www.ees.uni.opole.pl
ISSN paper version 1642-2597
ISSN electronic version 2081-8319
Economic and Environmental Studies
Vol. 18, No 4 (48/2018), 1381-1396, December 2018

Selected solutions of environmentally-friendly urban transport systems

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Abstract: The article is related to urban transport systems. The authors focus on solutions that will positively influence the problem of excessive noise or pollution generated in cities through transport activities. They refer to existing single initiatives, but also demonstrate the need for complex solutions that integrate solutions into a single system that enables the use of various means of transport through organizational and ICT solutions. The aim of the article was to present a review of selected solutions that could reduce the harmful effects of transport, which can be used to improve the environmental performance of urban transport systems.

Keywords: public transportation, public transport, bike-sharing, car-sharing, eco-mobility, electro-mobility, mobility, sustainable development of transport, ICT

JEL codes: R41, R42

DOI: https://doi.org/10.25167/ees.2018.48.11

1. Introduction

The multidimensional nature of the socio-economic and environmental crisis and its effects have led to a global focus on issues related to sustainable development. This policy has been reflected among all branches of the market economy. On the other hand, it has a special significance in the case of transport – an economic integrator – whose functioning is not only closely related to sustainable development, but also shapes it in its own right (Eberts, 2015:1). At present, we are dealing with a growing interest in the subject of sustainability in the planning and operation of transport systems (Litman and Burwell, 2006: 331-347). This balance could be applied to two

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main groups – issues related to mobility and issues related to transport accessibility (White Paper 2011) and the analysis itself can be done, taking into account a narrow or broad view of sustainable development of transport (Pawłowska, 2013: 198).

Mobility and accessibility features are more readily associated with social acceptance of transportation; however, due to their importance, the issue of sustainable transport must also be taken into account. Lesser accessibility of a given group to transport means causes a decrease in interest, e.g., in collective transport, and may finally cause negative environmental overtone in a selected area. From the point of view of a narrow approach, particular attention is paid to environmental aspects with factors such as: health and its protection, minimization of pollutant emissions, reduction of vibrations and noise, the right approach to the use of natural resources (Karl-Henrik et al., 1996). In a broad sense, sustainable development of transport is understood as a system striving to achieve an integrated order (Pawłowska, 2013: 201). The sustainable development of transport system means then a system that ensures transport accessibility in a responsible manner through respecting the environment, public opinion and, at the same time, an economically acceptable transport (OECD 2004: 45).

In this research work, the authors focused in more detail on the narrow approach to the sustainable development of transport, i.e. on issues related to the environmental aspects of balancing transport in urban systems. The purpose of the work was to present the possibilities that could be implemented to achieve an integral, broadly understood sustainable, developed, environmentally-friendly transport. The authors focused on the presentation of individual transport initiatives, but also on showing the need to integrate solutions into one coherent system using various organizational solutions and ICT solutions.

2. Transport means and organizational approach

2.1. Public transport

The most important need to balance transport in cities is to make change in the behavior of travelers and provide a viable alternative to the common car. The steady increase in the number of passenger cars using the road network, while limiting the possibility of further expansion of the infrastructure, causes congestion – especially visible in city centers. This situation additionally increases other unfavorable effects of transport on the environment in these areas,

like emission of harmful substances and noise. One of the basic ways to improve the situation is the implementation of urban public transport responding to the needs of travelers. Public transport (buses, trams, trolleybuses, city railway, subway, etc.) allows reducing traffic in the city and is a more environmentally-friendly solution than traveling in an individual car. The bus, even when it emits a larger amount of exhaust (depending on the technology used) than a car, transports as many people as 70 cars in the city and 30 cars outside the city (Pawlak and Pawlak, 2010: 6). In addition, in recent years, the number of electric buses in cities has increased (Figure 1). Therefore, public transport is much less harmful to the environment than individual transport.

The statistics on the use of electric buses in urban transport systems show that that kind of solution is able to bring environmental and social benefits. Based on the report "Alternative Fuels in Public Transport" published by The Polish Congress of Alternative Fuels (PKPA, The Polish Congress of Alternative Fuels 2018: 11), it can be stated that electric buses are characterized by a better range, noise reduction and significantly affect the emissivity of both CO2 and sulfur compounds of NO_x and particulate matter (PM). A comparison of a vehicle that uses CNG type and electric vehicle in comparison to EURO 5 bus with conventional drive is presented in Table 1.

Table. 1. Comparison of electric and CNG drive buses to conventional EURO 5 bus

Feature	Bus with electric drive	Bus with CNG
Range	-60% to -80%	From -20% to -40%
CO_2 emission [kg/100 km]	to 100%*	- 15%
NO_x emission $_{MISJA}$ [NO_x /km]	to 100 %**	- 80%
PM emission 10 [g/km]	To 100%**	- 95%
noise emission [dB]	from -5 to -7 dB	from -2 to -4 DB

Source: PKPA, The Polish Congress of Alternative Fuels, 2018.

Figure. 1. An example of the electric bus, Hangzhou, China

Source: Author's own elaboration

The basic problem in the organization of this type of solution is the need to know real needs and selection of timetables, routes and stops ensuring an increase in the competitiveness of public transport. Organizers of urban transport and local authorities should ensure that public transport in the selected area has the following characteristics (Janecki, Krawiec and Sierpiński, 2010: 112):

- high communication accessibility provided by a line system in line with the needs for transport services (minimizing the time of arrival at the bus stop),
- time integration of various means of urban public transport at interchanges (ensuring a short waiting time for a change),
- adjusting the frequency and course of individual lines to the needs of users,
- a joint ticket and a clear tariff system and a clear timetable,
- providing high travel comfort (modern, quiet, reliable fleet)
- increasing the communication speed to a competitive level in relation to individual transport (eg. through separated lanes or tracks and priorities at intersections).

From the above list, apart from organizational activities, one could also distinguish infrastructural activities, such as separated lanes for busses. This solution increases the speed of public transport, often with a simultaneous reduction of urban space for a car. That is a clear message for car drivers to change travel habits and take advantage of the city offer. In some cities, more advanced solutions are used regarding the management of separate bus lanes. That

kind solution is the implementation of bus rapid transit (BRT) systems. The system consists of buses (mainly electric vehicles or powered by alternative fuels) and infrastructure (including bus lanes often physically permanently separated from the rest of the lanes, bus stops resembling metro stations, traffic control system and passenger information (Levinson et al., 2003: 4-5)). The BRT system perfectly fits into the assumptions of the sustainable development of transport.

The first BRT system was launched in 1974 in Curitiba in Brasil and was called "Rede Integrada de Transporte" (Integrated Transportation Network') (Cervero, 1998: 265-296). Now, the systems are becoming more and more popular as urban transport systems. Currently the BRT systems are functioning in 169 cities around the world (BRT Data 2018). Thanks to its application, it is possible to reduce traffic by using a more ecological means of transport. In addition, the system provides an alternative for individual transport supporters by providing the possibility of fast movement similar to metro or high-speed city trains, while being a much more economical initiative for the city (Levinson et al., 2003: 5). The number of BRT systems depending on the continent, the average length of routes and the speed of buses is presented in Table 2.

Table 2. The BRT systems around the world – selected data sheet

Continent	Number of cities	Length of routes	Speed of the buses	Passengers per day
Africa	5	131 km	26 – 30 km/h	491 578
Asia	43	1953 km	15 – 31 km/h	9 301 472
Europe	44	875 km	14,5 – 60 km/h	1 613 580
Latin America	55	1798 km	16 – 40 km/h	20 552 629
North America	18	526 km	16.4 – 47.2 km/h	912 598
Oceania	4	96 km	25.3 – 80 km/h	436 200

Source: BRTdata, 2018.

Separate lanes make BRT reduce emissions in relation to public transport using common lanes with private vehicles. Based on updated data (BRTdata 2018) it should be noticed that

many of the BRT systems use exactly electricity, LNG, CNG or hybrid, which increase the environmentally-friendly effect of this solution.

An example of a bus operating within the framework of the BRT system and specially adapted road infrastructure is presented in Figure 2.

Figure 2. The example of BRT system operating in China, Lanzhou, China

Source: Author's own elaboration

2.2. Bikes, rental systems, Bike&Ride

Bicycles provide high mobility and are many times cheaper than cars. The cycling costs are more than twenty-four times lower than traveling by car (Berdo 2006: 66). Experiences from Denmark, the Netherlands or Germany (Wesołowski, 2008: 144; Tundys, 2008: 207, 228) show that on the streets closed to car traffic (open only for cycling and walking) business activities (shops, cafes, etc.) are developing very well and people are happy to change their habits regarding the availability of the passenger car. Another way to achieve more environmentally-friendly transport within cities is to take advantage of the opportunities offered by the sharing economy. Due to the increase in its popularity in cities, an increasing number of solutions made available for use by residents of vehicles for "minutes" or short-term rentals began to appear. The combination of the idea of traveling by bicycle and the idea of sharing resulted in the creation of

the most popular and in recent years also intensively developing city bike rental systems in Poland (Czech et al., 2017: 161-169). Although short-term rental bikes are not a new idea, and their creation dates back to 1965, they are now becoming an increasingly popular solution. This can be proved by the fact of the next generations of systems appearing on the markets of urban transport systems like the 5th generation of dock-less bike-sharing systems (Chen et al., 2018: 5-13).

Their implementation is confirmed not only by the arguments related to the health of users or the fact that it is the most ecological form of transport. Bicycle transport also allows reaching destinations where traffic is limited. It is also a factor affecting the improvement of air quality in city centers. In addition, it significantly reduces the load on road networks, provides greater transport accessibility and is a complementary service to public transport, makes the city more attractive, where it is implemented for tourism and reduces the costs associated with the need to expand the road network. And as a result, it becomes an element integrating the transport system (Czech, Turoń, Urbańczyk, 2017: 103-111). Bike-sharing make travelling more environmental friendly. For example, this solution in Shanghai decreased the CO2 emissions by 25,240 tones and saved 8,358 tons of petrol in 2016 (Zhang and Mi, 2018: 296-301). Figure 3 presents examples of bicycle stations, including one of the bases of the world's largest urban bike rental in the world – in the Chinese city of Hangzhou, in Spanish Barcelona and in the Hungarian Esztergom.

Figure 3. Examples of urban bicycle rentals stations (Hangzhou, China; Barcelona, Spain; Esztergom, Hungary)

Source: Author's own elaboration

2.3. Electric cars and car-sharing

Another option to make urban transport systems more ecological is to invest in an increasing number of electric vehicles. In one of the documents defining the European strategy on alternative fuels (Clean Power for Transport 2013) attention was drawn to the risks resulting from the fact that Europe is heavily dependent on oil (in relation to mobility and transport). This requires intensive changes to meet the long-term needs of all transport modes. Among the alternative fuels listed in the document were: LPG, natural gas (LNG and CNG), electricity, liquid biofuels and hydrogen. At the moment, many countries are intensifying work towards the development of electromobility (for example, in Poland the Plan for the development of electromobility covering the years 2016-2025 has been developed). Using these vehicles despite their higher initial price is an important alternative to conventional cars. In addition to the well-known advantages associated with their possession such as environmental issues, a special policy is addressed to vehicle owners. electromobility (Himmel et al., 2016: 472-484). As part of its activities, special privileges are introduced such as the possibility of bus-lanes, exemptions and tax breaks, access to city centers with access to car-free zones or with restricted traffic, free parking in zones payable to users of traditional vehicles, free use from the charging station (Longo et al., 2015: 439-445). Examples of publicly available charging stations for electric vehicles are shown in Figure 4.

Figure 4. Examples of publicly available electric vehicle charging stations (Shanghai, China, Budapest, Hungary)

Source: Author's own elaboration

Another of the solutions directly related to the economy of sharing is the implementation of the concept of car-sharing in city areas. The idea is the short-term rental of vehicles made available in cities. There are three types of car-sharing (Shaheen, 2015: 519-536):

- stationary / classic (round-trip) – when the vehicle is rented and we always take it from and bring it back to one and the same location,
- unidirectional (one-way) – when we rent a vehicle at one point, and return it to another point, but at the same time limiting ourselves only to the rental points established by the system operator,
- free (free-floating) – when we rent and give away a vehicle from any publicly available location in the city.

The advantages of the car-sharing system are related to issues such as:

- limiting the formalities related to renting a vehicle to a minimum,
- the impact on reducing the number of vehicles entering the city (less load on the road network),
- pro-ecological (electric vehicles, age of vehicles, EURO standards, etc.),
- integration of pro-ecological solutions – inclusion of an additional solution to the urban transport offer,
- eliminating the need to own a vehicle and incur costs related to its use and maintenance.

Examples of vehicles made available in car-sharing systems are presented in Figure 5.

Figure 5. Examples of electric vehicles operating in car-sharing systems (Shanghai, China, Rome, Italy)

Source: Author's own elaboration

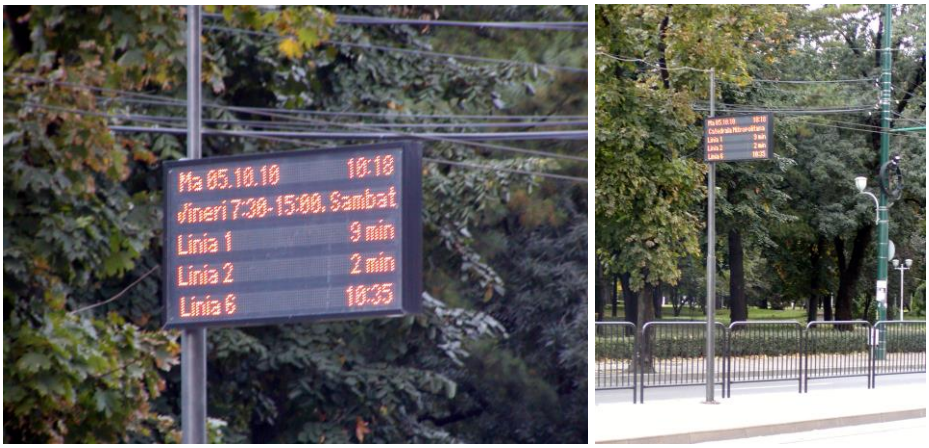
The rapid increase in the popularity of systems proves a significant interest in the development of services. The car-sharing systems are gradually starting to become an increasingly large alternative to taxis (Kubik et al., 2018: 923-930). The popularity of car-sharing systems is also intensively growing on the Polish market. The first system appeared in Poland in 2016 and currently there are 6 operators on the market (Turoń and Czech, 2018: 17-26) . On the other hand, analyzing the European market, on the basis of 40 rental companies and 187 vehicles offered by them, it can be stated that 72% of all the cars are vehicles with classic drive and 28% are vehicles with alternative drive (hybrid and electric) (Turoń et al., 2018: 412-414). In addition, it should be remembered that the intensive development of sharing services and electric vehicles is to lead to the implementation of autonomous cars on the market (Czech et al., 2018: 15-22).

3. ICT solutions

3.1. Dynamic passenger information

The organizational and infrastructural solutions presented earlier, regardless of their selection and structure, require an additional element, which is transmission of information. Current information provided with the use of modern technologies is indispensable both for education and for improving the image of alternative solutions in the field of travel. The most frequently used solution is dynamic passenger information related to the functioning of public transport. The example of one of the passenger information modules for public transport is shown in Figure 6.

Figure 6. Element of electronic passenger information (Timisoara, Romania)



Source: Author's own elaboration

The solution provides information that takes into account current road conditions (e.g., current delays). It can be used separately or as part of complex Intelligent Transport System (Paradowska, 2011: 391). This type of communication helps to improve the trust in public transport (even in the case of a delay the passenger is aware of this), and also significantly improves the readability of timetables. These and other features of dynamic information have a significant impact on the choice of the means of transport, and therefore, despite the lack of direct environmental importance, the effect of their operation may be a positive change in the behavior of travelers.

3.2. QR code and other solutions to urban rental systems

The solutions supporting the operation of the urban transport system also include solutions aimed at facilitating access to the use of a given transport service. Such methods are, for example, the use of QR code techniques or the use of card readers. These solutions reduce the time to purchase a service and eliminates the need to use a paper form of documents (e.g., tickets). Identification using QR codes is often applied in relation to urban bike and car rental systems. In both cases, the system client (a traveler) using the mobile application can scan the QR code (Figure 7a) and thus start the loan service.

Figure. 7. Example of a QR code tag and a card reader when buying a car and city bike rental service

Source: Author's own elaboration

Another form of applying technology in the urban services, without requiring the usage of special mobile applications, is the city card. The integrated solution usually allows using any means of transport offered by the city (Figure 7b), as well as the purchase of other urban services (e.g., theater tickets, etc.). The card can be recharged in special machines located usually at public transport stops. In both cases, technology assists the traveler and speeds up the process of starting to use public transport. It is therefore also an indirect way to encourage change in travel behavior.

3.3. Travel planners as a complex solutions to transport means choice problem

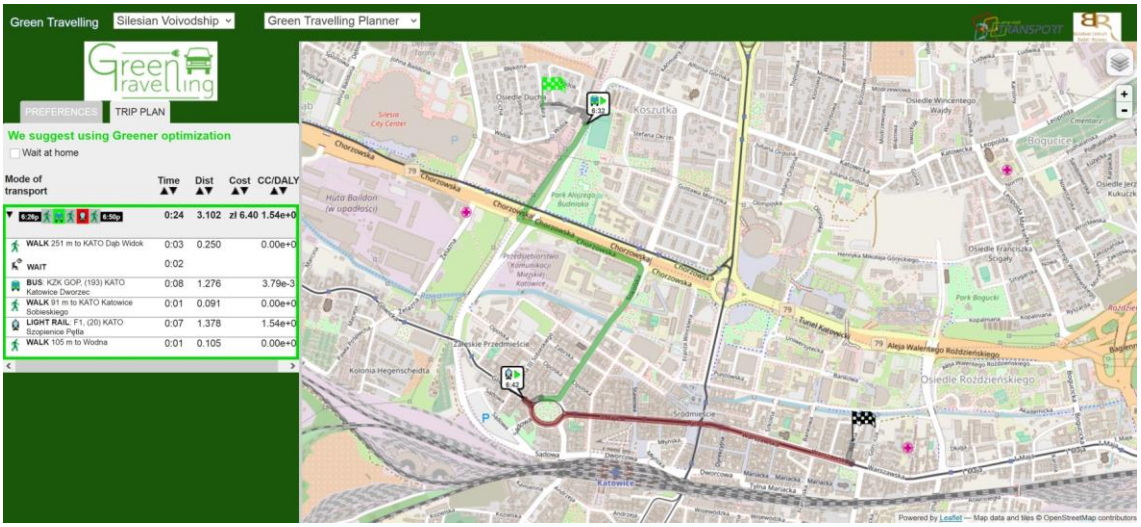
Information technology should provide up-to-date knowledge on the subject of, among others, the following:

- current choices of means of transport,
- applicable fares and ticket purchase venues,
- costs and times of displacements in the comparison set,
- alternative routes taking into account the real difficulties in traffic,
- city public transport timetables along with the update of delays.

The above possibilities are offered by travel planners, which provide a solution for travelers. They enable selection, visualization and comparison of displacement possibilities, and support their implementation in a given transport network between two (or more) specific points, using one or more means of transport in the displacement chain. Often, however, planners are dedicated to only specific ways of traveling and are limited, for example, only to planning individual journeys. There are also planners for mass transport operators. Then, it limits their functionality in a natural way only to this way of traveling. However, the majority of developers of planners do not pay attention to the environment, determining only the cost-time criterion (or criterion based on both parameters with appropriate weights), which is visible in the design of most travel planners (Borkowski 2017; Esztergár-Kiss and Csiszár 2015; and Földes and Csiszár, 2015). A few examples of pro-environmental approaches are described, inter alia, in (Lewczuk et al., 2013 and Sierpiński, 2017). It is also important to promote new types of environmentally-friendly transport means, like electric cars by including that option into travel planner (Sierpiński, Staniek, 2018).

A travel planner may allow a much broader information message than dynamic passenger information. Thanks to the databases it uses, it is possible to provide the traveler with several alternative solutions. This action forms the basis of education and increases the likelihood of a change in travel behavior. The example of planner – the Green Traveling Planner was presented in Figure 8.

Figure. 8. Example of a multimodal travel planner - GT Planner (Katowice, Poland)



Source: Author's own elaboration

5. Conclusions

The solutions presented in the article may help reduce the negative impact of transport on the environment. Each of the solutions presented by the authors in the text is becoming a more and more popular opportunity used to implement the policy of cities' sustainable development. Choosing the set of solutions that would be the most appropriate for a given area is not easy or clear. The condition for obtaining positive results is proper information transmission and the use of modern technologies facilitating the decision to change the means of transport from a passenger car to another way of moving. It is also possible to stay with cars, but buy those supplied with cleaner energy for the environment. There is not one solution satisfying all, but in any case it is first of all necessary to know the real needs of travelers. This is the foundation and fulfillment of the concept of needs being part of one of the most well-known definitions of sustainable development (Our Common Future 1987).

Based on a review of solutions presented by the authors in the text, the next step will be to perform research related to the impact of individual transport solutions, among others, bike- and car-sharing, for reduction of the congestion problem as well as reduction of vehicles per household.

Summing up, the review presented by the authors in the text may serve other scientists in the development of their articles dedicated to the sustainable development of transport, as well as city authorities considering the implementation of individual services to transport offers in local urban transport systems.

Acknowledgements

Selected elements of present research were financed from the means of the National Centre for Research and Development as a part of the international project within the scope of ERA-NET Transport III Future Travelling Programme "A platform to analyze and foster the use of Green Travelling options (GREEN_TRAVELLING)" and

Selected elements of present research were financed from the means of the National Centre for Research and Development as a part of the international project within the scope of ERA-NET CoFund Electric Mobility Europe Programme "Electric travelling - platform to support the implementation of electromobility in Smart Cities based on ICT applications".

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Wybrane, przyjazne środowisku rozwiązania miejskich systemów transportowych

Streszczenie

Artykuł poświęcony został tematyce miejskich systemów transportowych. W pracy skupiono się na rozwiązaniach, które mają pozytywnie wpłynąć na problemy nadmiernego hałasu czy zanieczyszczeń powstałych w miastach poprzez działalność transportową. Autorzy odnieśli się do istniejących już pojedynczych inicjatyw ale także ukazali potrzebę zastosowania rozwiązań kompleksowych, których zadaniem jest integracja rozwiązań w jeden system umożliwiający korzystanie z różnych środków transportu poprzez rozwiązania organizacyjne oraz ICT (*ang. Information and Communication Technologies*). Celem artykułu było zaprezentowanie przeglądu wybranych rozwiązań, które mogą ograniczyć szkodliwy wpływ transportu na wybranych rozwiązań stosowanych w celu poprawy ekologiczności miejskich systemów transportowych.

***Słowa kluczowe**:* miejski system transportowy, transport publiczny, bike-sharing, car-sharing, eco-mobilność, elekro-mobilność, mobilność, zrównoważony rozwój transportu, ICT.