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ENVIRONMENTALLY RESPONSIBLE MANAGEMENT OF TRANSPORT OF GOODS IN URBAN AREAS

Abstract

The aim of the article is to present the possibility of taking into account environmental aspects in managing the transport of goods in urban areas. The article presents the ICT system built within the framework of the international S-mile project, which may support both decision-making including environmental aspects in relation to institutions organizing the transport system of a particular area, as well as supporting environmentally responsible attitudes towards local freight carriers. The individual modules and interactions between the stakeholders of the system are also briefly characterized.

Keywords: environmental responsibility, transport planning, transport of goods, freight transport management

Introduction

The transport system, like every system, is a deliberately organized whole as a coordinated arrangement of elements, a set conditioned by a constant, logical ordering of its components, so that changing one element can affect the other elements of this system. That is why it is so important to identify negative phenomena whose interference in the structure of a particular area and the quality of life of residents should be minimized. In relation to transport in general, six basic aspects of negative impact on the environment can be distinguished – safety, congestion, energy consumption, land use, emission of harmful substances and noise. The transport of goods plays a special role in the impact on the environment due to its specificity. Transport of goods, carried out over long distances, close to the destination (in the urban area) often requires a change of means of transport, due to transport network constraints or lack of transport accessibility for large trucks in city centers.

The delivery of goods then often forces the use of the local market of final carriers. Large companies providing transport services or production companies at the stage of the so-called first and last mile problem[1] face problems related to, among others with little knowledge of the limitations of the urban transport network, including local difficulties caused by congestion (dynamics of daily and periodic changes resulting from specific local causes) or the quality of the road surface, as well as the increase in transport costs of the first and last mile due to the lack of full information about the services market in this regard. At the same time, there is still a lack of use of environmental criteria in the planning of transport of goods, both on the carrier (and specific journeys), and due to the planning of the transport system by local authorities. In the latter case, the reason is often the lack of tools for collecting data on the transport of goods[2].

The aim of the article is to present the possibility of taking into account environmental aspects in managing the transport of goods in cities. The problem is presented both in relation to a single transport company and local authorities. A comprehensive ICT solution was proposed to support decision making called S-mileSys, which is an IT system that is one of the results of the international project "Smart platform to integrate different freight transport, manage and foster first and last mile in supply chains (S-miles)" in ERANET Transport III co-financed by the National Center for Research and Development. Apart from the integration of three stakeholder groups (large transport companies, local carriers and local authorities), this tool takes into account environmental problems (in the form of three indicators identifying the impact of transport on the environment) at the stage of transport planning, while allowing simulation of goods transport in the city. Thanks to the feedback channel, the system administrator (local authority or other decision-making entity) receives data on the actual transports carried out and the possibility of transport simulation with the assumption of organizational changes. Such an approach allows in the long-term perspective to support the decision-making process in the area of traffic flow management (including transport of goods).

The article presents the basic modules of the S-mileSys system. Particular attention was paid to the planning stage, which requires the use of several optimization algorithms (among others in terms of route, selection of vehicles from the available fleet, the distribution of loads on vehicles and the distribution of cargo in the vehicle, etc.). Taking into account environmental criteria allows to limit the negative impact of transport on the environment. Planning transporting goods requires a considerably larger number of criteria to be taken into account than the planning of travellers' routes. A comprehensive fleet management platform together with a planning module, combined with other modules of the S-mileSys system being built, is also aimed at integrating large transport companies with first and last mile carriers.

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[1] *Logistyka. Nauka – Badania – Rozwój*, ed. M. Mindur, Scientific Publisher of the Institute for Sustainable Technologies – PIB, 2017.

[2] K. Kijewska, K. Małecki, S. Iwan, *Analysis of Data Needs and Having for the Integrated Urban Freight Transport Management System*, Communications in Computer and Information Science 2016, 640, p. 135–148.

1. Characteristics of the S-mileSys system and its assumptions

The problem of transporting goods in urban areas requires a multi-faceted look. Direct transport contractors, i.e. local carriers, create difficulties in changing the load on the transport network during the day, as well as the need to plan transport in an efficient manner. Information on the offer of local carriers, in turn, is required by large carriers (with domestic or international transport range) and producers. The third type of stakeholders are local authorities and institutions that influence the shape of the transport system in a particular area. In this case, the essence of the problem is the proper shaping of traffic flows on the transport network, which should also take into account future development plans and, to a large extent, environmental responsibility. In the S-mile project, an important emphasis was placed on pro-ecological solutions. Limiting the negative impact on the environment can be achieved, among others, through: improvement of transport performance, i.e.[3] optimization of routes and supply chains; taking into account the environmental criterion during transport planning, promoting environment-friendly carriers as well as infrastructure and organizational changes in the transport system.

The basic product of the S-mile project is the IT system (S-mileSys) supporting multimodal transport for the first and last mile, promoting transport and pro-environmental solutions. This system takes into account ecological criteria at the stage of route planning, which makes it possible to estimate the impact of transport of goods on the environment and on the health of residents. Among the criteria, the quality of transport was also taken into account. The system also supports the creation of road network quality maps and offers full information regarding the availability of various transport companies (local carriers) to the system's customers. The system operates on the principle of registered access to the cloud and is supported by the use of web services. Six basic elements of the system were distinguished[4]:

– S-mile Market Tool: this tool is a link between customers (large transport companies, manufacturers, logistics centers, etc.), and local carriers carrying goods for the first and last mile. The module resembles the functionality of a transport exchange, which in this case is assigned to a specific geographical area. The customer, by filling in an appropriate electronic form, can send an inquiry.

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[3] Among others: White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144; White Paper on the Future of Europe, Reflections and scenarios for the EU27 by 2025, COM(2017) 2025; Clean Power for Transport: A European alternative fuels strategy, COM(2013) 17; Sustainable Logistics and Supply Chains: Era-net Transport Flagship 2015 Call, 2015; M. Jacyna, J. Żak, I. Jacyna-Gołda, J. Merkisz, A. Merkisz-Guranowska, J. Pielucha, *Selected aspects of the model of proecological transport system*, Journal of KONES 2013, Powertrain and Transport, 20, p. 193–202; B. Tundys, *The Impact and Role of Transportation on the Construction and Operations of the Green Supply Chain* [in:] *Sustainable Transport Development, Innovation and Technology*, ed. M. Suchanek, Springer Proceedings in Business and Economics, Springer, Cham 2017, p. 15–26; B. Galińska, *Multiple Criteria Evaluation of Global Transportation Systems – analysis of case study* [in:] *Advanced Solutions of Transport Systems for Growing Mobility*, ed. G. Sierpiński, Advances in Intelligent Systems and Computing, vol. 631, Springer, Cham 2018, p. 155–171.

[4] M. Staniek, G. Sierpiński, *Smart platform for support issues of first and last mile in the supply chain – the concept of the S-mile project*, Scientific Journal of Silesian University of Technology. Series Transport 2016, 90, p. 11–21.

Market Tool selects from the available list of companies those that meet the criteria of the query and forwards the form to the next system modules. Finally, in response, he sends the client an offer to fulfill his order by carriers from the system;
- S-mile Freighter Tool is the main element of S-mileSys dedicated carrier. It has the ability to monitor the fleet and supporting the communication module. The tool is responsible for maintaining information on the current availability of the carrier's fleet and its location. It also watches over the plan of scheduled transports;
- S-mile Fleet Management Tool is a tool supporting carrier's decisions through algorithms of optimal distribution of goods and determination of transport costs;
- The S-mile Transport Planner Tool helps you determine the optimal routes of supply chains. The optimization is based on several criteria, including time, distance, cost and three environmental criteria. This system tool at the planning stage also takes into account the current level of congestion (with the use of internal, as well as the possibility of attaching external sources of information) and the quality of the road network. The quality of roads is monitored by an independent system module using directly the transport of carriers' vehicles;
- S-mile Visualizer Tool is available to local authorities (in the full range of data) and to carriers (access only to the carrier's data). This tool enables visualization of information collected during system operation. This applies to both the quality of roads and the distribution of transported goods to the road network. This element of the system allows you to perform a full overview of the area in terms of historical journeys with the goods. On this basis, local authorities may decide to introduce restrictions on heavy traffic in a specific part of the city or to enter access only for electric vehicles;
- S-mile Simulation Tool is intended for use by local authorities and other decision-making bodies. It is a multiagent simulator based on the existing base of carriers from S-mile Market Tool. This tool makes it possible to assess the impact of various changes introduced in the analyzed area in terms of incentives and restrictions on the implementation of transport of goods, and as a result allows to assess the impact of such changes on the environment and human.

2. Criteria for planning transport of goods and the need to increase environmental responsibility

Transport planning allows you to consider several possible variants of the supply chain and make the optimal choice depending on the additional internal factors of the carrier. Existing support tools, such as travel planners, intended for travelers allow you to choose ways of moving between two (or more) points using one or more modes of transport in the displacement chain. In the case of transport of goods, the basic functionality of the travel planner is not sufficient to maintain high efficiency of transport. This requires a much more extensive integrated IT platform that supports and optimizes carrier decisions. The lack of compatibility of the standard for data exchange, however, means that local transport companies use very different systems, which hinders integration and requires the adaptation of large carriers (interested in cooperation at the first and last mile stage) to various IT systems. Still, the majority of carriers do not pay attention to the environment, conditioning the transport of goods only with the criterion of cost and time (or a criterion based on both parameters with appropriate weights)[5].

Planning transport of goods in supply chains differs from planning individual journeys between source and destination. In this case, effective planning should consider substantially more parameters. The following modules participate in the S-mileSys tool in the travel planning process: Vehicle assignment optimization algorithm (connected with the proper distribution of goods), Freight transport cost calculating Tool (allowing you to estimate transport costs), Emission factor Tool (containing algorithms that estimate the negative impact on environment), Routing algorithms (related to the search for optimal routes) and Database for route planning (in the form of an archive of data on the transport network).

Optimal distribution of goods in a vehicle depends on many factors, including the size and shape of individual items of cargo, but also the order of delivery[6]. The second problem of the distribution of goods is the optimal allocation of cargo to the owned and currently available fleet of the carrier[7]. Another element in the described ICT system is an extensive cost calculator taking into account, among others, operating and personal costs, costs related to fleet maintenance, storage costs (in the case of storage of goods), etc.[8]

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[5] In the literature you can find comparisons comparing current solutions in this area, as well as few proposals for travel planners taking into account the environmental aspect, among others P. Borkowski, *Towards an Optimal Multimodal Travel Planner – Lessons from the European Experience* [in:] *Intelligent Transport Systems and Travel Behavior*, ed. G. Sierpiński, Advances in Intelligent Systems and Computing vol. 505, Springer, Cham 2017, p. 163–174; D. Esztergár-Kiss, Cs. Csiszár, *Evaluation of multimodal journey planners and definition of service levels*, International Journal of Intelligent Transportation Systems Research 2015, 13, p. 154–165; D. Földes, Cs. Csiszár, *Route Plan Evaluation Method for Personalized Passenger Information Service* Transport 2015, 30(3), p. 273–285; K. Lewczuk, J. Żak, D. Pyza, I. Jacyna-Gołda, *Vehicle Routing in Urban Area – Environmental and Technological Determinants*, WIT Transactions on The Built Environment 2013, 130, p. 373–384; G. Sierpiński, *Technologically advanced and responsible travel planning assisted by GT Planner* [in:] *Contemporary Challenges of Transport Systems and Traffic Engineering*, eds. E. Macioszek, G. Sierpiński, Lecture Notes in Network and Systems, vol. 2, Springer, Cham 2017, p. 65–77; M. Maciejewski, *Dynamic Transport Services* [in:] *The Multi-Agent Transport Simulation MATSim*, ed. A. Horni, K. Nagel, K.W. Axhausen, Ubiquity Press, London 2016, p. 145–152.

[6] Among ohers: D. Pisinger, J. Egeblad, *Heuristic approaches for the two- and three-dimensional knapsack packing problems*, DIKU Technical-report no. 2006-13, University of Copenhagen 2006; K. Popiela, M. Wasiak, *A method of loading unit formation taking into account mass, load-bearing strength and surfaces of packing units*, Scientific Journal of Silesian University of Technology. Series Transport 2017, 96, p. 151–160.

[7] Among others: Y. Shen, Q. Nie, Q. Yuan, X. Yang, *Study on express delivery service provider configuration by applying a synthetic method*, 1st International Conference on Information Science and Engineering 2009, p. 4514–4517; V. Naumov, *Estimating the Vehicles' Number for Servicing a Flow of Requests on Goods Delivery*, Transportation Research Procedia 2017, 27, p. 412–419.

[8] Similar cost models were used, inter alia, in the work of: M. Bąk, *Koszty i opłaty w transporcie*, University of Gdańsk Publisher, Gdańsk 2010; M. Berwick, M. Farooq, *Truck Costing Model for Transportation Managers*, Upper Great Plains Transportation Institute North Dakota State University 2003; G. Karoń, R. Janecki, *Concept of Smart Cities and Economic Model of Electric Buses Implementation* [in:] *Telematics – Support for Transport*, ed. J. Mikulski, Communications in Computer and Information Science, vol. 471, Springer, Berlin–Heidelberg 2014, p. 100–109.

One of the goals of the S-mile project is to promote environmentally responsible solutions. On the basis of European and world literature[9], several emission factors were defined. After further analysis, due to the need for the carrier to understand the message, in addition to the traditional criteria for optimizing the route over time, distance or cost, the S-mileSys system implemented an additional three criteria (as a generalized impact on the environment) aimed at seeking solutions to reduce the harmful impact transport to the surroundings[10]. For each criterion a separate value estimation model was built, however all of them were based on the following basic variables[11]:

$$CC, DALY, NOISE = f (VT, RT, S, TC, G, L, A),$$

where:
CC – impact on climate change [CO_2eq/km];
DALY – an indicator describing the expected loss of health or life caused in this case by transport (disability adjusted life-years) [daly/km];
NOISE – vehicle noise emission [dBA];
VT – vehicle type (classification by vehicle type, e.g. electric car, passenger car, commercial vehicle, lorry, etc.);
RT – road type;
S – speed [km/h], the parameter determines the speed at each section of the transport network (referring to the permissible speeds on sections and speeds recorded from traffic monitoring functioning in a given area of Intelligent Transport Systems – ITS);
TC – traffic volume [–], a parameter that takes into account the current or forecast traffic on individual sections of the transport network (data collected by S-mileSys or external data from traffic monitoring functioning in a given ITS area);
G – road lean [degrees];
L – load [–], the parameter determines the degree of loading the vehicle with a commodity;
A – fixed residual value.

[9] Among others: M. Maibach, C. Schreyer, D. Sutter, H.P. van Essen, B.H. Boon, R. Smokers, A. Schroten, C. Doll, B. Pawłowska, M. Bąk, *Handbook on Estimation of External Costs in the Transport Sector. Internalisation Measures and Policies for All external Cost of Transport (IMPACT)*, Delft 2008; H.P. van Essen, A. Schroten, M. Otten, D. Sutter, C. Schreyer, R. Zandonella, M. Maibach, C. Doll, *External costs of transport in Europe. Update Study for 2008*, Delft 2011; *The Calculation Of External Costs In The Transport Sector. A Comparative Analysis of Recent Studies in the Light of the Commission's 'Greening Transport Package'*, European Parliament's Committee on Transport and Tourism, Brussels 2009; U.J. Becker, T. Becker, J. Gerlach, *The True Costs of Automobility: External Costs of Cars Overview on existing estimates in EU-27*, Dresden 2012; B. Pawłowska, *Zrównoważony rozwój transportu na tle współczesnych procesów społeczno-gospodarczych*, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2013; A. Korzhenevych, N. Dehnen, J. Bröcker, M. Holtkamp, H. Meier, G. Gibson, A. Varma, V. Cox, *Update of the Handbook on External Costs of Transport*, Final Report. Ricardo-AEA/R/ ED57769, Oxford, Didcot 2014.

[10] S-*mile Report D4.1 Emission factor calculation tool*, Smart platform to integrate different freight transport means, manage and foster first and last mile in supply chains, Bilbao 2016.

[11] The constructed model of estimating the impact of goods transport on the environment is based on guidelines and databases, among others: *Handbook of Emission Factors for Road Transport* (HBEFA Version 3.2), 2014 and *The Noise Navigation Sound Level Database* (NNSLD), E•A•RCAL Laboratory, 2015. The model needed to be calibrated and implemented into the form of programming libraries A. Pijoan, I. Oribe-Garcia, O. Kamara-Esteban, K.N. Genikomsakis, C.E. Borges, A. Alonso-Vicario, *Regression Based Emission Models for Vehicle Contribution to Climate Change* [in:] *Intelligent Transport Systems and Travel Behaviour*, ed. G. Sierpiński, Advances in Intelligent Systems and Computing, vol. 505, Springer, Cham 2017, p. 47–63.

Using the described S-mileSys tool, the carrier receives a report with a list of optimal solutions for various optimization criteria. Depending on the chosen criterion, the S-mileSys system implemented in the S-mileSys algorithm will minimize distance, time, costs or negative impact on the environment by searching the set of R routes between individual pick-up/delivery points selected for the supply chain for a specific type of measure transport:

$$R = \{r_i : r_i(T, D, C_T, EI\ (CC, DALY, NOISE))\} \qquad \underset{criteria}{Opt} = \min\ (r_1, r_2, \ldots, r_n),$$

where:
R – a set of routes between selected points of the transport network;
T – travel time [h];
D – distance [m];
C_T – total cost [cost unit];
EI – impact on the environment determined by selected from emission factors;
Opt – objective function.

It should be noted that depending on your vehicle fleet, the planning algorithm for supply chains in the S-mile Transport Planner Tool takes into account additional transport infrastructure parameters, such as availability for a specific type of vehicle (e.g. some infrastructure elements may be impassable), location of parking spaces near the destination (in the case of small shipments), range of the vehicle, quality of the road, etc.[12] The S-mileSys IT system also includes various types of transport, including electric vehicles, as an alternative to conventional solutions.

3. Example of support for the carrier and local authorities in the field of freight transport management

The S-mileSys system is addressed to three groups of stakeholders. Relations in the S-mileSys IT system affect two groups of users – local carriers, whose environmental awareness may increase thanks to the use of S-mileSys and authorities affecting the shaping of the city's transport system, for which the tool is a source of information on transport of goods and support in making decisions to reduce the negative impact of goods transport on the environment.

As soon as all transport parameters have been agreed with a specific group of customers using the S-mile Market Tool element (and determining the optimal route), the carrier begins transporting the goods at the last mile stage. In this case, the following activities are carried out all the time (Figure 1):

– the carrier through the Freighter Tool has an overview of the current state of its rolling stock (location and transport plans), and can take current corrective action (1);

[12] M. Staniek, *Road pavement condition as a determinant of travelling comfort* [in:] *Intelligent Transport Systems and Travel Behaviour*, ed. G. Sierpiński, Advances in Intelligent Systems and Computing vol. 505…, p. 99–107.

– Fleet monitoring module constantly monitors the position of vehicles and enables the transmission of optimal routes and navigation instructions to mobile devices in vehicles (2);
– in the event of difficulties in the transport of goods (notification by the driver), for example due to the occurrence of a congestion, road accident or vehicle carrier failure, procedures are implemented to restart individual Fleet Management Tool and Transport Planner Tool necessary in the optimization process routes and assignment of goods to vehicles for reported additional restrictions (3);
– a separate activity is the acquisition of data from the carrier's vehicles using the Road condition tool (4). These data concern the condition of the road network surface and, after appropriate processing, constitute the basis for further planning of routes taking into account the quality of transport. Collecting the above data does not require any interference by the driver – the system registers and sends them remotely. The speed and exact route of the vehicle are also recorded (with additional parameters set, such as the weight of the vehicle and the load being carried).

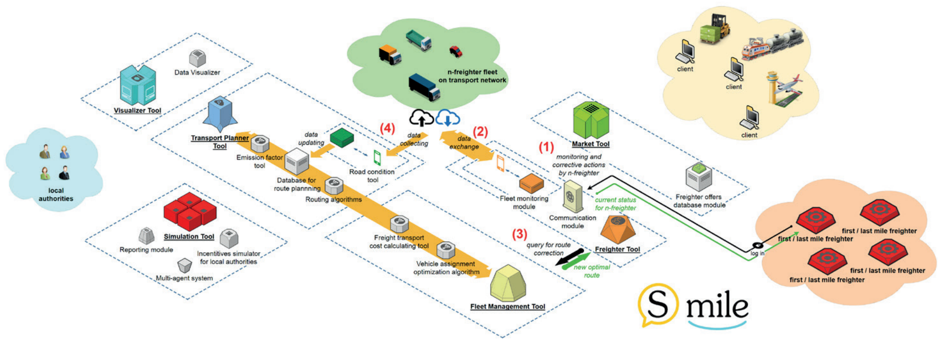

Figure 1. Visualization of the carrier – S-mileSys system interaction related to the transport of goods
Source: own elaboration

The S-mileSys system supports making decisions of local authorities and other decision-making entities in the scope of organizational and infrastructural activities by providing insight into the current status of goods transport in a selected area (visualization of the historical distribution of traffic flows) and simulating the functioning of goods transport within the city. Figure 2 illustrates the use of the scenario simulation tool related to the implementation of various Simulation Tool initiatives:
– local government requests for proposals with a specific initiative (1) for Simulation Tool;
– sending the complete carrier database from Market Tool to simulation modules (2), which allows to simulate the transport of goods based on existing companies and their actual parameters;
– obtaining optimal routes according to various criteria from the Transport Planner Tool (including emissions, noise, road conditions, costs, time and distance) (3);

– launching the Multi-agent system[13] and executing simulation of goods transport for the current state, and then simulating again (Incentives Simulator for local authorities module) for the proposed changes. The final analysis of the data generates a report (4) that supports decision making. An example of a simulation window is shown in Figure 3.

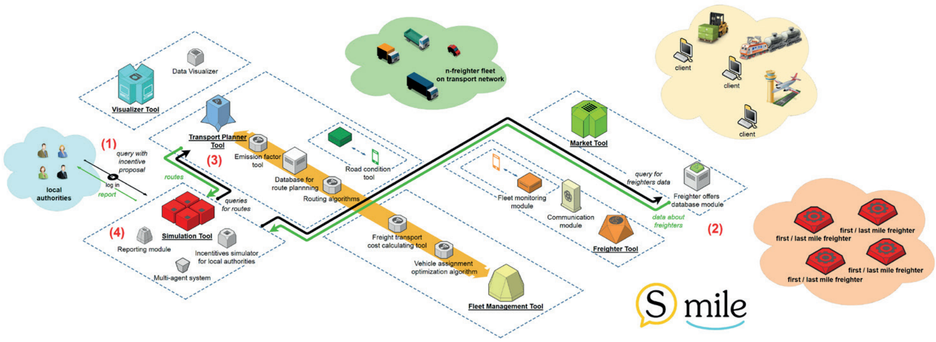

Figure 2. Visualization of the interaction of local authorities – S-mileSys system related to the assessment of the effects of introducing changes in the transport system
Source: own elaboration

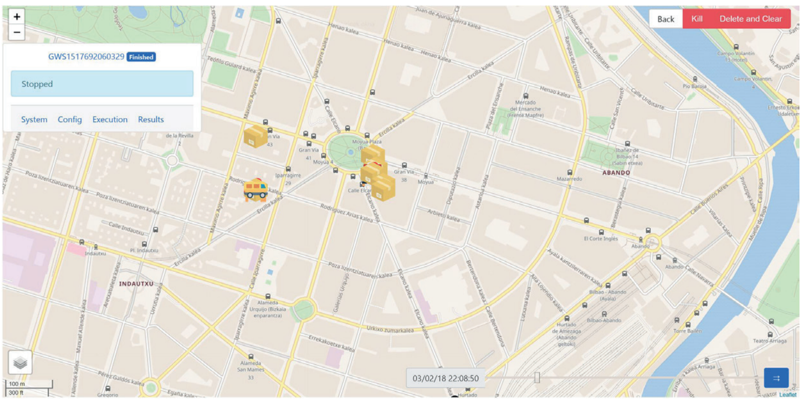

Figure 3. Window of the S-mileSys simulation tool
Source: *S-mile Report D6.3 Multi Agent System*, Smart platform to supply, Bilbao 2017

[13] The described multiagent system has been implemented, among others in: A. Pijoan, O. Kamara-Esteban, I. Oribe-Garcia, A. Alonso-Vicario, C.E. Borges, *GTPlat: Geosimulation for Assessing the Application of Incentives to Transport Planning* [in:] *Advanced Solutions of Transport Systems for Growing Mobility*, ed. G. Sierpiński, Advances in Intelligent Systems and Computing, vol. 631…, p. 74–89.

Conclusions

The environmentally responsible IT management of goods transport is a challenge for the efficient functioning of the modern city. Such management should be carried out both at the level of the undertaking performing transport of goods (optimal transport planning) and with the use of organizational and legal activities by local authorities and institutions shaping the city's transport system. If used on a larger scale, the described solution in the form of the S-mileSys system can change the way of transporting goods in cities. Taking into account environmental criteria allows to limit the negative impact of transport on the environment. A comprehensive fleet management platform along with a planning module in conjunction with other S-mileSys systems is also aimed at integrating large transport companies with first and last mile carriers.

As part of further research, it is planned to try to integrate the S-mileSys system with the result of another project – GTPlat – a platform supporting the travel of people in cities. Such an approach, especially in reference to simulation modules, enables more accurate analysis of the functioning and possibilities of changes in the city's transport system.

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