from brake systems is iron and its compounds, primarily oxides. Other metals, including barium, magnesium, aluminum, zinc, calcium, copper, silver, molybdenum, antimony and chromium, are also found in dust particles.

Suggestions for changes affecting flows in cities

Optimizing the flow of means of transport in urban areas requires decisive action. It is essential to organize the movement in such a way as to actually eliminate the harmful threat to health and life?

To this end, we should focus on decisive and specific economical solutions.

Proposal No. 1. Much can be achieved in terms of flow optimization by modifying and changing the organization of traffic. A decisive action is to limit the stream of vehicles entering the city by reducing the number of lanes for entry and making the exit clearer, e.g. 1 entry lane; 2-3 exit lanes.

Proposal No. 2. Another proposed solution for changing the organization of traffic by controlling the flow of vehicles is to increase the number of bus lanes, e.g. in the convention, the existing bus lanes will be replaced with lanes for other vehicles and the remaining lanes will be allocated to the traffic of: buses, minibuses, hybrid and electric vehicles and two-wheelers.

Proposal No. 3. Resigning from speed limiters in favor of not repairing roads. In urban areas, we can more and more often observe sequences of events in which investment in road surface renovation is followed by massive installation of speed bumps. This is not a very rational spending of funds, where as a result of expensive investments, we get an unchanged or even worse (in terms of permeability) communication network. We must consider her also the disadvantages resulting from the construction of speed limiters: increase in noise and vibration in the area – especially burdensome for properties located in the vicinity of the installed threshold, excessive emissions of vehicles that exceed the threshold and just after crossing it, a threat to cyclists who cross the threshold and other drivers of two-wheeled vehicles, the need to slow down emergency vehicles – ambulances, fire brigade, police during interventions, negative impact on the road structure and devices on the road - water and sewage networks, gas networks, difficulties related to proper clearing of snow from the road and frequent damage to thresholds slats during snow removal, difficulties in proper road drainage, frequent running over of roadsides and pavements by drivers avoiding thresholds, and the nuisance related to noise, vibrations and exhaust fumes.

Proposal No. 4. Respecting the provisions on road infrastructure, i.e.: “The curb should protrude above the level of the road surface, if between the road and the footpath for pedestrians or service or a bicycle path: there is no barrier – not less than 0.14 m and not more than 0.18 m” (Minister Transportu i Gospodarki Morskiej, 2000). Next, raising the height of curbs above 0.18. This will protect pedestrian space and limit parking on pavements and in unauthorized places. Currently, curb heights in most urban areas are illegal.

Proposal No. 5. Liquidation of pedestrian crossings in favor of footbridges. This is about avoiding frequent road situations where traffic is stopped on up to 6 lanes in order to cross a single pedestrian. Currently, an opposite trend can be observed in Warsaw, i.e. the creation of crossings in places with the highest traffic volume, i.e. in the very center of the city.

Proposal No. 6. Resignation from dipped beam in built-up areas. In urban areas, where vehicles move at low speeds, on separated lanes they are often stuck in traffic jams, the obligation to drive with lights only contributes to higher fuel consumption and the emission of harmful substances.

Proposal No. 7. Progressive fuel consumption. Programming fuel supply control systems to reward economical driving. Up to a speed of 90 km/h, fuel consumption should be consistent with the current characteristics of the vehicle, above this speed the increase in fuel consumption should radically increase in relation to the nominal characteristics. The increase in consumption could be generated by the additional resistance to drive the generator. The energy generated in this way could be used for further use to drive or power the road infrastructure.

Proposal No. 8. is not too new. This is about rewarding hybrid and electric vehicles by entering restricted zones. (car park, zones).

Proposal No. 9. Electronic speed limits enforced by a system of road transmitters. A uniform system with a mandatory set speed limit in motor vehicles, using RFID technology with passive tags stuck on the road in speed limit zones.

Proposal No. 10. Introducing innovations in the field of public transport. Continuation of changing the fleet to hybrid and electric buses. Diesel buses used in public transport are very loud.

Proposal No. 11. Rewarding car sharing solutions by: subsidizing, free parking. The average annual mileage of a car in Europe is 11,500 km.

In the summer ranking of average speeds (as of 2015), Warsaw took first place with an average speed during the day of 39 km/h. Drivers in Łódź drive only 1 km/h faster, in third place ex equo are Kraków, Poznań and Wrocław, where drivers move at an average of 41 km/h. With such mileage and driving speeds, there is a lot of room to convince residents to give up ownership of their cars.

Proposal No. 12. corresponds to the previous idea of supporting car sharing solutions. The system of city bikes is already gaining a fairly established position, so its development should be continued.

The *British Medical Journal* presented the results of research which proved that bicycle rental (and cycling) has a positive effect on health and quality of life. Short, regular trips made by rented bicycles have reduced the number of deaths caused by heart problems (despite the potential danger of air pollution and traffic). In Barcelona, it has been shown that there are 12 fewer deaths a year due to physical activity resulting from cycling (as well as fewer heart attacks, strokes and heart disease).

There were 610,000 registered users in the Warsaw system who rented bicycles a total of 5,300,000 times. There were 5,147 bicycles available at 355 stations. From March 1 to November 30, 2017, Veturilo system users traveled over 10 million kilometers, burning 200 million calories and reducing the production of harmful carbon dioxide by 800 million tons.

Currently, the system is stagnant. It does not develop, and in some cities it is liquidated (Poznań, Bielsko Biała).

As the research shows, achieving significant progress requires the adopting of different approaches. To validate their effectiveness, the following research procedures are necessary:

1. Conduct a comparative analysis of different cities that have implemented changes in traffic organization, such as reducing the number of inbound lanes into the city and clearly marking exit lanes. Compare data before and after these changes, including traffic capacity, travel time, and congestion levels. Conduct surveys among residents and drivers to assess their perception and experiences related to these traffic organization changes.
2. Perform a case study in selected urban areas that have increased the number of lanes for buses. Analyze data on the impact of these changes on traffic capacity, travel time, and public transport usage. Conduct surveys among residents to assess their satisfaction with these changes and their preferences regarding travel.
3. Conduct a comparative analysis of cities that have eliminated speed bumps in favor of road repairs. Compare data on road capacity, maintenance costs, noise and vibration levels, vehicle emissions, and road safety. Conduct surveys among residents to evaluate their satisfaction with these changes and their impact on safety and quality of life.
4. Conduct a spatial analysis in selected urban areas that have raised curb heights above 0.18 meters. Analyse data on the impact of this change in reducing sidewalk and unauthorized parking and enhancing pedestrian space protection. Conduct surveys among residents to assess their satisfaction with these changes and their impact on the quality of urban spaces.
5. Perform a comparative analysis of cities that have replaced pedestrian crossings with pedestrian bridges. Compare data on traffic capacity, road safety, and travel time. Conduct surveys among residents to evaluate their satisfaction with these changes and their impact on safety and travel convenience.
6. Conduct a comparative analysis of cities that have abandoned the requirement to use daytime running lights in built-up areas. Compare data on fuel consumption, vehicle emissions, and road safety. Conduct surveys among drivers to assess their satisfaction with these changes and their impact on travel convenience.
7. Conduct a comparative analysis of cities that have implemented a system for rewarding eco-friendly driving. Compare data on fuel consumption, vehicle emissions, and driver behavior. Conduct surveys among drivers to evaluate their satisfaction with this system and its impact on their driving habits.
8. Conduct a comparative analysis of cities that reward the use of hybrid and electric vehicles with access to restricted traffic zones and free parking. Compare data on the number of hybrid and electric vehicles, changes in traffic volume, and air quality. Conduct surveys among users of hybrid and electric vehicles to assess their satisfaction with these incentives and their impact on travel decisions.
9. Conduct a case study in selected urban areas that have implemented electronic speed restrictions. Analyze data on changes in road safety, speed limit compliance, and traffic flow.
10. Carry out a comparative analysis of cities that continue to transition their public transportation fleet to hybrid and electric buses. Compare data on vehicle emissions, air quality, and passenger satisfaction.
11. Carry out a comparative analysis of cities that incentivize car-sharing solutions through subsidies and free parking. Compare data on the number of private vehicles, car-sharing usage, traffic flow, and travel costs.

Final conclusions

The authors are aware that most of the twelve proposals presented are of a very radical nature. The issue is difficult because it requires many changes in terms of the changing of habits and way of thinking. From the technical and economic point of view, the implementation of the proposal seems uncomplicated. Leaving the issue of flows at the current level leads to dualism. On the one hand, we have examined and identified threats, and on the other hand, we selectively try to counteract them, which also leads to selective, local improvement, and sometimes to deterioration in favor of another threat or another location. The conducted research shows that the effective reduction of traffic jams in urban agglomerations requires a combination of various organizational concepts and technical solutions. Best practices in the field of traffic organization and road infrastructure include, among others, the development of public transport networks, the implementation of intelligent transport systems, the use of time-varying road charging and spatial planning taking into account traffic. The implementation of effective concepts for reducing traffic jams in urban agglomerations will have a positive impact on the health and budget of cities, and will also contribute to improving the quality of life of residents and road users.

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