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THE POSSIBILITIES OF CONDUCTING SCENARIO ANALYSES OF A SUSTAINABLE DEVELOPMENT OF THE TRANSPORT SYSTEM USING THE EMITRANSYS MODEL

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Abstract

The article presents selected aspects of shaping pro ecological transport system. Correct, socially responsible, economically reasonable and far-sighted allocation of resources is one of the basic tools of sustainable development shaping. In the case when this concept in a narrower sense refers to shaping the national transport system one can distinguish the general problem: how to invest financial resources in the development of the transport system and how to manage this system in order to one can say about it as "sustainable".

The article presents the principles of creating scenario analyses, discusses the procedure and elements of an algorithm for the development of scenarios of the sustainable transport system. The procedure for conducting scenario consists of three stages of research.

The analyses were conducted by the use of EMITRANSYS model. The EMITRANSYS model was developed in Visum. Its main elements are the network model, demand model, integrated database and a set of scenarios of an analysis of transport system development. The simulation model EMITRANSYS was developed under the PBS1 project "Shaping of the pro ecological transport system" financed by the National Centre of Science and Development. The project was realized within the consortium consisting of the Faculty of Transport of The Warsaw University of Technology and the Faculty of Machines and Transport of The Poznan University of Technology in the years 2012-2014.

Keywords: *scenario analyses, scenario procedure, transport ecology, EMITRANSYS, pro ecological transport system*

1. Introduction

The primary objective of the EU is to create favourable conditions for the sustainable development of the transport system, which will contribute to the future growth of the EU economy. The issue of ecology in transport primarily relies on minimizing the negative impact of transport in terms of: pollution of air, land and water, noise, the influence of vibrations [3, 11]. In order to shape the transport system, taking into account environmental issues mainly related to the limit of emission of harmful exhaust gases by means of transport [19, 23], it is necessary to conduct multivariate analysis using an appropriate model. The necessary analyses must take into account the elements of the transport system, which have a significant impact on the behaviour of

both buyers of transport services and the providers of these services. In the implementation of the movement of both people and cargo, many elements of transport system are involved, so such model must have the characteristics of both the infrastructure and superstructure of the organization and the demand for transport, which will have an impact on the ecological properties of the modelled system.

Strategies for the development of the transport system in terms of pro ecological should take into account the interests of all users of the transport process. In the process of the development of transport roads, the negative phenomena take place. They are assessed in two aspects [5, 9]. Firstly, from the point of view of the level of the harmful environmental impact (the ecological aspect), and secondly from the point of view of the traffic safety level (the number and consequences of accidents and disasters)

Therefore, the development of different modes of transport, and consequently each type of transport roads depends not only on the development of transport technologies which must take into account both factors boosting the development (e.g.: Just-in-time, just-in-place) as well as the factors restricting the development, such as ecology, safety [5, 9, 16, 18].

Due to the multi-aspect problems of the development of a sustainable transport system, the analyses should take into account such factors as: the needs of the buyers of transport services, technical potential of service providers including their vulnerability to changes, the state of the transport infrastructure including transport vehicles, solutions for traffic organization in the individual areas, regions, transport policy of a country or region, environmental concerns, and other. Besides, when making the analyses, it should be remembered that individual modes of transport are integral parts of the transport system and the development of each of them has certain effects in other sectors [6].

With regard to the above, conducting analysis using the EMITRANSYS simulation model, which was developed within the project "Shaping of the pro ecological transport system", many aspects should be taken into account:

- needs of the transport services clients in terms of goods and passengers transport,
- technical potential of transport services providers,
- the transport infrastructure and its condition as well as the means of transport, including e.g. the road vehicles structure due to the introduction of EURO emissions standards,
- solutions in the field of traffic organization in specific areas or regions,
- restrictions of the traffic,
- the possibility of introducing instruments of transport policy of a given country or region for the clients and providers of transport services,
- costs of transport including external costs, fees and taxes and co-modality of transport,
- the sectoral forecast of the demand for transport including forecasts of changes in the structure of vehicles and changes in the modal split,
- the projected expenditures for the development, the modernization and the revitalization of the transport infrastructure.

EMITRANSYS model, developed as the part of project: "Shaping the pro ecological transport system", enables multi-variant analysis of the distribution of the stream of traffic on both the transport links in selected transportation network as well as on the national transport network. Moreover, this model enables multi-aspect analysis, e.g. the allocation of funds for the modernization of the infrastructure, the choice of the variant of the modernization of the infrastructure, which allows reducing the level of emissions especially for the areas at risk, determining the cost of emissions of harmful exhaust gases with different structures of road vehicles.

The analyses of the development of the transport system can be made based on the distribution of the traffic stream on the transport network with different boundary conditions and criteria. The research of the effects of different policies on the behaviour of the transport service providers

shaping the infrastructure of the transport network is conditioned by the disposition of appropriate research tools, which allow performing this type of research.

2. Scenario analyses algorithm

Given the fact that all kinds of the infrastructure investments are cost and time consuming and without an adequate analysis using appropriate methods and tools it is impossible to develop a normal transport system. One of the methods which is used in performing any kind of feasibility studies in the area of transport is a scenario method.

The scenario method in general is based on the description of the object or system, specifying the maximum number of important factors that affect them, and the presentation of the possible development variants. The result of this method is many potential images of the future, [14], [20]. The procedure for conducting scenario analyses using the EMITRANSYS simulation model requires a proper approach and knowledge of many legal, organizational technical and economic conditions, which must be taken into account.

When determining the scenarios of development of the transport system, the comprehensive approach to the analysis of the problem is very important. According to the definition [7], the comprehensive approach to the problem means the same as the systemic approach to the overall design and planning of studies. The systemic approach is based on three main elements, i.e.: a general overview of the problem in which the purpose of research is defined taking into account the potential recipient (e.g. legal, technical, technological, innovative economic, environmental, quality factors, etc.), development of mathematical and simulation models and multivariate analyses taking into account all these factors.

The procedure for conducting scenario analyses is divided into three main stages of research, according to the systemic analysis, i.e. (Fig. 1): stage I – the formulation of the aim of research, stage II – stage of construction of the model, stage III – an assessment of variants on the basis of the multi-criteria evaluation including the prepared system of criteria values.

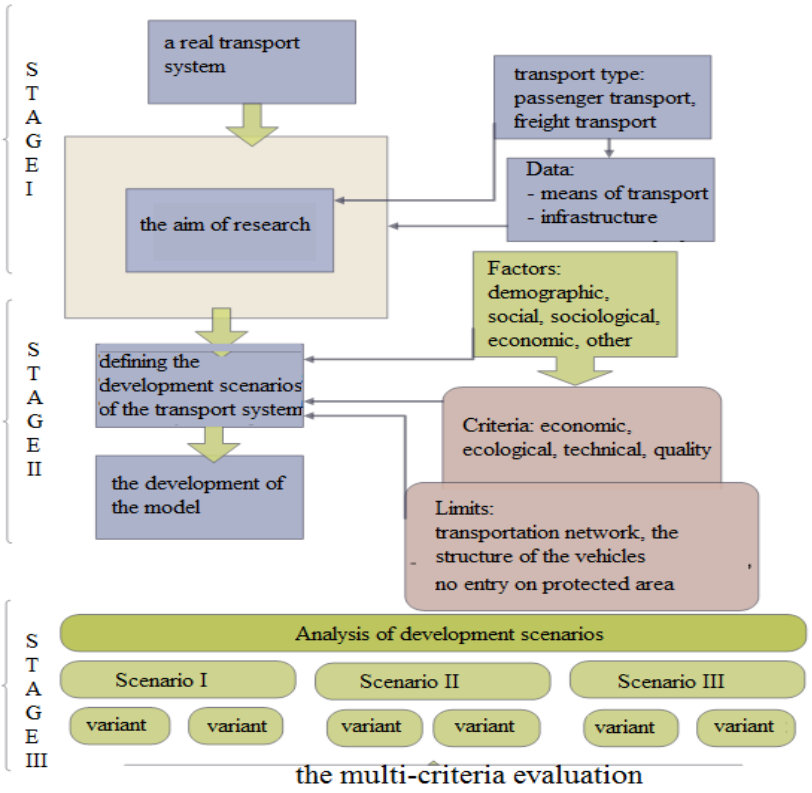


Fig. 1. Scenario analyses algorithm

Taking into account the need for raising the standards of transport infrastructure and the requirements of the European Commission in the field of sustainable development of the transport system, strategic objectives of the legitimacy of infrastructure investment implementation are divided into three main groups: technical, economic and environmental ones.

The objectives referring to technical aspects are applied to increase the technical parameters of roads, which occur in the main transportation network routes. The main task of the economic objective is to achieve better economic results. The environmental objective is very important because of the growing care for the environment and in the face of the destructive impact of transport.

The next stage of the procedure is to construct the model of a transport system development. This stage is the main stage of the procedure. The construction of the model of the system or process, in this case the construction of transport system development model, is conducted in iterative way [7, 14].

The mathematical formulation of transport system development model taking into account the selected limitations of the transport network was developed under the project and already presented in several publications such as: [1, 2, 4, 5, 8-13, 19]. In this model, the costs of emissions were established as a main criterion of the assessment of the solution quality.

An important step in the whole procedure of choosing the correct scenario of the transport system is to establish an evaluation system and indicators for assessing the quality of solution i.e. the criteria of decision-maker.

The evaluation of the positive and negative effects of each of the possible variants of the procedure, taking into account the uncertainty of the future, refers to the comparative analysis of various scenarios according to defined criteria or indicators of the evaluation.

3. Examples of scenario analyses using the EMITRANSYS model

The EMITRANSYS model was implemented in the PTV VISUM environment. Its main elements are the network model, demand model, integrated database and a set of scenarios of an analysis of transport system development. Simplified diagram of the transport system modelling with the usage of PTV VISUM was presented in Fig. 2.

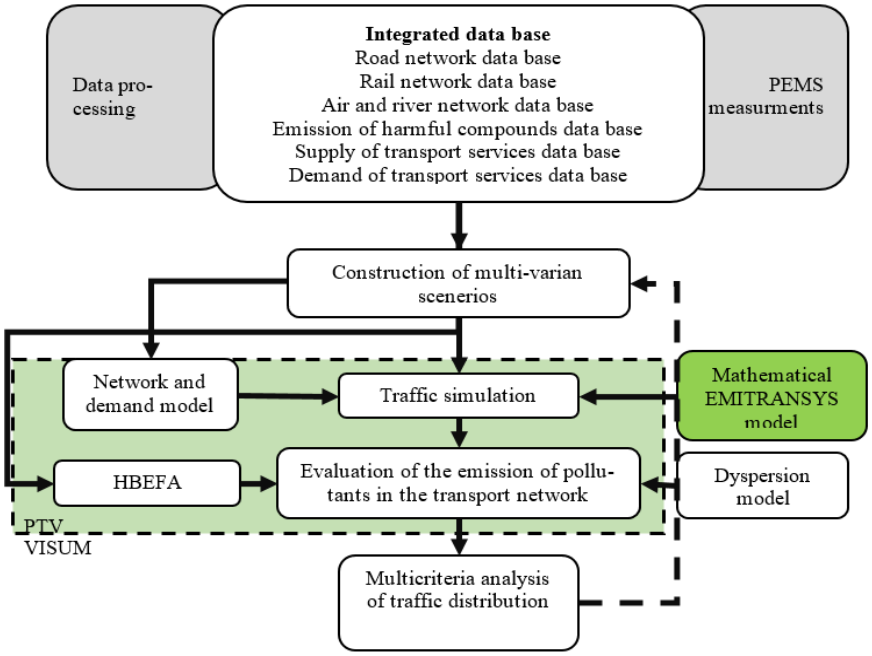
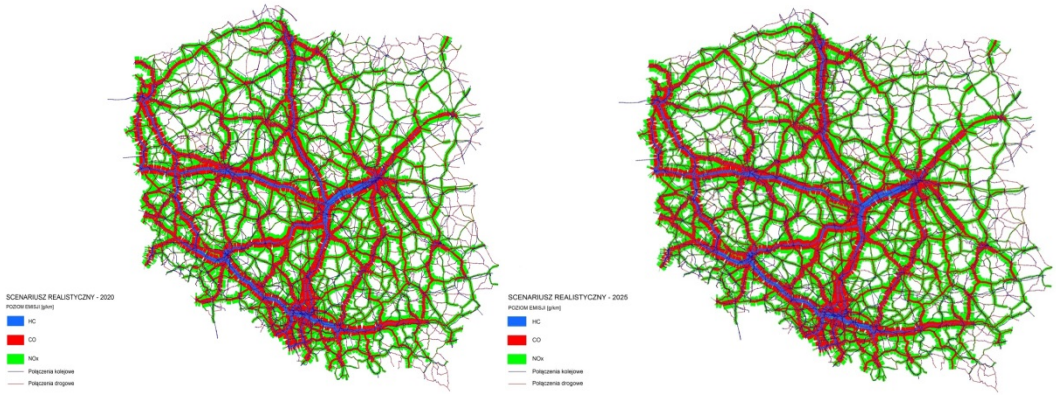


Fig. 2. EMITRANSYS model elements in VISUM

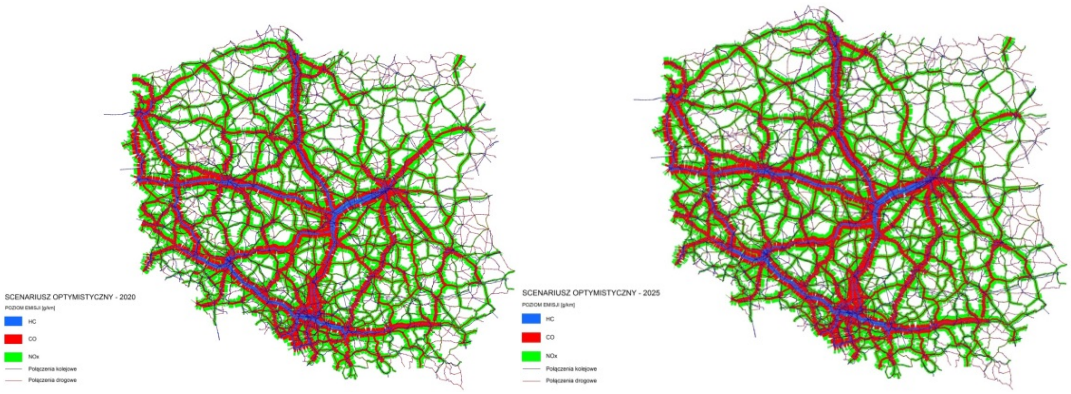
Conducting the research in terms of the development of the transport system taking into account ecological aspects, the analyses of emissions of harmful exhaust compounds for selected variants of the traffic distribution in the transport network were made.

The study analysed the following materials: carbon monoxide (CO – red), nitrogen oxides (NOx- blue) and hydrocarbons (HC – green). Emissions of individual harmful compounds for the realistic and optimistic scenario of the traffic distribution for 2020 and for 2025 were presented respectively in Fig. 3 and 4.



a) 2020 *b) 2025*

Fig. 3. Emission of harmful compounds for the realistic scenario a) variant for 2020, b) variant for 2025



a) 2020 *b) 2025*

Fig. 4. Emission of harmful compounds for the optimistic scenario a) variant for 2020, b) variant for 2025

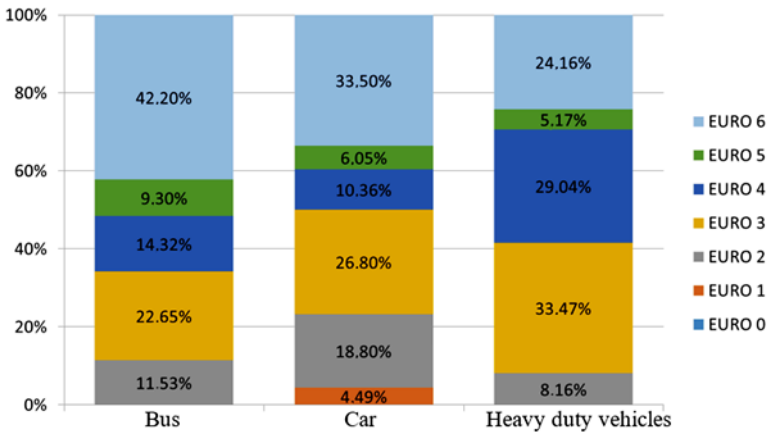


Fig. 5. The structure of road vehicles in Poland in 2014 in terms of EURO standard

The structure of road vehicles in Poland in 2014 in terms of share of vehicles with specific

emission standards is schematically shown in Fig. 5. The Fig. 6 shows the structure of the vehicle in terms of EURO standard in 2025, which may be a potential result of the implementation of pro ecological transport policy.

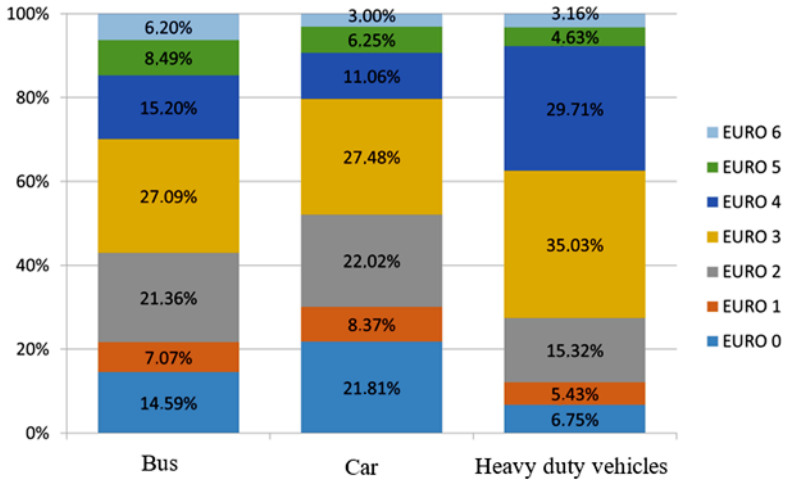
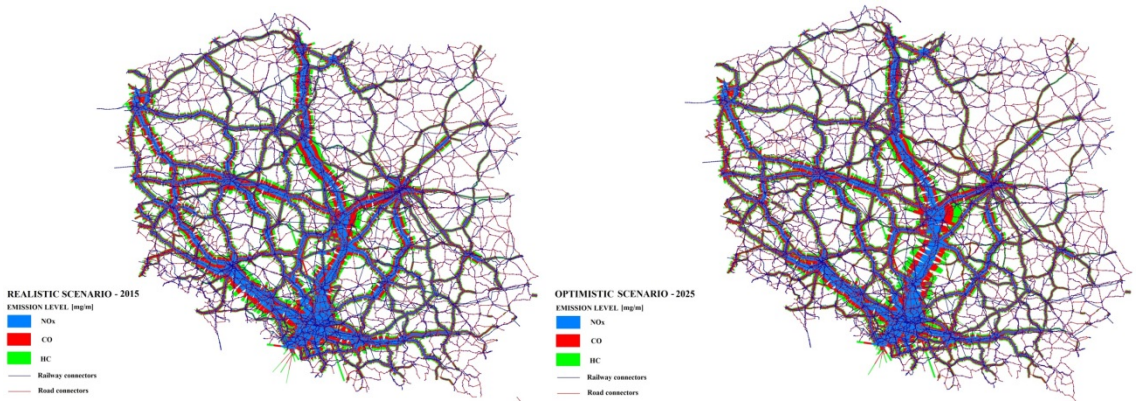


Fig. 6. The structure of road vehicles in Poland in 2025 in terms of EURO standard

In order to examine the effect of putting into the transport policy targets to reduce the number of vehicles of low EURO standard, the corresponding sets of data (forecasts) concerning passenger and freight transport by road and rail in the years 2014 and 2025 (according to the realistic scenario of development of the transport market presented in [17]), together with mapping the current and future transport infrastructure and the factors influencing the modal split of transport tasks were prepared. On this basis – taking into account the structure of the vehicles – basic harmful compounds NOx, CO and HC with an indication of routes characterized by the highest density of the contamination were estimated. The results for the year 2014 are shown in Fig. 7 a) and for 2025 in Fig. 7 b).



a) 2014 *b) 2025*

Fig. 7. Exhaust emission of harmful compounds due to the EURO standards a) in 2014 – for the current vehicles structure, b) in 2025 for the change in vehicle structure

The reduction of emissions in 2025 can be observed despite the projected increase in transport performance by 19.9%, partly due to the replacement of old vehicles with new, and partially because of the implementation of policies that stimulate the use of transport vehicles with a higher EURO standard and electric and hybrid vehicles. Of course, this transport policy requires additional funds in order to create favourable conditions for exchange of vehicles for more environmentally friendly.

4. Conclusions

The study of the transport system from the point of view of transport policy requires an assessment of how the infrastructure and superstructure fit to a range of transport services. Such assessment is the basis for the decision of transport policy aiming to a balance between tasks (demand) and equipment (supply of transport services).

EMITRANSYS simulation model is a tool for decision support based on multivariate analyses of the functioning and the development of transport system. It can be used to analyze the scenarios for the development of the transport system for a variety of needs for transport or different values of external costs.

The simulation model allows developing and testing multi-aspect scenarios of the impact of transport on the environment at the national or regional scale. It can be used for planning changes in technical parameters (the modernization and revitalization) and the location of the infrastructure. It can support the decision to increase the attractiveness of the preferred modes of transport or to restrict the use of the transport network in protected areas. This model is a valuable tool to support strategic decision-making in the development of the transport system taking into account its impact on the environment.

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References

[1] Ambroziak, T., Gołębiowski, P., Pyza, D., Jacyna-Gołda, I., Merkisz-Guranowska, A., *Identification and analysis of parameters for the areas of the highest harmful exhaust emissions in the model EMITRANSYS*, Journal of KONES Powertrain and Transport, Vol. 20, No. 3, Warsaw 2013.

[2] 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, Polish Academy of Sciences, Vol. 32, No. 4, pp. 7-16, Warszawa 2014.

[3] *European Environment Agency, Air quality in Europe – 2012 report*, Copenhagen 2012.

[4] Jacyna-Gołda, I., Gołębiowski, P., Jachimowski, R., Kłodawski, M., Lewczuk, K., Szczepański, E., Sivets, O., Merkisz-Guranowska, A., Pielecha, J., *Traffic Distribution into Transport Network for Defined Scenarios of Transport System Development in Aspect of Environmental Protection*, Journal of KONES, Vol. 21, No. 4, 2014.

[5] Jacyna-Gołda, I., Merkisz-Guranowska, A., Żak, J., *Some aspects of risk assessment in the logistics chain*, Journal of KONES Powertrain and Transport, Institute of Aviation, Aeronautics, BK, Vol. 21, No. 4, Warszawa 2014.

[6] Jacyna-Gołda, I., Żak, J., Gołębiowski, P., *Models of traffic flow distribution for various scenarios of the development of proecological transport system, Archives of transport*, Polish Academy of Sciences, Vol. 32, No. 4, pp. 17-28, Warszawa 2014.

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

[8] Jacyna, M., *Wielokryterialna ocena rozłożenia potoku ruchu w aspekcie rozwoju infrastruktury systemu transportowego*, Wydawnictwa AGH, Automatyka – półrocznik, T. 3. Krakow 1999.

[9] Jacyna, M., Lewczuk, K., Szczepański, E., Gołębiowski, P., Jachimowski, R., Kłodawski, M., Pyza, D., Sivets, O., Wasiak, M., Żak, J., Jacyna-Gołda, I., *Effectiveness of national transport system according to costs of emission of pollutants,* in: Saferty and Reliability: Methodology and Applications, CRC Balkema, pp. 559-567, 2014.

[10] Jacyna, M., Wasiak, M., Jacyna-Gołda, I., Pyza, D., Merkisz-Guranowska, A., Merkisz, J., Lewczuk, K., Żak, J., Pielecha, J., *A holistic approach to modelling of the ecological domestic transport system*, Materiały konferencyjne XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística, PANAM 2014, Santander 2014.
[11] Jacyna, M., Wasiak, M., Lewczuk, K., Kłodawski, M., *Simulation model of transport system of Poland as a tool for developing sustainable transport*, Archives of transport, Polish Academy of Sciences, Vol. 31, No. 3, pp. 23-35, Warszawa 2014.
[12] Jacyna, M., Żak, J., Jacyna-Gołda, I., Merkisz, J., Merkisz-Guranowska, A., Pielecha, J., *Selected Aspects of the Model of Proecological Transport System*, Journal of KONES Powertrain and Transport, Vol. 20, No. 3, pp. 193-202, Warszawa 2013.
[13] Merkisz, J., Bajerlein, M., Dobrzyński, M., Michalak, D., *A comparison of the exhaust emission from city buses fuelled with diesel oil and CNG*, Urban Transport XIX. Nineteenth International Conference on Urban Transport and the Environment (ed. by C.A. Brebbia), WIT Transactions on the Built Environment, WIT Press, Vol. 1, Southampton 2013.
[14] Merkisz, J., Pielecha, J., Radzimirski, St., *New Trends in Emission Control in the European Union*. Springer Tracts on Transportation and Traffic, Is. 4, 2014.
[15] Pisano, G. P., *Knowledge, integration, and the locus of learning: An empirical analysis of process development,* Strategic Management Journal, 15 (2), pp. 85-100, 1994.
[16] Rodrigue, J. P., Comtois, C., Slack, B., *Transport Planning and Policy, in: The Geography of Transport Systems*, 3rd Edition, Nowy Jork, Routledge 2013.
[17] *Strategia rozwoju transportu do 2020 roku (z perspektywą do 2030 roku*), Ministerstwo Transportu, Budownictwa I Gospodarki Morskiej, Warszawa 2013.
[18] Tietenberg, T., *Environmental and Natural Resource Economics*, Pearson Education; International, 2003.
[19] Wasiak, M., Kłodawski, M., Lewczuk, K., Jachimowski, R., Szczepański, E., *Chosen aspects of simulation model to designing proecological transport system*, Journal of KONES Powertrain and Transport, Vol. 21, No. 4, pp. 525-532, 2014.
[20] Worthington, W. J., Collins, J. D., Hitt, M. A., *Beyond risk mitigation: Enhancing corporate innovation with scenario planning*, Business Horizons, Vol. 52, pp. 444, 2009.