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THE FREIGHT TRANSPORT EFFECTIVENESS ASSESSMENT IN THE ASPECT OF THE USE OF ENVIRONMENTALLY FRIENDLY VEHICLES

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Abstract

The freight transport combines the issue of supply services organization for various types of entities, including large shopping centres, stores of various industries, restaurants, work and leisure places, small-scale outlets, or municipal waste shipments. Due to the location of customers, transport services encounter many difficulties related to infrastructural constraints and increased traffic. This adversely affects the safety and obstructions in traffic and air pollution and thus is a disturbing factor for the lives of inhabitants. There is also a growing problem of the smog in large cities (in Poland, for example, Warsaw or Cracow). Traffic safety, minimization of congestion, and minimization of environmental pollution by transport activities are of particular importance in the development of freight traffic organization plans. In connection with the above, in recent years, the use of Environmentally Friendly Vehicles (EFV) in various spheres of human activity has been dynamically developing, and this concerns the cargo transport. Currently, vehicle manufacturers are providing an increasing number of delivery vehicles and trucks. On the other hand, entrepreneurs planning to implement pro-environmental solutions face a decision problem related to the efficiency of a transport system based on the use of EFV as well as the economic validity of implementing this type of innovation. In connection with the above, in this article, the problem of the impact of transport on the environment and the use of EFV in the freight transport was analysed. The main issues related to the functioning of the transport system and its negative impact on the environment has been presented. Environmental friendly vehicles and their parameters have been characterized. The main decision problems in organizing the transport system, also in the context of the use of EFV, have been identified and analysed. Finally, an example of a model for assessing the efficiency of a transport system with an emphasis on its impact on the environment was presented. The article was concluded with the summary of considerations and the proposal for further work.

Keywords: *freight transport, external costs, Environmentally Friendly Vehicles, EFV, Multicriteria Decision Analysis, transport system effectiveness*

1. Introduction

The emphasis on sustainable development is currently felt in every area of life. It is no different in the case of transport systems. The progress that has taken place in this matter is impressive. The growth of interest in ecological forms of transport is on the one hand marketing and, on the other hand, an increase in public awareness. Other factors that have an impact on the development in this area are the increasingly better parameters and characteristics of vehicles as well as the development of infrastructure in terms of quantity and quality. In highly developed countries, e.g. Norway or Germany, growth is also stimulated by a suitably shaped policy of support for environmentally friendly vehicles. Also in Poland, regulations that positively influence the development of environment-friendly transport systems are implemented.

Cargo transport is an activity characterized by high-energy consumption and, at the same time, high environmental pollution. Therefore, effective planning of environmentally friendly transport systems must take into account the relationship between the organization of the transport system and the infrastructure and its parameters in terms of impact on the environment. Therefore, one should choose an appropriate approach in planning, managing, and maintaining the transport system; a simplified scheme is presented in Fig. 1. Selection of appropriate resources, including means of transport for tasks, can be considered in two variants, balance distribution and minimum cost. Both approaches are of particular importance, with the balance being more closely related to external costs.

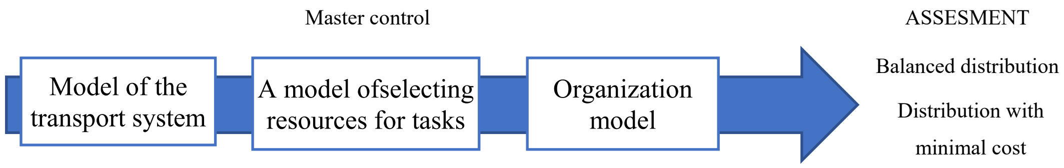


Fig. 1. Layout of transport system models in the context of organization evaluation (based on [10])

The purpose of this article is to present the problems of assessing the efficiency of the transport system in a pro-ecological approach. The use of EFV is currently increasing in commercial activity, and more and more entities are faced with the decision to modernize transport and at the same time assess the impact of the actions taken. The article in the second chapter contains a description of the transport system and its impact on the environment. The characteristics of environmentally friendly vehicles are presented in part 3. Part 4 presents decision problems in organizing the transport system of loads and in the next chapter an example of the criteria for model for assessing the efficiency of the transport system were presented. The article is concluded with a summary.

2. The transport system and its impact on the environment

The transport system, as is apparent from the well-known definition, is the system of elements whose purpose is to move material objects in a properly organized manner. Elements in transport activities are not only vehicles, drivers and loads, but also infrastructure or legal regulations. The assessment of effectiveness should take into account the dependencies of all elements. This also applies to the search for areas in which solutions can be introduced to reduce the negative impact of transport on the environment. An overview of the main areas is shown in Fig. 2.

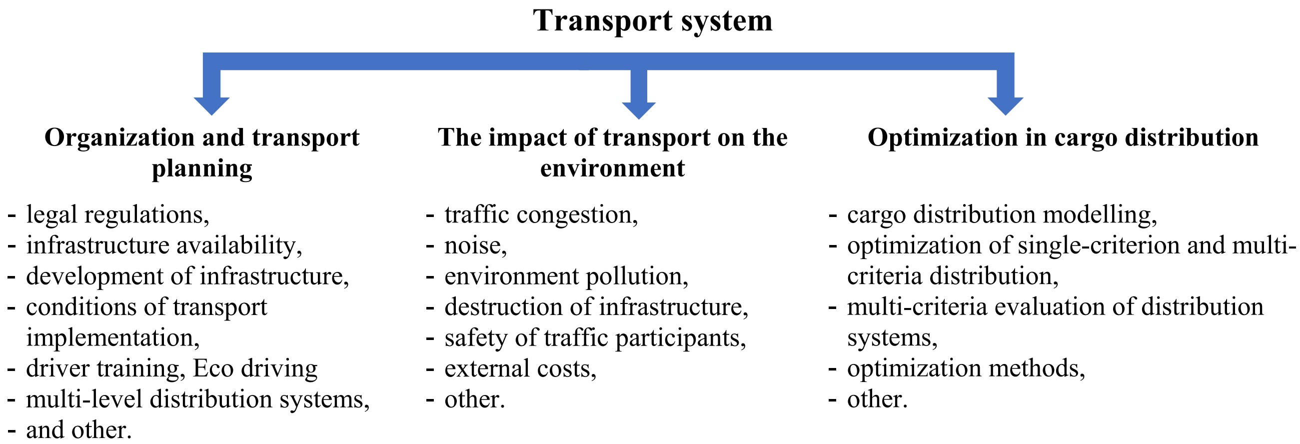


Fig. 2. Review of areas affecting the assessment of the efficiency of the transport system

The negative impact of transport on the environment is widely known. Aspects worth attention in this regard are: exhaust emissions, noise, congestion, safety. The functioning of the transport system is associated with its negative impact on the environment. It is mainly manifested by the emission of exhaust gases into the atmosphere and excessive noise. This has particular consequences in urban areas due to the high traffic volume and the negative impact on the health of residents

[1, 11, 18]. The development of means of transport and infrastructure allows limiting the emission of pollutants. However, as the forecasts in 2025 show in Poland, still, the share of vehicles with standards below EURO6 will be prevailing (Fig. 3), which obviously involves significant environmental pollution emitted by means of transport (Fig. 4).

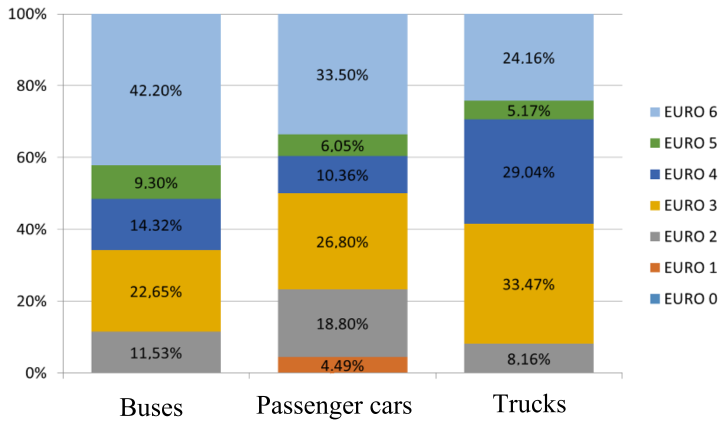


Fig. 3. Forecast of the structure of vehicles due to EURO emission standards in 2025 in Poland [13]

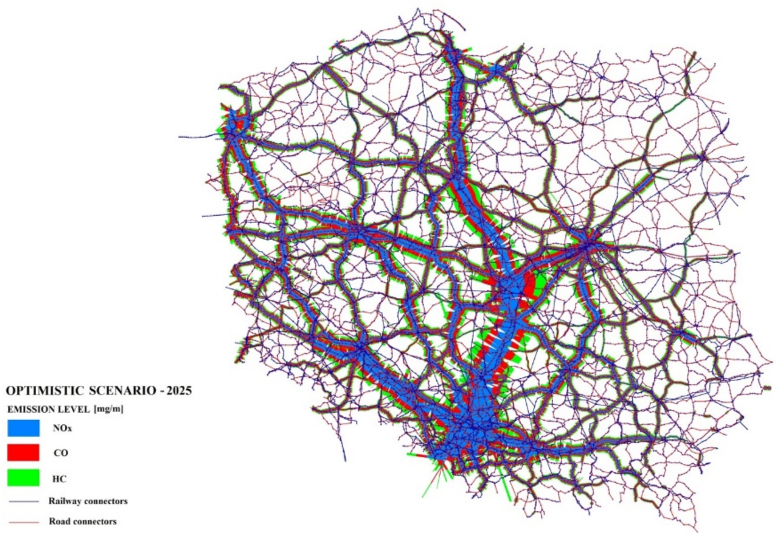


Fig. 4. Emission of harmful exhaust compounds in 2025 for the estimated structure of vehicles [13]

The problem of the impact of noise on the lives of residents in the city is described, inter alia, by Badyda [2], Fuks et al. [7]. The conducted research concerns mainly the impact of noise on health, as well as the methods of measuring or noise levels depending on the road conditions. In addition, often unserviceable or overloaded vehicles not only cause vibrations and destruction of neighbouring objects but also destroy the transport infrastructure of Korzeb and Chudzikiewicz [17].

Undoubtedly, a major nuisance for most large cities, but not only, is the growing congestion of traffic. As they indicate de Palma & Lindsey [4] and Igliński, [8] congestion has a significant impact on the generation of external costs. Levy, Buonocore and Von Stackelberg [18] emphasize that congestion also has a negative impact on health. In connection with the increase of travel time on the given route, the stress of the traffic participants increases, the blood pressure increases, the driver's ability to react properly decreases, and the traffic safety decreases. It is worth to mention that although the effects of congestion resulting from excessive traffic, poor organization, or driver errors are difficult to measure, an action is taken to limit traffic, especially truck traffic.

The safety of traffic participants, both pedestrians and drivers, is also important for the operation of the transport system. Excessive traffic is conducive to the emergence of dangerous situations leading to collisions and traffic accidents. The high-volume vehicle traffic also has a large share in this area.

All the above factors contribute to the increase of external costs. As Igliński [8] noted, emissions of harmful substances, noise emission, congestion, destruction of infrastructure, negative impact on the local community and road accidents are included in external costs. Their estimation is very difficult, which is why the problem of internalising external costs (e.g. Musso and Rothengatter [21]), i.e. transferring these costs to entities generating them.

3. Characteristics of environmentally friendly vehicles

Environmentally friendly vehicles and their implementation are aimed at limiting the negative impact of transport on the environment. This is manifested both in the context of harmful emissions and noise emissions. Different types of environmentally friendly vehicles can be distinguished, but generally, the best way to classify is the type of fuel and the propulsion system [9, 12, 26]. The main types of environmentally friendly vehicles used in transport include electric vehicles, hybrid vehicles, hydrogen powered vehicles, LPG and CNG fuelled vehicles, vehicles fuelled with BIO fuels.

Electric vehicles are characterized by the supply of electricity from batteries. Vehicles of this type do not use any other type of energy or alternative power. This, in turn, is characteristic of subsequent types of vehicles. Electric vehicles are a small means of transport, in particular for delivery vehicles and lorries, as a rule up to 150 km. In the case of a distribution system serving a small area, this is quite sufficient. One disadvantage is the charging time of the battery, which in turn depends on the power and charging current and can range from several dozen minutes to several hours. For this reason, these vehicles can only be used for tasks that can end within 1 cycle without having to be recharged [6, 22, 26].

Hybrid vehicles can be divided into micro, mild and full hybrid. This division depends on the degree of support of the main propulsion system by electric motors. In full hybrid, this stage is the largest and the vehicle can only use electricity while driving. Next, in order, we can distinguish the division into serial, parallel and mixed hybrids. In serial hybrids, the diesel drive produces electricity for the electric motor, the parallel combustion engine is main and the electric motor serves as its support, but both drives transmit power to the wheels. Classic hybrids can be distinguished, without the possibility of recharging with electric power from the socket or plug-in type, i.e. those that can be covered by a distance of several dozen kilometres on the electric motor alone and the batteries can be recharged from an external source [3, 6].

Hydrogen-powered vehicles are basically also electric vehicles. The main difference is that instead of or next to the battery in the vehicle, fuel cells are mounted. This solution is much more flexible and with a larger range and shorter charging time (a few minutes, the range is even above 500 km). Hydrogen supply, storage, and production are a bigger problem. This, in turn, translates into its price, which, combined with the high costs of purchasing such a vehicle and the available refuelling infrastructure, affects their limited popularity. However, it is a relatively new type of vehicle, and many experts consider it an excellent alternative to electric vehicles and predict their dynamic development in the future.

Other types of vehicles are vehicles with internal combustion engines but using alternative fuels. Environmentally friendly fuels are LPG, CNG, as well as BIO fuels (e.g. biodiesel or biomass). These vehicles require either a special construction of an internal combustion engine or an additional power installation. These vehicles as well as hybrid vehicles, however, emit pollutants in the form of harmful substances. However, electric and hydrogen vehicles are considered to be emissive. Of course, it should be borne in mind that the energy they consume must be somehow created (e.g. in a wind, coal, nuclear power plant).

Currently, the most attention is given to passenger vehicles. This trend is understandable due to the larger number of vehicles compared to commercial vehicles. This is also related to appropriate transport policy measures supporting the exchange of vehicles into environmentally friendly ones by introducing privileges such as subsidies, free parking, free entry to urban areas, or the possibility of using dedicated bus lanes. Nevertheless, the return on investment in a private vehicle is spread over time. With an average mileage of 15,000 km per year, it can be around 10 years. In view of the above, at the moment it is rather a question of consumer awareness than economic issues. As can be seen in the graph shown in Fig. 5, the increase in new registrations is significant [20, 26].

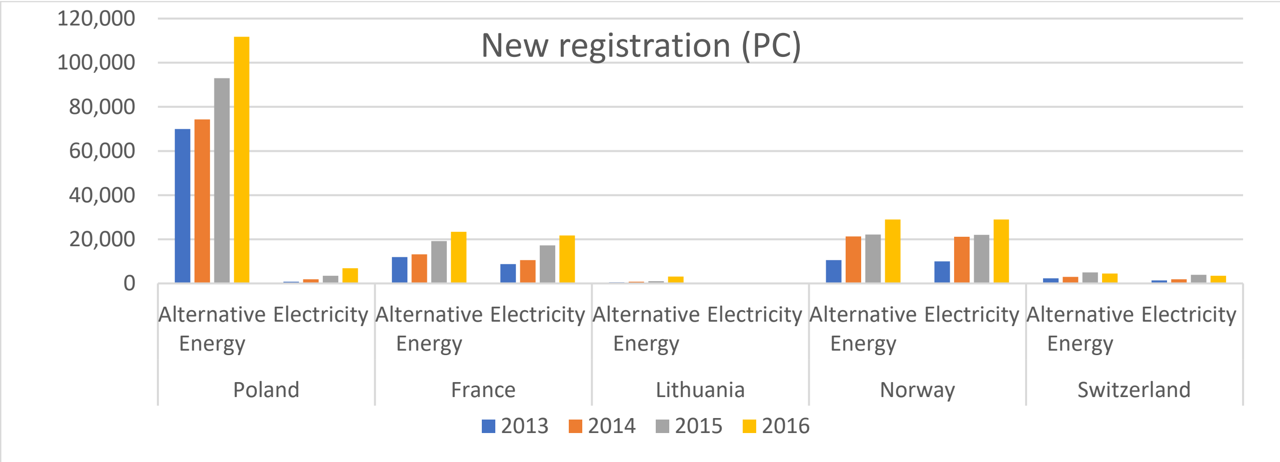
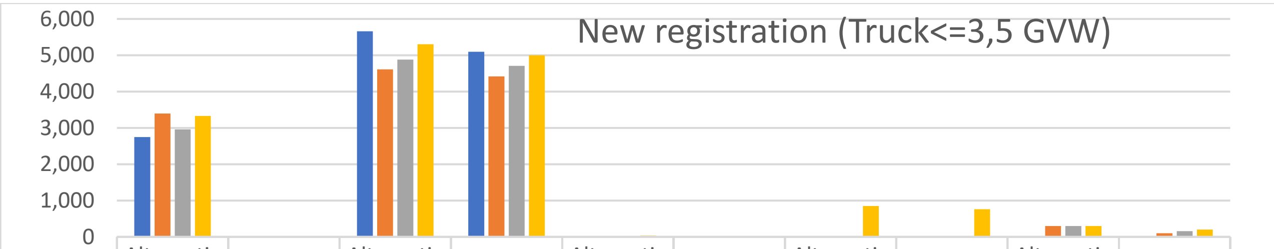


Fig. 5. Number of new registration of passenger cars (based on [5])

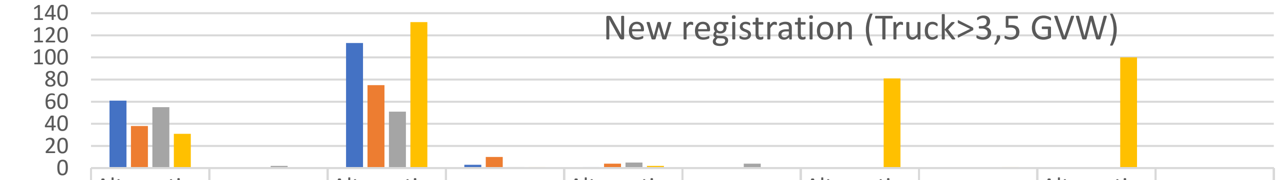
However, the above may have a different word in the case of entrepreneurs. Both distribution vehicles and passenger cars used, for example, by sales representatives or vehicles in rental companies, are much more beneficial in terms of finance. Entrepreneurs obtain measurable savings in the form of deductions from taxes, subsidies for investments and, of course, in the form of drive materials and lower service costs. For obvious profits, one should also indicate an increase in the marketing value of an enterprise that uses ecological vehicles. The number of new EFV vehicle registrations is shown in Fig. 6.



	Poland		France		Lithuania		Norway		Switzerland	
	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity
2013	2,748	14	5,660	5,098	3	0	0	0	0	0
2014	3,398	21	4,610	4,420	5	1	0	0	300	100
2015	2,960	15	4,880	4,709	15	3	0	0	300	160
2016	3,328	17	5,303	4,999	33	3	850	762	300	200

Fig. 6. Number of new registration of truck under 3,5 GVW (based on [5])

Vehicles with a GVW above 3.5 t in size are vehicles using diesel fuel (self-ignition). However, interest is also growing in this context. Until now, the main support was to supply the LPG or CNG vehicle, but currently, manufacturers are developing prototypes of electric and electric saddle tractors with hydrogen fuel cells. New registrations of vehicles over 3.5 t are shown in Fig. 7.



	Poland		France		Lithuania		Norway		Switzerland	
	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity	Alternative Energy	Electricity
2013	61	0	113	3	1	0	0	0	0	0
2014	38	0	75	10	4	0	0	0	0	0
2015	55	2	51	1	5	4	0	0	0	0
2016	31	0	132	1	2	0	81	1	100	0

■ 2013 ■ 2014 ■ 2015 ■ 2016

Fig. 7. Number of new registration of truck above 3,5 GVW (based on [5])

The above charts include the number of registrations of new vehicles with alternative drive, including electric vehicles, which were additionally separated. Only a few countries were selected to show the main trends. It should be emphasized that undoubtedly in recent years the increase in interest in vehicles with an alternative drive is enormous, especially in Poland. This is well predicted in the context of the development of this industry and new investments in increasingly efficient batteries and an increasingly better and more densely located accompanying infrastructure. Such actions, in turn, will affect the lower costs of purchasing EFV vehicles, and this will further stimulate their development.

Transport bicycles, including electric bicycles, should be indicated as an interesting means of transport. In urban transport for short distances, this is a very interesting alternative for vans. The main limitation here, however, is the load capacity of such measure and range [22].

4. Decision-making problems in organizing a sustainable transport system

One of the key problems being the subject of analysis of many studies and interests of researchers is the effective use of available resources, with particular emphasis on the use of available means of transport. It is also necessary to properly manage and use transport infrastructure.

The transport of cargo is mainly carried out by road transport. This is due to the availability of infrastructure and the ability to carry out the so-called "Door to door". Unfortunately, this type of transport is at the same time the most burdensome for the environment. One of the possible actions is the development of road infrastructure, but it is not so easy due to terrain restrictions and cost-efficiency. On the one hand, to meet the requirements of participants of the transport process, and on the other hand, to limit the negative impact of road transport on the environment with regard to safety and reliability of transport, it is necessary to search for innovative solutions that increase the efficiency of transport. Of course, the introduction of new solutions must be preceded by appropriate research and multivariate analysis. Such activities may include rolling stock replacement and the use of electric bikes and electric delivery vehicles. Any such activities, however, require additional measures to reorganize the operation of such entity, including route planning and deployment of transhipment warehouses. Examples of decision problems and areas of the transport system in relation to the efficiency and reliability of the process are presented in Fig. 8.

Due to different times of the day, rush hour, accidents, repairs, special events, travel times can be dramatically different, and this significantly affects the reliability and efficiency of deliveries. The reliability and efficiency of the transport process is also the reliability of transport means and proper organization and planning of transport. In the case of cargo transports, transhipment points are also of significance, enabling reduction of transport work and better use of transport means.

Conditions of cargo transportation and customer requirements cause the need for carriers to use solutions that increase the efficiency of transport, including the planning and optimization of the transport process or telematics systems. The solutions concern both multi-level transport systems and involvement in innovative forms of cargo transport in the last kilometre logistics (Fig. 9). The implementation of such solutions requires tools to assess their effectiveness.

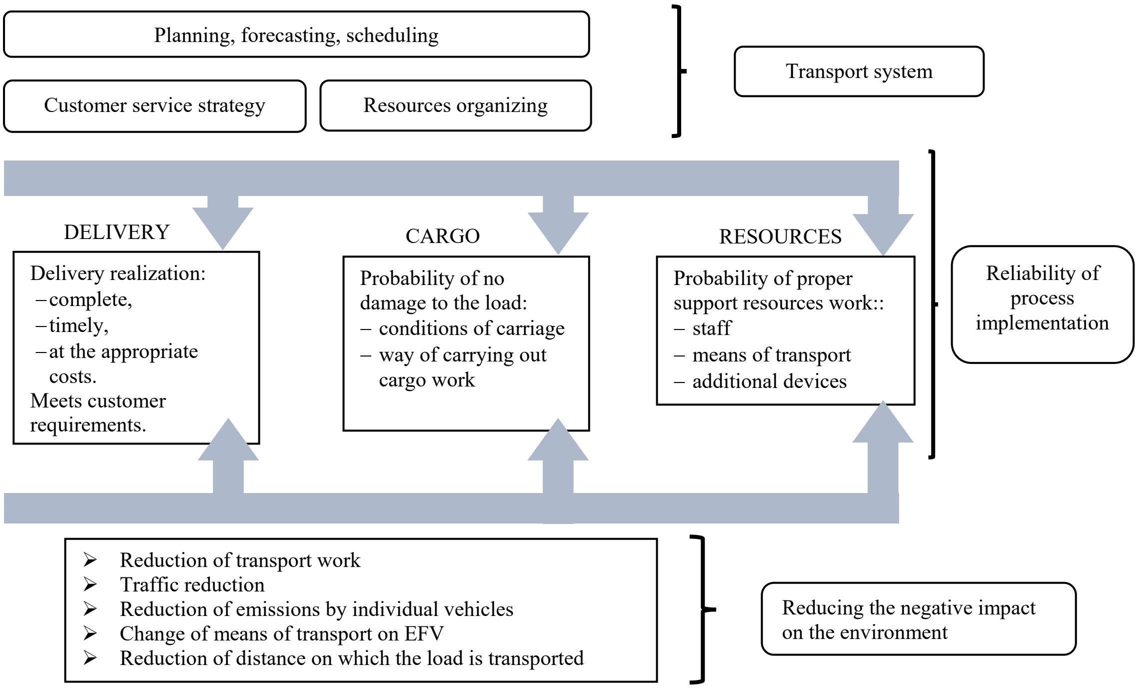


Fig. 8. Elements of the transport system affecting the efficiency and reliability of the transport process in the context of reducing the negative impact (based on [15, 25])

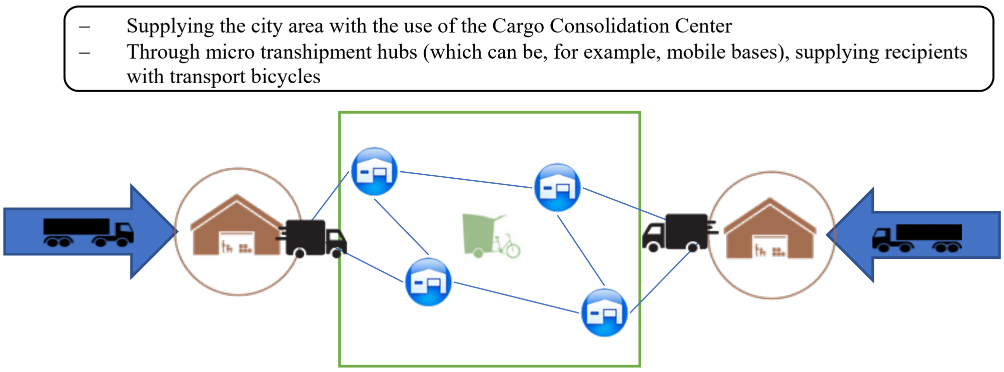


Fig. 9. An example of a transport system in a multi-level approach with the use of electric bikes (based on [22, 24])

The analysis of studies devoted to these issues indicates the benefits of using the examples of improved freight traffic [14, 16, 27]. Can be mentioned for example:

– less traffic congestion in interurban traffic,
– reduction of road damage and road infrastructure,
– preventing congestion in the city centre,
– reduction of excessive emissions and other pollutants associated with the operation of vehicles.

5. Criteria for assessing the transport system on the example of a cargo distribution system

Verification of the functioning of the transport system, undertaken undertakings and implemented innovations requires their evaluation. Therefore, it is necessary to assess the effectiveness of such a system based on certain criteria. This article presents selected efficiency criteria. However, apart from the assessment based on the meters, each system must function according to certain rules, therefore it should be verified whether it meets imposed boundary conditions. The following set of criteria has been selected and developed on the basis of work [9, 15, 19, 23]. A division into economic, technical and ecological criteria was assumed. The development of such indicators is an indispensable element of the multi-criteria decision support system (MDA). As economic criteria, these will be indicators expressed in currency, for example:

- economic efficiency indicator of transport performance μ made by the transport system expressed in tkm / PLN, it takes into account the volume of transport $q(s)$ expressed in tonnes realized by s-th means of transport and average distance of transport $L(s)$ expressed in km in relation to the cost of operation of the transport system KS in PLN:

$$\mu = \sum_{s \in S} q(s) \cdot L(s) / KS, \tag{1}$$

- economic efficiency ratio of vehicle involvement to the r-th distribution route, expressed as a unit cost (*sc_unit* (s)) and distance on a given route ($L2$ (r, s), but also the fixed cost of vehicle maintenance (*sc_fixed* (s)) in relation to the operating costs of the KS transport system::

$$\forall r \in R, \quad \chi(r) = \sum_{s \in \boldsymbol{S}} \left[sc\_unit(s) \cdot L2(r,s) + sc\_fixed(s) \right] / KS. \tag{2}$$

As technical criteria allowing assessing the transport potential and its adjustment to the tasks performed, you can indicate:

- load utilization rate of vehicles during the r-th distribution route $\theta_P(r)$**,** resulting from the volume $q2(r,s)$ and distance on route $L2(r,s)$ in relation to the available capacity $Q(s)$ for all vehicles in the system ($N(s)$-number of the s-th vehicles) and their route $L(s)$:

$$\forall r \in R, \quad \theta_P(r) = \sum_{s \in S} \frac{q2(r,s) \cdot L2(r,s)}{Q(s) \cdot N(s) \cdot L(s)}, \tag{3}$$

- the utilization rate of the time of using the means of transport $\tau(r)$ on r-th route, it is the sum of the values of the expected driving time during the route $\mathbb{E}(\mathrm{TJ}(r))$, time of loading operations $\mathbb{E}(\mathrm{TL\_HUB}(r))$ and vehicle service time $\mathbb{E}(\mathrm{TM\_VEH}(r))$ – charging, refuelling, service, etc., per one route in relation to the time of all deliveries in the system:

$$\forall r \in R \quad \tau(r) = \frac{\mathbb{E}(\mathrm{TJ}(r)) + \left[\mathbb{E}(\mathrm{TL\_HUB}(r)) \cdot q2(r,s)\right] + \mathbb{E}(\mathrm{TM\_VEH}(r))}{TD}. \tag{4}$$

The ecological criteria include the emission factor of harmful substances and the share of "ecological" energy in the energy balance of the transport system, i.e.:

- indicators of ecological effectiveness expressed emission of the third-degree pollution from the 1st transport means based on the unit emission factor including the share in the cold emission at each route -2/$L3(r)$ and the hot/cold coefficient $e^{cold} / e^{hot}(s)$ for every type of vehicle. This ratio is calculated as the ratio to the total emission of the p-th pollution (based on [23] can be estimate the emissions of carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), particulates, etc.):

$$\forall r \in R \; \forall p \in P, \quad EM(r) = \frac{\sum_{s \in S} \left[Ef(p,s) \cdot L2(r,s) \cdot \left(1 + 2 / L3(r) \cdot (e^{cold} / e^{hot}(s) - 1)\right) \right]}{ET(p)}, \tag{5}$$

- share of "ecological" energy in the energy balance of the transport system ψ**,** expressed as the sum of energy used for the implementation of the *r*-th route by EFV ($EC_{EFV}(efv,r)$, to the total energy consumption of the distribution system *TEC*

$$\psi = \frac{\sum_{efv \in S_{EFV}} \sum_{r \in R} EC_{EFV}(efv,r)}{TEC}, \qquad S_{EFV} \subset S. \tag{6}$$

5. Conclusions

The article presents a certain systematic approach to the assessment of the transport system using EFV vehicles. The article presents examples of criteria, which, however, does not cover such a broad topic. In connection with the above, in future works, the emphasis will be on additional criteria, but also on evaluation tools. Additional criteria that can be taken into account are noise, congestion, destruction of infrastructure, the health of residents. However, as the authors of the manual [13] indicate, the estimation of this type of external costs is very difficult and often impossible to determine for a single transport system.

The MDA systems and simulation methods are particularly important from the point of view of transport system planning. They allow for a comprehensive examination and assessment of the efficiency of distribution systems even with regard to quality fuzzy criteria and reliability criteria. Nowadays, it is also necessary to take into account the dynamics of changes taking place in transport systems. The above issues will be developed in future research works.

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References

[1] Ambroziak, T., Jachimowski, R., Pyza, D., Szczepański, E., *Analysis of the traffic stream distribution in terms of identification of areas with the highest exhaust pollution*, Archives of Transport, 32(4), 7-16, 2014.

[2] Badyda, A. J., *Zagrożenia środowiskowe ze strony transportu*, Wyd. Nauka, No. 4, pp. 115-125, 2010.

[3] Bradley, T., Quinn, W., *Analysis of plug-in hybrid electric vehicle utility factors,* Journal of Power Sources, 195, 5399-5408, 2010.

[4] de Palma, A., Lindsey, R., *Traffic congestion pricing methodologies and technologies*, Transportation Research Part C: Emerging Technologies, 19(6), 1377-1399, 2011.

[5] Eurostat. *New vehicles registration – Passenger cars, Lorries* [road_eqr_carpda, road_eqr_lormot], Retrieved from https://ec.europa.eu/ eurostat/web/transport/data/database, 2018.

[6] Foltyński, M., *Electric fleets in urban logistics*, Procedia-Social and Behavioral Sciences, *151*, 48-59, 2014.

[7] Fuks, K., Moebus, S., Hertel, S., Viehmann, A., Nonnemacher, M., Dragano, N., Hoffmann, B., *Long-term urban particulate air pollution, traffic noise, and arterial blood pressure,* Environmental Health Perspectives, 119(12), 1706, 2011.

[8] Igliński, H., *Koszty kongestii w miastach*, Przegląd Komunikacyjny, 47(10), 25-31, 2008.

[9] Jacyna, M., Merkisz, J., *Kształtowanie systemu transportowego z uwzględnieniem emisji zanieczyszczeń w rzeczywistych warunkach ruchu drogowego*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2014.

[10] Jacyna, M., *Modelowanie i ocena systemów transportowych*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2009.

[11] Jacyna, M., Żak, J., Jacyna-Gołda, I., Merkisz, J., Merkisz-Guranowska, A., Pielecha, J., *Selected aspects of the model of proecological transport syste*m, Journal of KONES, 20, 2013.

[12] Jacyna, M., Merkisz, J., *Proecological approach to modelling traffic organization in national transport system*, Archives of Transport, 30(2), 31-41, 2014.

[13] Jacyna, M., Merkisz, J., Lewczuk, K., Szczepański, E., *Transport policy development with EMITRANSYS simulation model*, In: Jacyna, M., Wasiak, W. (Eds.), *Simulation model to support designing a sustainable national transport system*, Index Copernicus, pp. 155-163, Warsaw 2014.

[14] Jacyna, M., Wasiak, M., Lewczuk, K., Karoń, G., *Noise and environmental pollution from transport: decisive problems in developing ecologically efficient transport systems*, Journal of Vibroengineering, 19(7), 5639-5655, 2017.

[15] Jacyna-Gołda, I, Izdebski, M., Szczepański, E., Gołda, P., *The assessment of supply chain effectiveness,* Archives of Transport, 45(1), 43-52, 2018.

[16] Jacyna-Gołda, I., Gołębiowski, P., Izdebski, M., Kłodawski, M., Jachimowski, R., Szczepański, E., *The evaluation of the sustainable transport system development with the scenario analyses procedure*, Journal of Vibroengineering, 19(7), 5627-5638, 2017.

[17] Korzeb, J., Chudzikiewicz, A., *Evaluation of the vibration impacts in the transport infrastructure environment*, Archive of Applied Mechanics, 85(9-10), 1331-1342, 2015.

[18] Levy, J. I., Buonocore, J. J., Von Stackelberg, K., *Evaluation of the public health impacts of traffic congestion: a health risk assessment*, Environmental health, 9(65), 1-12, 2010.

[19] Maibach, M., Schreyer, C., Sutter, D., Van Essen, H. P., Boon, B. H., Smokers, R., Bak, M., *Handbook on estimation of external costs in the transport sector*, CE Delft, 2008.

[20] Mirhedayatian, S. M., Yan, S., *A framework to evaluate policy options for supporting electric vehicles in urban freight transport*, Transportation research part D: transport and environment, 58, 22-38, 2018.

[21] Musso, A., Rothengatter, W., *Internalisation of external costs of transport-A target driven approach with a focus on climate change*, Transport policy, 29, 303-314, 2013.

[22] Navarro, C., Roca-Riu, M., Furió, S., Estrada, M., *Designing new models for energy efficiency in urban freight transport for smart cities and its application to the Spanish case*, Transportation Research Procedia, 12, 314-324, 2016.

[23] Ntziachristos, L., Samaras, Z., *EMEP/EEA air pollutant emission inventory guidebook,* EEA 2017.

[24] Szczepański, E., *Overview and analysis of solving method for cargo distribution problems in multi-objective optimization model*, In J. Feliks (Eds.), *CLC 2013: Carpathian Logistics Congress - Congress Proceedings*, TANGER Ltd., pp. 628-634, Ostrava 2014.

[25] Szczepański, E., Jacyna, M., *An approach to optimize the cargo distribution in urban areas*, Logistics and Transport, 17(1), 53-62, 2013.

[26] Visvikis, C., Morgan, P., Boulter, P., Hardy, B., Robinson, B., Edwards, M., Dodd, M., Pitcher, M., *Electric vehicles: review of type-approval legislation and potential risks*, Transport Research Laboratory, 2010.

[27] Wasiak, M., Jacyna, M., Lewczuk, K., Szczepański, E., *The method for evaluation of efficiency of the concept of centrally managed distribution in cities*, Transport, 32(4), 348-357, 2017.

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