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THE FUTURE OF PUBLIC TRANSPORT IN LIGHT OF SOLUTIONS FOR SUSTAINABLE TRANSPORT DEVELOPMENT

Summary. The paper highlights possible directions in the development of sustainable public transport solutions. When appropriately identified and implemented, such solutions can contribute to improved quality of urban life by reducing the adverse effects of transport on human health and the natural environment. The paper also raises questions about implementing pedestrian traffic zones, expanding the level of cycling, and introducing a workable parking policy, congestion charges, electromobility and intelligent systems for road traffic management in conurbations.

Keywords: public transport; sustainable transport development; road traffic; environmental sustainability.

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1. INTRODUCTION

The expansion of urban structures, which is currently commonplace within large conurbations, as well as their development, presents a major challenge to public transport systems. The result is increased demand for fast, safe efficient and environmentally friendly travel options, which also meet to the specific requirements of different social groups.

The predominance of individual motor means of transport, changes in lifestyles and the unsatisfactory functioning of public transport have contributed to a lowered quality of life in European cities [1]. As a result, conurbation inhabitants may feel, among other things, increased environmental pollution, transport congestion and noise. The situation in cities is so difficult that local authorities are not able to handle existing problems on their own. Coordination and cooperation related to public transport are necessary, not only at local level, but also at the state and even European levels. A strategy for the development of public transport, based on the doctrine of sustainable transport development and published by the European Commission in 2007, is an expression of that need for coordination and cooperation. The strategy creates favourable conditions for the implementation of modern solutions to improve the quality of transport, including within Polish cities.

Creating a cohesive transport system for conurbations is a complex and difficult task. It requires that both internal and external factors be taken into account. Internal factors include ensuring the proper operation of public transport, together with suburban and regional transport. As for external factors, one can single out, among other things, the need for co-shaping cities' transport and spatial development, as well as implementing a sustainable development strategy [2].

The aim of this paper is to simply highlight possible directions in shaping and developing public transport with respect to the idea of sustainable development. The paper describes selected solutions that are currently linked to the provision of transport in developing cities: the promotion of walking and cycling, areas of paid entry into city centres, intelligent systems for road traffic management, and special designated parking zones known as Park&Ride.

Adequate and proper implementation of the suggested solutions can considerably improve the quality of public transport and, thus, the quality of urban life by, among other things, minimizing the adverse effect of toxic exhaust gas components and noise on the natural environment and inhabitants' health. Sustainable transport solutions can be a source of a long-term attempt to improve the general functioning of conurbations because they are marked by availability, safety and care about the environment.

2. SUSTAINABLE TRANSPORT DEVELOPMENT AS A DETERMINANT OF THE FUNCTIONING OF INDIVIDUAL AND COLLECTIVE TRANSPORT SYSTEMS

Sustainable transport refers to means of transport that minimize noise and emissions of carbon dioxide and other substances harmful to the environment. However, sustainable transport development is a concept that combines social, environmental and economic aims from the perspective of the transport policy of individual state governments and the whole of the EU [2].

Most of the existing definitions of sustainable transport refer to three main problem categories, i.e., environmental, economic and social problems [1, 3, 5, 31]. Sustainable transport allows us to [4, 6]:

- Meet the emission standards for noise and toxic exhaust gas constituents

- Minimize the needs for land use
- Fulfil the needs of the current generation regarding mobility
- Improve the quality of life
- Guarantee improved human health and ecosystem cleanliness
- Make effective use of renewable and non-renewable resources
- Offer affordable prices and support as part of regional and general competitiveness
- Provide transport means the offer high availability and diversity in terms of use

When observing the current situation in conurbations with regard to the action taken, we can see that the main effort relates to investment projects and tasks related to collective transport and the road system, whereas other measures, such as those significantly influencing mobility and thus limiting the motor means and limiting their adverse effect, are considered to a small extent.

The concept of sustainable transport development is not based on investment undertakings in this regard, but on [7]:

- Alternative travel offers - popularization of collective transport and suitable cycling and walking policies
- Better use of existing resources - access control for selected urban areas, system management, traffic influx control, traffic disturbance information, quick response to emergency situations, and communal transport priority
- Fiscal policy - introduction of parking and city centre congestion charges, use of selected infrastructure items and shaping the prices for public transport tickets
- Spatial policy - strengthening roadside structures on the routes and corridors used by communal transport, enhancing the functional attractiveness of city centre areas and countering excessive urban expansion

Therefore, the implementation of the sustainable development concept requires that a number of transport problems be solved. Development must be considered with regard to the spatial distribution of social and economic activity, land development and limitations resulting from the need for environmental protection. Therefore, the planning of public transport development must be coordinated with other sector-related measures that can lead to solving transport problems in a given area.

2.1. Individual transport

The issue of individual transport is based on pedestrian or motor traffic with the use of individual means of transport, such as bicycles, motorcycles or cars. According to the sustainable development doctrine, the authorities of European cities strive to restrict the use of motor means of transport in favour of cycling, walking and public transport.

Creating the best possible walking routes means that it is necessary to take measures consisting of the partial or total closure of particular streets or whole city districts to motor traffic, then designating them for pedestrian traffic only. In respect of the level of traffic restrictions, three types of zone can be singled out, namely [11, 12, 13]:

- Walking zones, which are totally closed to passenger cars and collective transport (access open only for delivery trucks during working hours, rescue service cars and municipal cars)
- Walking zones with limited access for passenger cars and full access for public transport

- Walking zones with a total ban on entry for passenger cars, but with access for public transport

The highest level of safety and freedom of walking is ensured by a total restriction on access to the designated zones by cars. However, the most common practice is to apply solutions ensuring the coordination and coexistence of cycling, walking and public transport traffic within one particular area. This results in maximizing the benefits from the implementation of a walking zone alongside prioritizing public transport. Solutions consisting of periodically closing streets at times of anticipated increases in pedestrian traffic (e.g., in summer, on public holidays, feast days and during pre-holiday seasons) are also frequently applied.

The walking zones described above can comprise an essential element of an urban transport system on condition that they are properly situated and appropriately organized. It is important to reasonably connect the walking zones with the public transport system (the distance between a designated walking zone and a public transport stop or car park should be less than 300 m).

The creation and organization of a walking zone must strictly involve [1]:

- Restrictions on or the elimination of lorry and passenger car traffic
- Limitations or reductions with regard to a minimum number of points of collision with other forms of traffic by the appropriate location of facilities of interest to pedestrians (shops, offices etc.)
- Creating favourable environmental conditions (a low level of air pollution and noise emission)
- Adequate site furnishing and structures (benches, appropriate lighting, playgrounds for children)
- Minimization of physical obstacles to pedestrian traffic (appropriate kerbs, steps, a smaller number of stretches with large slopes of land)

Partial or total restrictions on car traffic in city centre areas are more and more common. European examples of cities that apply such solutions include Graz, Rome, Copenhagen, Vienna and Warsaw.

The use of a bicycle for travelling within conurbation zones is also an example of individual transport solutions in terms of sustainable development.

The use of a bicycle refers in particular to [13]:

- The use of a bicycle as an indirect means of transport, that is, a means enabling a journey to a public transport interchange hub (trams, trains, buses, underground)
- The use of a bicycle as an individual means of transport over short distances
- A well-functioning bicycle transport system should have the following features:
- Directness, ensuring fast and easy travel around the city
- Safety by reducing the points of collision with motor traffic to a minimum
- Cohesion by connecting all destinations and ensuring the city’s exit routes are linked up to its bicycle lanes,
- Comfort, thanks to appropriate solutions (with regard to the type and geometry of the roadway surfacing etc.) regarding roads and their proper maintenance (e.g., clearing of snow in winter)
- Clarity and attractiveness by linking the bicycle transport system to a city’s functions and users’ needs

Among the solutions that can improve the conditions of cycling around a city are [6, 11]:
- Sectioning off parts of roadways for bicycle lanes
- Building bike routes independent of roadways
- Allowing two-way bicycle traffic in one-way streets with speed and traffic limits
- Creating advanced cycle stop lines at intersections with traffic lights
- Permitting passengers to carry their bike on public transport
- Adapting interchange hubs to store bikes as part of the Park&Ride system
- Implementing a cycle hire scheme.

The German city of Freiburg, in which bicycle traffic has increased twofold since 1976, is an example of a cycling policy developer. At present, cycling constitutes 20% of the overall traffic within the city, which has been made possible by the creation of a bike route network with a total length of 135 km and the introduction of a speed limit of 30 km/h in the city centre. Strasbourg is another model city, which has closed its centre to motor traffic as part of its campaign for bikes to be regarded as a main means of transport, thereby increasing bicycle traffic to around 12% [14].

Barcelona, Bremen, Amsterdam, Copenhagen, Ferrara, Graz and Edinburgh are cities that use a system of incentives to encourage inhabitants to use bikes or public transport to travel within these cities, while, at the same time, introducing bans related to the use of cars in these cities' centre. For example, the city of Ferrara has around 132,000 inhabitants, while the number of bicycles is around 100,000. It should also be mentioned that the described measures have had no adverse effect on the economic development of these cities or accessibility to shopping centres.

Table 1. Proportions of journeys made by bicycle within selected European cities with different population sizes

Country	City	Number of inhabitants (in thousands)	Proportion of cycling journeys (%)
England	Cambridge	100	27
Denmark	Copenhagen	1,400	32
Netherlands	Amsterdam	1,013	25
Ireland	Dublin	1,100	11
Germany	Freiburg	215	20
Italy	Ferrara	132	31
Italy	Parma	176	19
Switzerland	Basle	230	23
Switzerland	Bern	127	15
Poland	Rzeszow	186	4

The 5-10% proportion of journeys made by bicycle can be claimed by most European cities. With an adequate transport policy, the proportions may increase by 20-25% in cities with a population ranging from 50,000 to 500,000 inhabitants [2].

In Polish cities with large populations, such as Warsaw, Wroclaw, Krakow or Poznan, the construction and appropriate promotion of bicycle routes should bring about a 10% increase in the proportion of bicycle journeys in the city. In smaller cities, the proportion should reach 20-50% within 10 or fifteen years, once appropriate infrastructure has been created.

The potential benefits, which cities can gain as a result of the implementation of the above-described solutions, include the following [15]:

- Space saving (parking and roadways) and, in turn, reduced expenditure regarding the building of new urban roads
- General improvement in the quality of conurbation life (reduced air pollution, reduced noise)
- Direct reduction in road traffic disruption by limiting the number of motor vehicles in motion and improving the flow of the traffic

2.2. Parking policy

An appropriate policy concerning the organization of parking spaces is a key element of the sustainable development of urban transport. The problem with the appropriate adaptation of parking spaces primarily concerns city centre areas, which are characterized by an increased demand for parking spaces. However, the action taken by municipal authorities to solve the problem of parking space shortage should be prompted by the abandonment of the attempt to adjust the supply of such spaces to meet current demand. The adjustment of the number of parking spaces should be dependent on the character of a given urban area, the density and type of housing, and the efficiency of the public transport system. All measures taken to sort out parking problems should aim to maintain a balance between traffic capacity, road system accessibility and car parking capacity.

According to the principles of sustainable transport development, the basic procedure for urban parking systems consists of [7, 15]:

- Applying a limit on new parking spaces depending on the city’s needs
- Creating car parking lanes on local and collector streets
- Setting up, as a priority, Park&Ride and Kiss&Ride systems near peripheral bus stops, tram termini, and underground and railway stations
- Introducing paid parking zones within the very centre of the city, which is characterized by an agglomeration of destinations, as well as in selected parts outside the city centre (the parking charges should vary according to the nature of the urban zones)
- Organizing car parks in residential zones, particularly in significant housing areas,
- Restricting the possibility of parking on the kerbs along main streets, especially during traffic rush hours

Park&Ride systems are usually built along track transport routes (underground, trams, trains) and support journeys into the city (e.g., combined journeys by car and commuter train), or journeys from the outskirts to the centre (with the use of public transport corridors). A Park&Ride system must offer both passenger car and bicycle users quick, easy and safe access to public transport, resulting in benefits such as:

- Reduced noise and pollutant emissions from vehicles with internal combustion engines
- Reduced social costs linked to crowded streets (time saving)
- Reduced traffic in city centres
- More effective public transport (as a result of changing from cars to public transport by some car users)
- Fewer road accidents (in comparison with journeys made by car, the probability of an accident is 30 times less for train journeys and 10 times less for bus journeys)

Within Poland, the Park&Ride system has been a success in Warsaw, with 12 special parking zones located on the outskirts of the city. Free parking is available on production of at least a one-day public transport pass [31].

2.3. Congestion charges

A congestion charge is a charge related to road traffic intensity or entry into the city centre by motor means of transport. It is justified by the fact that, as the centre is one of the city's most precious resources, entry into it should be priced as any other good. In addition to taxes, this charge is a source of financial support for expensive public transport infrastructure, as well as one of the ways to limit the stream of motor vehicles by increasing the costs of maintaining a private car.

The imposition of charges for the use of city centre streets brings about the following results:

- The funds raised are intended to help develop and maintain the existing road network and, by that, to fairly charge drivers for road maintenance
- The charges are treated as an "environmental tax", which leads to a reduction in the environmental pollution caused by motorized road users
- The roads are less busy, while their use is adjusted to actual needs, thus eliminating traffic hold-ups and congestion in the centre

The problem of using urban roads is that, when drivers start their journeys, they take into account their own private costs only (time, fuel costs etc.), but they do not count the additional costs they generate for other traffic participants. Essentially, beginning with a specific level of traffic, cost generation is on the basis that every additional motor vehicle makes the cost of using a given road higher for all drivers as a result of lengthening the drive time (due to a reduction in the average speed of a vehicle). In the majority of cases, this situation also leads to traffic congestion. In conclusion, excessive use of an urban road network adversely affects both individual road users and the general public. In order to prevent such a situation, urban road users should pay additional charges. Working out an appropriate charge is a complex task because it requires the current state of the city's traffic to be defined.

Currently, the following types of congestion charges are in operation [16]:

- Zonal charges to restrict access to the urban zone
- Charges for the distance covered
- Charges collected at different points of entry into the urban zone
- Charges for driving on a road that is heavily crowded on a regular basis
- Charges collected in cases where there is an alternative Class I road

The technologies related to charge collection have so far not been standardized. Digital cameras and a DSRC/OBU solution (a device with microwave contact installed inside the vehicle) can be rated among the most popular methods for charge collection. In some cities, charges are collected manually. At present, congestion charges apply in Singapore, Bergen, Trondheim, Oslo, Rome, Riga, London, Milan, Stockholm, Durham, San Diego and several other cities.

2.4. Electric vehicles as an alternative to private combustion vehicles

Even though there are many alternative forms of transport within conurbations, including walking, cycling and public transport, there are still urban areas where transport needs can only be fulfilled by private cars. Unfortunately, journeys made by diesel-driven passenger vehicles are inextricably linked with an increase in the emissions of toxic exhaust gas components, thus causing environment contamination.

Electromobility and electric vehicles critically offer the possibility of reducing the negative impacts of combustion engines without limiting the important role of cars. Electric vehicles constitute a practical solution to the problem of environmental impact, but the general awareness of such a concept is still limited. Significant progress can be achieved through the redefinition of mobility, by, among other measures, the introduction of electric vehicles. For this purpose, cities must seize the initiative in order to ensure that electric vehicles will not remain a niche market, but will be a real alternative to vehicles powered by a combustion engine.

The most important environmental and social benefits from the use of electric vehicles include the following [17, 18, 30]:

- Reduction in noise emission from internal combustion cars
- Improvement in the country's energy security because of reduced imports of fuel
- Improvement in air quality in conurbations and on roads with high traffic
- Zero-emission of toxic compounds and CO2 from vehicles on roads

The increased demand for energy related to its generation, which, on balance, results in an increase in the emission of toxic constituents, is often quoted as a counterargument to the environmental merits of electromobility. With regard to the source of electric energy used to charge batteries, the emission of pollutants into the air is moved to the location of a power station (this mainly applies to coal power plants).

The total balance of CO_2 emissions from electric cars, computed for the process that starts with the place of energy generation and ends with the use of the energy on roads, is more favourable in comparison to a diesel-driven car, according to the available data [9]. The information presented in an American report on the generation of toxic exhaust gas components in the power generation process proves that, on balance, even assuming that the power is generated from coal only, electric cars are 25% less harmful to the natural environment, compared to conventional vehicles [19, 20, 29, 32].

Although electromobility is no response to every challenge faced by conurbations, it solves a good part of the significant environmental problems related to individual mobility. From the local, and even from the regional and the national perspective, the environmental benefits of supporting electromobility may significantly exceed the financial costs of the steps made in this respect.

2.5. Intelligent systems for urban traffic management

The dynamic growth in the number of passenger cars is directly associated with higher traffic in urban roads. This phenomenon brings about restrictions and, at the same time, a need for the development of a road network. The restrictions may be political or financial in nature. Modern, intelligent systems for urban traffic management represent the key factor in both cases.

Management and traffic control solutions offer the possibility of considerably improving an urban transport system for a much lower capital investment compared to the costs of expansion of the road infrastructure.

Intelligent systems for urban traffic control and management are intended to [21, 22, 23, 24, 25]:

- Monitor traffic intensity for key road stretches, urban spots and tunnels (with the use of video systems that can detect collisions and other road incidents requiring intervention by competent services)
- Inform about the current state of the environment (i.e., the measurement of humidity, pollution and air temperature)
- Control the light signalling system (depending on the time of the day and during periods of congestion, they offer the possibility of prioritizing signals in relation to the means of public transport, rescue vehicles etc.)
- Provide information about the current traffic situation (using the variable message sign technologies located by main urban roads)
- Support car park management

An urban traffic management system is a solution consisting of elements involving measurement, processing and execution [22]. The advanced control of particular intersections, which uses data on the direction- and type-related structure of traffic, as well as on its intensity, offer considerable possibilities, while streamlining the flow of vehicles in a given system. In addition, these solutions also enable the influencing of traffic in selected urban areas and transport corridors. In this way, it is possible to implement selected management strategies, e.g., by limiting the inflow of traffic into congested roads or by limiting access to designated urban zones.

Traffic management systems have a significant advantage in terms of prioritizing the means of public transport. This solution requires vehicle detection systems to be adequately adjusted in order to identify these means. The most common solutions for vehicle detection include induction loops, video detectors, acoustic detection and radio detection [19, 27]. Working in real time, such devices generate input information for the data processing system. Priority can be given locally (e.g., at a single intersection) or centrally (by appropriate control from a traffic control centre).

At present, the trend for quickly implementing solutions for urban traffic management systems can be seen in European cities. In Poland, such systems already function in Rzeszów, Poznań, Krakow, Lublin, Warsaw and other cities.

An appropriately designed system for intelligent traffic control can optimize the flow of goods and people within conurbations, thus reducing traffic jams, enhancing the comfort of travelling and decreasing the environmental impact of transport.

3. CONCLUSION

The conceptualization and realization of the idea of sustainable transport development are intended to ensure future access to resources, particularly natural resources, at a level that is at least equal to the present possibilities of their utilization. Sustainable transport appears to be an important element and a tool for accomplishing both socio-economic and environmental goals.

The methods for the sustainable development of urban transport, as presented in this paper, are examples supporting the thesis that, in the context of a contemporary transport policy based on the application of environmental solutions, cycling and walking, if appropriately coordinated with public transport, can be an alternative to the current predominance of individual motor transport. In order to make this kind of transport policy function properly, it is necessary to take appropriate measures, such as raising drivers' awareness of social responsibility in terms of being guided by care for the environment and improving health, as well as effective utilizing the city's resources (cultural, sports and recreational resources etc.).

Unsustainable transport involves a considerable amount of energy and pollutes the environment, whereas increasing expenditure in order to attain its short-term aims does not always improve the level of services. The concept of sustainable development is a response to the transport policy failures of the second half of the 20th century [28].

It is estimated that, within the EU, a change in the mode of urban travelling and the proportions of public transport (at the expense of individual transport) could result in a reduction of about EUR 560 billion in the annual costs of accidents, congestion, pollution and energy consumption.

Public transport is, in many cases, a catalyst for processes leading to development and economic growth in the conurbations. It is evaluated that, for every EUR 1 billion invested in public transport infrastructure, around 20,000 jobs are created on an annual basis [33].

References

1. Beim Michal, Haag Martin. 2010. "Freiburg's way to sustainability: the role of integrated urban and transport planning." *Real Corp 2010: Cities for Everyone, Liveable, Healthy, Prosperous - Proceedings*, 285-294. Competence Centre of Urban and Regional Planning. 18-20 May 2010, Vienna, Austria. ISBN 978-39502139-8-0.
2. Brzezinski Andrzej. 2014. "What can be a sustainable urban transport?" (text of a lecture given at UBCS, Warsaw).
3. Brzezinski Andrzej, Magdalena Rezwow. 2014. *Sustainable Transport - Ecological Transport Solutions - Technical Report*. *Ekorozwoj i Agenda 21.* Szczecin: Collegium Balticum.
4. Brzustewicz Paweł. 2013. "Sustainable solutions for urban transport - directions of development". *Journal Zarzadzanie* XL(413): 85-96. ISSN: 2450-7040.
5. Chowdhury Mashrur, Adel Sadek. 2003. *Fundamentals of Intelligent Transportation Systems Planning*. Boston: Artech House. ISBN 978-1580531603.
6. Chwesiuk Krzysztof. 2009. "Intelligent transportation systems". *Scientific Journals of the Maritime University of Szczecin* 72: 29-39. ISSN 1733-8670.
7. Dekoster Johan, Ulric Schollaert. 2000. "Cycling: the way ahead for towns and cities". Available at: http://ec.europa.eu/environment/archives/cycling/cycling_en.pdf.
8. Ittmann Hans W. 2017. "Private-public partnerships: a mechanism for freight transport infrastructure delivery?" *Journal of Transport and Supply Chain Management* 11: 1-13. DOI: 10.4102/jtscm.v11i0.262.
9. Jyoti D. Darbari, Vernika Agarwal, Venkata S.S. Yadavalli, Diego Galar, Prakash C. Jha 2017. "A multi-objective fuzzy mathematical approach for sustainable reverse supply chain configuration". *Journal of Transport and Supply Chain Management* 11: 1-12. DOI: 10.4102/jtscm.v11i0.267.

10. Khakbaz Amir, Ali Shahandeh Nookabadi, Seyyed Nader Shetab Boushehri. 2017. "Urban bus fleet routing in transportation network equipped with park-and-ride: a case study of Babol, Iran". *Transport* 32(1). DOI: http://dx.doi.org/10.3846/16484142.2017.1277551.
11. Knez Matjaz, Ali Celik, Tariq Muneer. 2015. "A sustainable transport solution for a Slovenia town". *International Journal of Low-carbon Technologies* 10: 386-392. ISSN 1748-1317.
12. Kopta Tadeusz, Bartłomiej Lustofin, Grzegorz Obara, Marek Rolla. 2009. "Cycling in Poland compared to other EU countries". Available at: http://ec.europa.eu/environment/archives/cycling/cycling_en.pdf.
13. Kozlak Aleksandra. 2008. "Intelligent transport systems as instrument of improvement in transport's efficiency". *Logistyka* 2: 10-16. ISSN 1231-5478.
14. Kulmala Risto. 2010. "Ex-ante assessment of the safety effects of intelligent transport systems". *Accident Analysis & Prevention* 42. ISSN 0001-4575. DOI: 10.1016/j.aap.2010.03.00.
15. Leurent Fabien, Elisabeth Windish. 2011. "Triggering the development of electric mobility: a review of public policies". *European Transport Research Review* 3: 115-126. ISSN 1867-0717. DOI:10.1007/s12544-012-0086-5.
16. Litman Todd. 2003. "Sustainable transportation indicators". Available at: http://www.vtpi.org.
17. Miłasiewicz Danuta, Bogusław Ostapowicz 2011. "Terms of sustainable transport development in the light of EU documents". *Studies and Work of the Faculty of Economic and Management Sciences* 24: 103-118. ISSN: 1429-6063.
18. OECD. 1996. *Towards Sustainable Transportation*. Paris: OECD Publications. Available at: http://www.oecd-ilibrary.org.
19. OECD. 2004. *Assessment and Decision Making for Sustainable Transport*. Paris: OECD Publications. Available at: http://www.oecd-ilibrary.org.
20. Ornetzeder Michael, Edgar Hertwich, Klaus Hubacek, Katarina Korytarova, Willi Haas. 2008. "The environmental effect of car-free housing: a case in Vienna". *Ecological Economics* 65: 516-530. *ISSN* 0973-1385.
21. Public Transport Authority of Warsaw. Available at: http://www.ztm.waw.pl/.
22. Pucher John, Lewis Dijkstra. 2003. "Promoting safe walking and cycling to improve public health: lessons from the Netherlands and Germany". *American Journal of Public Health* 93: 1509-1516, ISSN 033-3506.
23. Pucher John, Ralph Buehler. 2008. "Making cycling irresistible: lessons from the Netherlands, Denmark and Germany". *Transport Review* 28: 495-528. ISSN 0144-1647. DOI: 10.1080/01441640701806612.
24. Ruckelhaus William. 1989. "Toward a sustainable world". *Scientific American* 1: 114-120.
25. Starowicz Wiesław. 2010. "Expert opinion: 'the concept of the development of public transport in cities'". Available at: http://www.akademor.webd.pl/download/ZST_02_raport.pdf.
26. Sun Yuchao, Doina Olaru, Brett Smith, Stephen Greaves, Andrew Collins 2017. "Road to autonomous vehicles in Australia: an exploratory literature review". *Road & Transport Research* 26(1). ISSN: 1037-5783.
27. Sussman Jospeh. 2005. *Perspectives on Intelligent Transportation Systems*. New York, NY Springer. ISBN 978-0-387-23260-7.

28. Texas Transportation Institute. 2008. *Alternative Vehicle Detection Technologies for Traffic Signal Systems: Technical Report*. Accessed: 7 April 2017. Available at: http://tti.tamu.edu/documents/0-5845-1.pdf.
29. U.S. Department of Transportation. 2007. *Federal Highway Administration, A New Look at Sensors, Public Roads*. Available at: https://www.fhwa.dot.gov/publications/publicroads/07nov/04.cfm/
30. U.S. Energy Information Administration. 2000. *Carbon Dioxide Emissions from the Generation of Electric Power*. Available at: http://www.eia.gov/environment/emissions/carbon/
31. U.S. Environmental Protection Agency. 2010. *Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle*. Available at: http://www.epa.gov/sites/production/files/2016.../420f14040a.pdf.
32. WCED. 1987. *Our Common Future*. Available at: http://www.un-documents.net/our-common-future.pdf.
33. Witkowski Krzysztof. 2011. “Infrastructure investment in implementing public services”. *PWSZ IPiA* 7: 261-285. ISSN 1733-8271.

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