SUSTAINABLE LOGISTICS: A FRAMEWORK FOR GREEN CITY LOGISTICS - EXAMPLES OF POLISH CITIES

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Abstract

Background. The emission of hazardous substances has a significant impact on environment pollution and becomes a noticeable problem. Public transport, warehouse processes, and waste management are the main sources of pollution in cities. Ecology oriented solutions in the city's logistics systems may lead to improve the quality of citizens' life. The use of sustainable logistics may cause positive feedback on the surrounding environment. The interest of green logistics increases rapidly due to a growing amount of urban waste, energy consumption and greenhouse gases released to the atmosphere. The aim of this paper is to analyze the green logistics solutions and to consider their application in Polish cities.

Method. The article is theoretical and is based on a literature review. The main research method is an analysis of green logistics solutions and possible ways to implement them in Polish cities.

Results. Implementation of planned solutions in Polish cities could improve the shape of the natural environment together with a citizen's life quality. Cooperation between local government, entrepreneurs and citizens is indispensable to achieve the expected results. A necessary (but not sufficient) condition for increasing the quality of life in the city is an implementation of green logistics solutions. The basic ones include the development of infrastructure for public transport and vehicles powered by alternative fuels (mainly electricity). It is important to implement sharing concepts based on vehicle sharing, as well as a participatory approach to city management, allowing each resident to feel jointly responsible for it. Nowadays, Polish cities invest money in renewable energy to power public transport vehicles. In addition, the number of charging stations for electric vehicles is increasing very quickly. This means we observe positive changes in people's behavior about their environment.

Keywords: Sustainable development, green logistics, ecology

1. INTRODUCTION

Nowadays, ecology has a significant role in society life. Development of technology, costs optimization trend, overestimated consumption and direction of personal needs leads to increase of environment pollution. One of the most the pollution affecting factors are a logistics processes, mainly the transport. Among the main unwanted effects are the increase of greenhouse gases emission, intensification of noise pollution, more time-consuming congestion, unsafety roads and decreasing a quality of life as a result of factors mentioned above. All of those phenomenons are noticeable primarily in the cities. The mobility of people and the flow of goods to, from and within Europe must be cost effective, safe and environmentally sustainable [1]. Considering, society have to reduce negative influence on the environment, implementing ecology solutions. European Union is working on an environmental protection plans, leading to minimize impact of transport system on climate and environment through promotion of a resource efficient transport, which respects the environment [2]. From another side, local governments take into account implementing new ecological solutions from the sustainable green city logistics field. Significant progress towards low-emission mobility is therefore an essential component of the broader shift to the low-carbon economy needed for cities.

The aim of this paper is to analyze the green logistics solutions and to consider the application in Polish cities.

2. SUSTAINABLE LOGISTICS - FOUNDATIONS AND IMPLEMENTATION

Sustainable development meets the needs of present generations without compromises about the ability of future generations to meet theirs [3]. Its affects on reconciling economic development objectives, maintaining or improving the living conditions of populations and protecting the environment [4]. Sustainable development should affect every sector of economy. Furthermore, sustainable logistic is very important, because the logistics processes have an enormous influence on economy, society and environment. Especially, sustainable logistics solutions should concern the cities, because the traffic and concentration of companies in big agglomerations causes many environmental problems due to logistics task execution.

The researchers are focusing on four topics in their sustainable logistics studies: transport-related impacts reduction, reduction of nuisances linked to logistics buildings, energy and material consumption reduction, logistics development activities as a tool for economic growth [5]. Cirovic et al. [6] believe that the increasingly serious traffic problems lead to traffic congestion and environmental pollution, which greatly raise the cost of living in cities, and at the same time, have an important impact on the health of urban residents. Municipal administrations are investing in sustainable city logistics initiatives such as urban distribution centers, congestion pricing, delivery timing and access restrictions in order to improve the condition of goods transport in cities and reduce their negative impacts on citizens and their environment [7]. The transport issue is considered from the perspective of shifting to less polluting modes than road transport or by developing “clean” transportation: electric vehicles, bicycles and alternative fuels, for instance [8]. Roumboutsos et al. [9] pointed out that low emission vehicles can effectively solve the adverse effects on the environment caused by the city logistics distribution, they through the introduction of electronic transport vehicles car, using the system innovation research of city green logistics problems, and puts forward the system innovation framework to promote the development of green logistics in city. Against Jamshidi A. et al. suggest, that there is a need to identify the most common and suitable criteria and factors for evaluating the sustainable city logistics initiatives and more importantly, advanced decision-support systems (DSS) which could be applied for selecting the best initiatives in different cities [10]. Unfortunately, people involved in decision process of implementing environment friendly solutions in logistics are not aware of long term finance benefits [11].

Based on a literature review researchers studies regarding the sustainable city Logistics are focused mainly on green logistics cargo transportation. However, there is much less studies regarding passengers transport problems. This article concentrates on a public transport logistics problems and concerning green solutions.

Implementation of green solutions in cities is a long process, divided into few stages. Process of implementing eco-solutions on city logistics (**Figure 1**) should begin with creating legal and organizational regulations. This stage is performed on European Union and different countries level. The next unit responsible for sustainable logistics are local governments of the cities, which are creating city development plans. Next stage tells about corporate social responsibility between local entrepreneurs, because they control material and citizens flow. The most important stage is leaving existing habits and implementing of ecological solution in logistics. This stage should also involve citizens of the cities. Intensity of mobility models should be reduced through promotion of public transport and other low-emission passenger transport types. Creating of physical and IT infrastructure is necessary to implement rest of green logistics points and should be done by local governments. The last stage is a society education and behavior change.

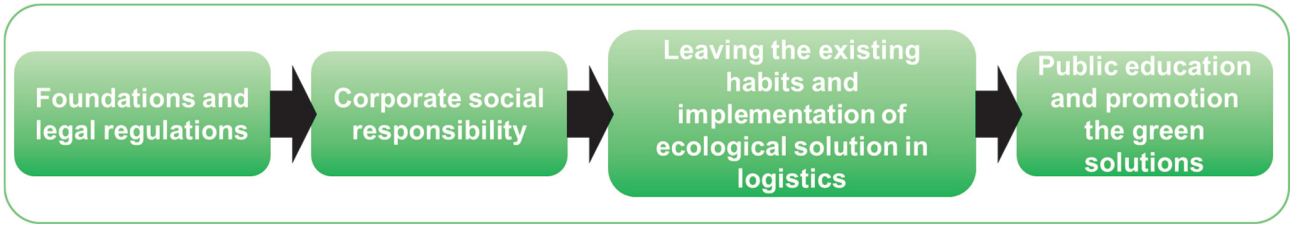

Figure 1 Green city logistics process implementation

Despite of length and complexity of green logistics implementation should result a long-term benefits and status of environment pollution. The Green City Index [12] illustrated the ranking of cities with positive experience in green logistics solutions. The ecological indicators included CO_2 emissions, energy, buildings, transport, water, waste and land use, air quality and environmental governance. Copenhagen has one of the lowest CO_2 emissions and the most environmentally friendly transport. In Stockholm, 68 % of people cycle or walk to work, the highest percentage in the European Index [13]. Riga offers the longest public transport network - 8.6 km per km^2, almost four time the average Index of 2.3 km per km^2. In Kyiv, 74 % of the population uses public transport to get to work. Oslo has the lowest emission of CO_2 and uses the highest share of renewable Energy at 65 %. 63 % of the population by data of the European Index uses green forms of transport reach to work. Warsaw is placed in this ranking on 16^{th} position among European cities. The high green indicators of the cities listed above are conditioned by the authorities' appropriate approach to their development strategies. This is a positive example to act towards the implementation of sustainable urban logistics.

According to above information, the main objective of sustainable city logistics concept is to modify freight transportation and logistics for increased economic, environmental and societal efficiency and sustainability. In turn, these green practices can be a role model for other developing cities.

3. POLISH CITIES TOWARD GREEN LOGISTICS

Polish cities have a high level of air pollution, due to exhaust gases from cars powered by fossil fuels. In 2016, yearly emission in Poland created by transport and warehouse sector was 22-27 mln tons, what is 8 % of whole emission in this country [14]. In the same time, European Union noticed that the transport and the warehouse sector was responsible for 14 % of whole CO_2 emission. This means logistics processes in Poland are not as critical as in the rest of Europe for environment. Aside the numbers, Poland should also reduce emission of hazardous substances. Citizens are affected by congestion and noise pollution what have a negative influence on quality of life. In 2018, per 1,000 citizens was a 610 personal cars, what is a 36 % more than in 2010 [15]. Regarding this information, Poland is highly motorized country with 6th position of the most motorized countries in Europe. Between 1993 and 2016, public transport outside the city loses almost 75 % of passengers, together with liquidation the 50 % of lines. Joining the European Union in 2004 resulted reduction of the average fill of buses by 40 %. In 2018 number of people using rail transport decreased by 14 % comparing to year 2000 and was 310.3 mln of passengers [16].

However, ecological awareness of people was increased in the last few years. Number of hybrid and electrical vehicles on polish roads rises from one year to another. At the end of June 2019 in Poland, there was 6,092 electrical passenger cars. 67 % was the fully electrified cars (BEV) - 3,855, the rest of them was the plug-in hybrid cars (PHEV) - 2,237 [17]. According to other European Union countries, number of electrical vehicles is small. For comparison, in Germany at the end of September 2019, the number of registered passenger electric vehicles was around 274,000, of which 83,175 were fully electric, while the rest were hybrid cars [18]. Inferior result was noticed in Czech Republic, Slovakia and Lithuania. For example, in the Czech Republic in 2019, there were only 421 fully electric cars and 4,439 hybrid cars (of which 156 plug-in) [19]. Unfortunately, the number of electric trucks and vans in Poland at the end of May 2019 was only 337 pcs, and electric scooters and motorcycles - 4,604 pcs. Moreover, the number of electric buses was 198 pcs [20]. One of the problems for electric car owners is the limited availability of car charging stations outside city centers. In July 2019, there were 971 normal power charging points and 486 high power charging points. Despite this, it can be said that the charging station network is well developed in comparison to the number of electric cars - there are less than 4 passenger cars per one point. Considering the information, it can be stated that Poland, as a country, is striving to develop ecological logistics solutions, but it is still not as advanced as Western European countries. In spite of all, the recent development trends could lead to significant improvement in the near future.

In attempt to evaluate the stage of implementation of green logistics in Polish cities, three agglomerations were analyzed. Warsaw, Cracow and Wroclaw were selected for the comparative analysis of green logistics indicators. Those agglomerations were selected because of:

- Warsaw is the capital of Poland and the city of biggest population,
- Cracow - the second largest city in Poland,
- Wroclaw - the fastest growing city, very important for country economy.

Table 1 presents statistical data on logistic indicators related to green logistics in Poland in general and in Warsaw, Wroclaw and Cracow in 2018. The largest number of vehicles per 1000 inhabitants was in the capital of the country and amounted to 749.7 pcs. In Cracow and Wroclaw by 8 % and 15 % correspondingly. This means that the inhabitants of these cities mainly use passenger cars, not public transport. The negative effect of this situation is the increased noise and CO_2 emissions, as well as traffic congestion. In Warsaw, solutions will be introduced to limit the mobility of cars with high levels of air pollution in the city center. In Poland, educational activities will be carried out to promote means of transport other than a passenger car. In Cracow, it is also planned to limit the possibility of cars entering to the city center. Such practices are used in many European cities. Low- or zero-emission zones are for e.g. in Vienna, London, Amsterdam. On the one hand, the high level of motorization in the analyzed cities shows economic development, and on the other hand, the low ecological awareness of the residents. To limit the negative impact of the increase in the number of passenger cars, inhabitants should be encouraged to use public transport.

Table 1 Logistic indicators in Poland and in Warsaw, Wroclaw and Cracow in 2018

Logistic indicators	Warsaw	Wroclaw	Cracow	Poland
Motor vehicles (pcs) per 1000 inhabitants	749.7	639.4	689.9	610
Fleet of public transport vehicles (pcs)	727 - trams 1,831 - buses	358 - trams 329 - buses	389 - trams 643 - buses (10 % hybrid, 4 % elektric)	no data
Length of bicycle paths (km)	590	540	213.7	13,904.7
Number of parking lots (pcs) in the Park & Ride system	16	13	4	175
Number of electric car charging stations (pcs)	100	43	45	1,457

A modern ecological solution is the Park & Ride (P + R) systems, which allow to park car and change to public transport in order to get to the city center. They are widespread in most European cities. In the analyzed period, there were 175 places of Park & Ride in Poland: 16 in Warsaw, 14 in Wroclaw and 4 in Cracow. Car parks of this type contribute to reducing traffic jams in the center of an urban area. Such solutions should be actively implemented in cities, which requires the interference of local authorities.

The fleets of public transport vehicles in these cities are well developed according to the needs of residents. There are 727 trams and 1,831 buses in Warsaw. In addition, you can use the metro in Warsaw. In Cracow, passengers are transported by 389 trams and 643 buses, and in Wroclaw by 358 and 329 accordingly. It should be noted that Cracow invests in eco-buses, consisted of 90 hybrid and electric buses. Warsaw and European cities such as Paris and London have placed new orders for this type of vehicle. Currently, over 30 e-buses travel around Warsaw [21]. Moreover, the purpose of the Wroclaw Sustainable Public Transport Development Plan [22] assumes to ensure sustainable transport development in this area to achieve both

ecological, as well as social and economic goals. Unfortunately, Wroclaw only tested the electric bus, which was not permanently assigned into service.

In the future, public transport in Polish cities should be more popularized in order to reduce traffic jams in the city and reduce greenhouse gas emissions. This idea requires actions in the field of creating pro-ecological communication behaviors of the inhabitants.

The idea of the green logistics implies the use of alternative means of transport, which can be bicycles and scooters, also with electric drive. All of analyzed cities have a well-developed bicycle route infrastructure. The total length of cycling routes for Poland in 2018 was 13,904.7 km. Warsaw has 590 km, Wroclaw has 540 km and Cracow has 213.7 km. Cracow wants to have a modern infrastructure, what should be useful for creation an effective network of high-speed connections, joining all resources. According to the Investment Program - Study of Basic Bicycle Routes [23], approximately 223 km of bicycle routes should be created in Cracow. Also in Cracow, Warsaw and Wroclaw you can move on electric scooters, which are a shared means of transport, positively affecting the environment. In Wroclaw there are 540 km of bicycle paths, as well as over 700 km of streets with a speed limited to 30 km / h, where cyclists ride next to cars. Wroclaw has introduced one of the first city bike sharing systems in Poland; today there are 2 thousand city bikes and although Warsaw has more of them, in relation to the number of inhabitants Wroclaw is on the top. A complex bicycle transport and pedestrian system will be developed in Warsaw, including architectural and environmental barriers will be eliminated. Road safety will be improved, especially for walking and cycling citizens. This is a positive indicator of green mobility in Polish cities that are chasing green European cities.

Data on the number of electric car charging stations indicate an increase in demand for such logistics infrastructure. There are 43 electric car charging stations in Wroclaw, 45 in Cracow, and 100 in Warsaw [24]. Taking over the experience of European cities, charging for the first few months is free, which should encourage city residents to buy electric cars. Holders of electric and hybrid cars registered in Cracow can enter the restricted traffic zone and park in the paid parking zones as part of a monthly subscription costing PLN 100 [25]. Such benefits should contribute to the increase in the number of electric passenger cars in the Polish cities.

Cracow is mainly struggling with too high a share of individual cars in the city's transport system and poor air quality. According to the Cracow 2030 strategy [25], the city aims to become a smart city, which optimizes energy consumption, carries out activities for the protection and adaptation to climate change, measures to reduce emissions of pollutants into the environment, and the city's resource management is based on the principle of sustainable development, with using infrastructure based on modern technologies.

The development strategy of the city of Wroclaw 2030 [26] is based on the principles of green logistics, which is reflected in focusing on ecological ways of getting around the city and the development of public transport, clean air, renewable energy sources, noise reduction, halting suburbanization and logistics planning. Also in Wroclaw undertaken promotional activities for sustainable transport.

In Warsaw, in accordance with the implementing strategy Warsaw 2030 [27], integrated interchanges will be built in the next few years. Also solutions in the field of intelligent transport systems will be implemented to facilitate efficient movement around the city.

Analysis of the logistics indicators in selected cities resulted the Polish cities started to implement environment-friendly ecological solutions. The **Table 2** shows problems of city logistics, separated from the literature review and the situation in the selected cities. The most important problem is the low environmental awareness of government. Next problem is the high CO_2 emission. Another problem is a lack of green solution subsidization in a private transport. Low emission cars and buses (for ex. BEV and PHEV) have the lowest rate of CO_2 emission. Last one is the high motorization level of society, what leads to congestion, noise and lack of safety on the roads.

Table 2 The city logistics problems and the green solutions

№	Problem	Solution	Realization
1	Low ecology awareness of government, entrepreneurs and citizens	Shaping pro-ecological attitudes	Wide promotional campaigns about the environment status and assign logistics process influence on that. Education of society.
2	High greenhouse gases emission	Reduction of greenhouse gases emission and pollution	The use of low-emission vehicles, popularization of public transport. Introduction of low-emission zones in the city and a ban on vehicles entering the city center. Introduction of alternative ways of travelling
3	Low level of support for the use of environmentally friendly vehicles	Government subsidies for the purchase of low-emission vehicles	Financial encouragements for the purchase of clean energy personal and cargo vehicles. Adaptation of infrastructure (charging stations) to the needs of low-emission vehicles Fast charging systems adapted to cars and freight trucks. Creating priority lanes for environmentally friendly vehicles.
4	A large number of vehicles moving on the road and causing congestion	Adaptation of public transport to the needs of the citizens	Increasing the fleet of public transport vehicles, number of lines, frequency of fares

Elimination of the above-mentioned problems is possible due to the correct formularization of objectives and the appropriate way of implementing green logistics strategies. The first step should be a dialogue between authorities, residents and entrepreneurs. At the same time, it is important to emphasize the huge importance of ecological awareness of society. Therefore, people should know about the benefits of the use of low-emission vehicles and the use of public transport. Government subsidies for the purchase of low-emission vehicles, extension of the infrastructure necessary for free movement and other benefits can be developed through the development of urban logistics.

4. CONCLUSION

Sustainable city logistics should be based on green solutions. Based on a literature review, it was found that too little attention was paid to the problem of passenger transport in cities. Therefore, cities were implementing green solutions in the public transport. It was found, that barriers for develop of green logistics are mainly lack of cooperation between local government, citizens and entrepreneurs. Positive phenomenon is the implementation of city strategy based on green economy through investing in bicycle roads, developing on public transport, low-emission areas and investments in green infrastructure. On the other hand, companies start to implement visible ecological solutions like electrical bikes or scooters for a rent. Citizens can quickly move around the city. It also contributes to greater variety of mobility and has a positive impact on noise level and air pollution, because cycling is more environmental friendly than travelling by a car. Those solutions are most suitable in cities with well-developed bicycle road network. Another conclusion is a fact, that cities should launch campaigns promoting the sustainable development, green logistics and caring about surrounding environment.

The research gap depends on the lack of empirical research on public attitudes towards proposed green solutions in the field of sustainable logistics. Therefore, attention should be given to the mentioned problem.

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