Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Smart solution for the last mile problem in urban areas

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Abstract

The article presents a comprehensive solution proposed in response to the last mile problem tackled in freight transport. This specific part of the supply chain requires considerable funding, particularly in urban areas, as well as organisational solutions specifically matching the needs of the given territory. One of the measures undertaken under of the S-mile project was implementation of an ICT solution enabling integration of large transport companies (system clients, in this case) with carriers along with reduction of negative environmental impact of freight transport. Basic modules of the extended S-mileSys system are as follows: *S-mile Market Tool* (supporting contacts between an urban carrier and customers), *S-mile Freighter Tool*, *S-mile Fleet Management Tool* and *S-mile Simulation Tool* (supporting fleet management by means of such features as e.g. vehicle assignment optimisation algorithms, route planning etc.), *S-mile Transport Planner Tool* (used for route planning optimisation) as well as *S-mile Visualizer Tool* (Big Data base addressing local authorities, enabling them to generate a concise review of the overall impact of freight transport on the given area, of the emission distribution as well as of the freight transport distribution against the transport network for spatial planning). The article also provides a description illustrating individual phases of interaction between clients/users and the system.

Keywords: sustainable development; supply chains, transport modes, multimodal, environmentally friendly transport

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1. Introduction

Many of the initiatives undertaken in the sphere of transport and environment problems pertain to transfer of people. One should also note that freight transport requires integrated solutions as well. This problem is particularly evident under conditions of continuous deliveries of goods. The process in question requires optimisation in numerous stages. What seems crucial from the carrier's perspective is minimising transport related costs and performing transport services as quickly as possible. Hence the importance of appropriate distribution of goods between vehicles, combining freights into supply chains, but also seeking optimum transport routes. On the other hand, the issues considered significant for the city include the land use (and optimum traffic flow of the transport network), minimisation of the transport infrastructure maintenance costs and emission level monitoring in individual areas.
The article presents an innovative integrated approach to the implementation of urban freight transport using ICT (information and communication technologies). The S-mileSys system has been developed as a part of an international project implemented under the ERA-NET Transport III Programme entitled "Smart platform to integrate different freight transport means, manage and foster first and last mile in supply chains (S-MILE)," financed by the National Centre for Research and Development. The project is implemented by the following entities: Saitec, Factor CO2 and DeustoTech (Basque Country), the Silesian University of Technology (Poland) and PlusOneMinusOne (Turkey). International collaboration makes it possible to develop case studies addressing different areas of diverse specificity.

2. Current problems with urban freight transport and the S-mile project

What is characteristic of the current state of matters is the lack of comprehensive solutions. Goods are now typically transported in long distances by planes, sea vessels and large heavy road vehicles. Numerous organisational solutions have already been implemented in this fundamental sphere of transport management on the level of the network of trans-European connections. Another problem which needs to be addressed is the demand for complete large freight shipments to be formed (first mile), and primarily for the cargo to be divided into parts and dispatched in an environmentally and financially optimised manner between the place of completion of the primary transfer and individual destination points (last mile). Where the latter is the case, it poses a considerable challenge, particularly in heavily urbanised areas. Various EU documents highlight clear deficiencies in terms of the solutions and development strategies addressing urban freight transport (including *Urban Mobility – Research Theme Analysis Report* (2016)). The foregoing fact stems from numerous factors, including the existence of many small and independent privately-owned transport companies whose scope of operations is limited to the area of a specific town or agglomeration. And this is exactly what distinguishes global supply chain related solutions from those dedicated to the last mile problem. Another issue to be tackled is the lack of a suitable information system that would provide an interface between large transport companies and local carriers (*White Paper* (2011)), the consequence of which is the declining last mile transport efficiency. Large freight operators or production companies storing their goods at logistics centres at the last mile stage are also faced with other problems, including:

- significant restrictions or transport inaccessibility for large goods vehicles in city centres,
- low level of knowledge about the limitations typical of the urban transport network, including local obstacles due to congestion or poor quality of road pavement,
- increase of last mile transport costs due to the lack of comprehensive information about the market of related services.

The incompatibility of data exchange standards force local carriers to use very different fleet management support systems. These solutions offer various features, including the opportunity to track the location of vehicles, making it easier to plan transport routes. There are also solutions used by carriers to optimise the last mile supply chain. For instance, *My Route Online Route Planner* can determine an optimum sequence of deliveries for a single vehicle. However, the non-integration between carriers leads to the lack of knowledge on the current distribution of transport streams over the road network. Nevertheless, most carriers still pay no attention to natural environment, and the only condition they apply in freight transport management is the time or cost criterion, which becomes particularly evident when analysing how most route planners are built (including Borkowski (2017), Esztergár-Kiss and Csiszár (2015) and Földes and Csiszár (2015)).
The third group of stakeholders involved in the discourse is that of local authorities. The negative environmental impact of transport is among the most serious issues facing contemporary cities. It is in cities that one may

particularly witness the increase in emission of harmful substances and noise. Local authorities undertake various initiatives to change the modal split of transport to the benefit of eco-friendly solutions, however, their actions are mainly focused on passenger transport. Meanwhile, it is the transport of heavy cargo that should mainly be held responsible for degradation of the transport infrastructure. To control all processes local authorities need enough data about freight transport in city (Kijewska et al. (2016)).
With the foregoing problems in mind, the opportunities rendered by the project entitled "Smart platform to integrate different freight transport means, manage and foster first and last mile in supply chains (S-MILE)" were used to propose an ICT system to be prepared in order to support and interface all three of the aforementioned stakeholder groups, namely:

- large transport companies (as clients),
- local carriers (as primary users),
- local authorities (as priority users capable of using the system to simulate individual solutions aimed to improve the efficiency of the given area's transport system).

Strong emphasis in the S-mile project has been placed on eco-friendly solutions. The goal of reduction of the negative environmental impact may be achieved by various means, including those suggested in White Paper (2011), Clean Power for Transport (2013), Sustainable Logistics and Supply Chains (2015), Jacyna et al. (2013) and Tundys (2017)):

- improvement of transport performance conditions though optimisation of routes and supply chains,
- taking the environmental criterion into consideration when planning individual transfers,
- promotion of environment-friendly carriers,
- infrastructural and organisational changes to the transport system.

3. S-mileSys as a complex ICT system for the first/last mile freight transport – methodology description

The main deliverable of the S-mile project is a system (S-mileSys) designed to support the first/last mile logistics and multimodal transport, fostering green transport means and solutions. The system takes environmental protection criteria into account at the route planning stage, making it possible to estimate the impact of freight transport on natural environment and human health. Transport quality is one of such criteria. With the extensive range of functions, S-mileSys covers both the first and the last mile. This article focuses on the latter aspect. Additional features of the system enable road network quality maps to be created and provide comprehensive knowledge on the availability of individual transport companies to the system clients. The operating principle of the system is based on registered access to a cloud, which is managed by web services. Each stakeholder must first register to the system before they can use it. They are then verified on the system administrator side. There are six basic system components (Staniek, Sierpiński (2016)), most of which consist of several modules that perform different functions:

- *S-mile Market Tool* provides an interface between clients (large transport companies, manufacturers, logistics centres etc.) and carriers rendering services of last mile transport of goods. Having filled in an appropriate electronic form, the client can send a request. From a list of available companies, *Market Tool* selects those which meet the request criteria and forwards the form to subsequent system modules. In response to the client, it finally sends proposals for performance of the given contract, as submitted by the carriers available in the system.
- *S-mile Freighter Tool* is the S-mileSys system's main component dedicated to carriers, these being also referred to as freighters. It can monitor the fleet and features an additional communication module. Consequently, the tool is responsible for maintaining up-to-date information about availability of the carrier's fleet and location of individual vehicles. It also manages the schedule of planned transfers.
- *S-mile Fleet Management Tool* is a solution that supports the carrier's decision making process by means of algorithms for optimum cargo distribution (distribution between available vehicles as well as optimum arrangement of goods in a vehicle depending on the sequence of deliveries) and calculation of transport costs (regarding all transport-related costs, including unit fuel costs, operating costs, personnel costs etc.).
- *S-mile Transport Planner Tool* provides support for optimum routing of delivery chains. The optimisation is based on a number of criteria by taking into account time, distance and costs as well as two other environmental criteria related to the impact exerted on natural environment and human health. At the planning stage, this system tool also regards the current level of congestion (using internal information sources as well as enabling some external sources to be additionally utilised) and the road network quality. The quality of

roads is monitored by an independent system module directly based on the transfers performed by the vehicles managed by carriers.

- *S-mile Simulation Tool* is intended for local authorities. It is a multi-agent simulator based on *S-mile Market Tool's* current database of carriers. The tool makes it possible to assess the impact of various changes introduced in the area subject to analysis in terms of the incentives and restrictions for the performance of freight transport, consequently enabling assessment of the impact exerted by such changes on the environment and people.
- *S-mile Visualizer Tool* offers its full capabilities to local authorities, but it also supports carriers in a more limited scope (only with reference to certain data). The tool enables visualisation of the information acquired while the system is being operated. The foregoing pertains to both the road quality and the distribution of completed transport services over the road network. This system component makes it possible to perform a full analysis of the area in question with regard to completed cargo transport services. Based on such data, local authorities can, for example, make a decision on introducing specific restrictions for heavy vehicle traffic in individual parts of the city or establish zones of electric car only access.

Further on in this chapter, a detail description has been provided to characterise selected features of the S-mileSys system as well as individual stages of the processes implemented in the system and interactions between the system and the three groups of stakeholders.

3.1. S-mileSys and clients' requests

Enabling interaction between the client (large transport companies) and the system may be brought down to actions performed by means of *Market Tool*. However, submission of a request initiates an entire process comprising specific actions handled in the system, the basic ones being as follows (Fig. 1):

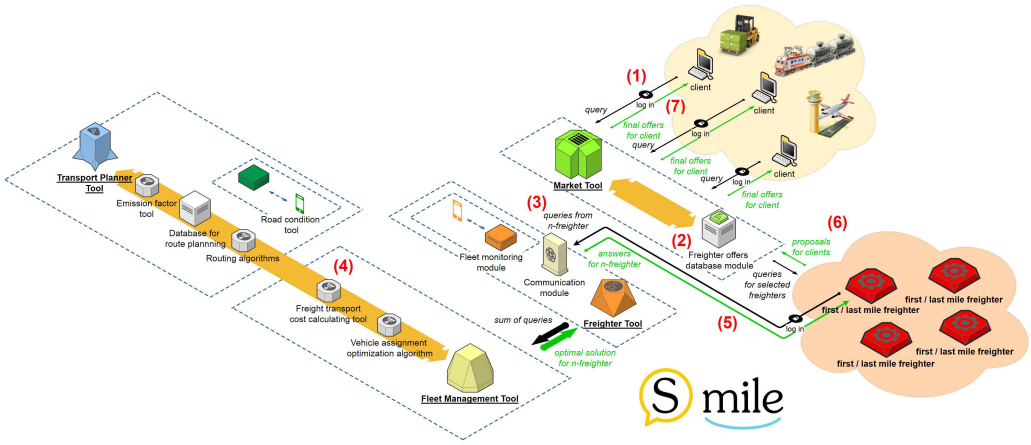

Fig. 1. Visualisation of the interactions between the client and the S-mileSys system connected with submitting a query concerning available goods transport options (only selected elements of S-mileSys related to that processes were shown)

- each client fills in a special request form using *Market Tool* (defining cargo volumes and types, criteria, time limits, list of addressees for destination points etc.) (1);
- *Market Tool* filters the data extracted from the database of available carriers according to the parameters submitted by clients and sends requests to selected carriers (2);
- after logging on the S-mileSys system, each carrier initiates an analysis of the requests received using *Freighter Tool*. The requests are added to information about the current status of the carrier's vehicle fleet and orders (3);
- further two tools are enabled, namely *Fleet Management Tool* and *Transport Planner Tool*, making it possible to perform a number of calculations and optimisation processes using modules dedicated to optimum distributive of cargo in a vehicle and across the fleet (the dedicated module is referred to as *Vehicle assignment optimisation algorithm*), but also to calculate the costs and emissions involved (using the *Freight transport cost calculating tool* and the *Emission factor tool* modules). In each case, the processes consist in finding an optimum route based on the road network condition data (including pavement condition and forecasted volume of traffic streams) (4);
- a selection of potential solutions is summarised in a report and returned to *Freighter Tool*, and subsequently to the carrier (5);

- the decision on the choice of an individual proposal in terms of the costs and time limits involved for the freight transport service to be provided based on the given request is sent to *Market Tool* (6);
- *Market Tool* collects the proposals concerning individual clients and provides them with a comparative report (7). This solution allows for full information about the available freight transport capabilities to be rendered.

Only two system components, namely *Simulation Tool* and *Visualizer Tool*, have not been used in the case discussed above.

3.2. S-mileSys and freight transport services rendered by carriers

Every carrier can use the S-mileSys system after previously logging on. Once all the relevant transport service parameters have been arranged between a group of clients and the carrier (and after the transport route has been re-optimised), the last mile transport stage begins. Where the foregoing is the case, the following actions are continuously performed (Fig. 2):

- using *Freighter Tool*, carriers can monitor the current status of their fleet (location and transport plans for individual vehicles) as well as undertake corrective measures on an ad hoc basis (1);
- *Fleet monitoring module* performs ongoing vehicle location supervision enabling optimised routes and navigation instructions to be sent to on-board mobile devices (2);
- whenever problems occur while freight transport is conducted (as reported by the driver), e.g. due to on-route congestion, a road traffic accident or a defect of the carrier's vehicle, restart procedures are initiated for the *Fleet Management Tool* and *Transport Planner Tool* modules required to complete the process of route optimisation and assignment of cargo to individual vehicles with regard to the additional restrictions reported (3);
- as a separate activity, data are acquired from the carrier's vehicles using the *Road condition tool* module (4). The data in question describe pavement condition in the road network, and after being appropriately processed, they provide grounds for further route planning, taking the transport quality into consideration. Acquisition of these data requires no intervention from the driver, as the system records and sends them remotely. What is also recorded is the speed and exact route traversed by individual vehicles (regarding additional pre-set parameters, such as the vehicle and the cargo weight).

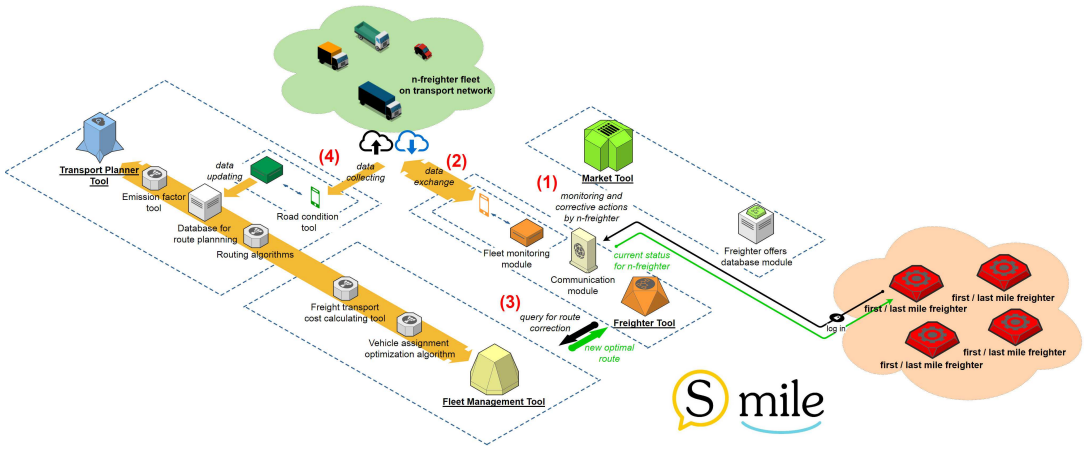

Fig. 2. Visualisation of the interactions between the carrier and the S-mileSys system in relation to performance of a freight transport service (only selected elements of S-mileSys related to that processes were shown)

3.3. S-mileSys and the need for urban freight transport assessment

Local authorities form the last group of stakeholders. The S-mileSys system supports decision making in the scope of organisational and infrastructural actions by providing access to information on the current status of freight transport in the chosen area. Moreover, the system makes it possible to prepare comparative reports concerning the situation following the changes introduced by local authorities (using the simulation tool).
The former of the system features has been illustrated in Fig. 3. *Visualizer Tool* uses the *Data visualizer* module to store data concerning all the completed freight transport services with the accuracy down to individual sections of the road network (using Open Street Map). In this case, the actions performed in the system are as follows:

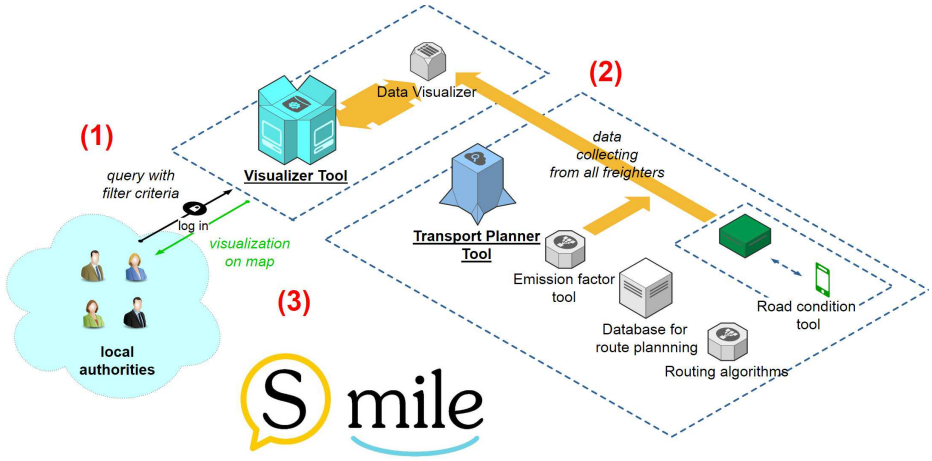

Fig. 3. Visualisation of the interactions between local authorities and the S-mileSys system in relation to assessment of the current status (only selected elements of S-mileSys related to that processes were shown)

- local authorities (having logged on the system) send requests for visualisation of a specific type of data (1). The data may be filtered out according to a date (either a time interval or a specific day), a business name (local authorities have full access to the related data stored in the system) and a vehicle type (selected from an available list);
- most data are extracted from the *Road condition tool* (2) module, whereas the information on emissions and noise is estimated using *Emission factor tool*;
- *Visualizer Tool* enables graphical presentation (on the road network map) of many data types (3), such as road conditions (regarding pavement condition), congestion (in the form of average speed acquired form the base), number of vehicles and total weight of the cargo transported (down to a road network section), estimated emission and noise (established depending on such factors as vehicle type, speed, road inclination, road type etc.) (incl. Pijoan et al., 2017).

Scenarios related to implementation of diverse initiatives by local authorities can be simulated by means of *Simulation Tool* (Fig. 4):

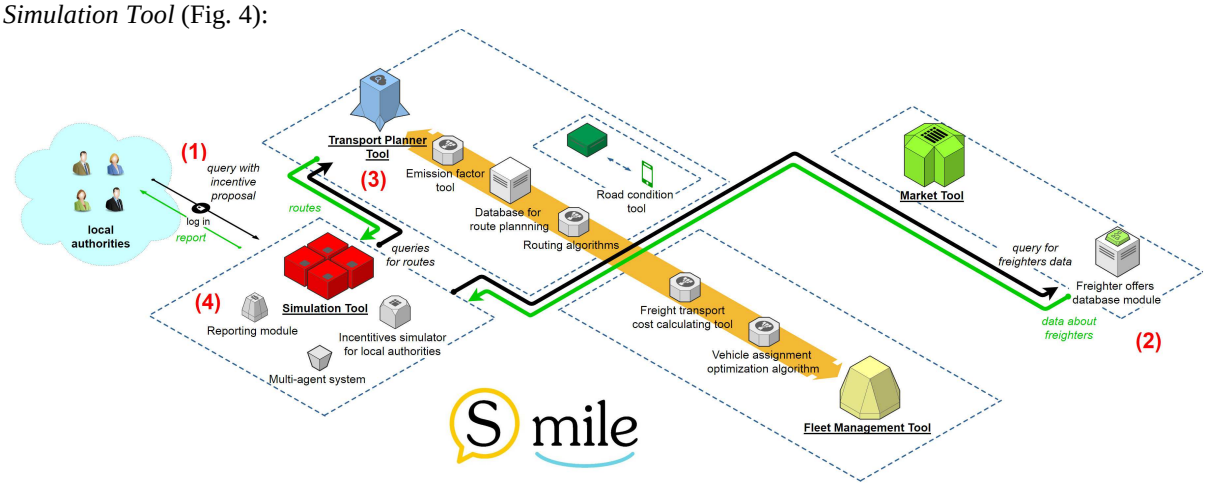

Fig. 4. Visualisation of the interactions between local authorities and the S-mileSys system in relation to assessment of the outcomes attained by introducing changes to the transport system (only selected elements of S-mileSys related to that processes were shown)

- local authorities (having logged on the system) submitting proposals of individual initiatives (1) to *Simulation Tool*;
- sending a full database of carriers from *Market Tool* to simulation modules (2). This enables simulation of freight transfers with regard to existing companies and based on their actual parameters;
- establishing optimum routes according to different criteria using *Transport Planner Tool* (taking emission, noise, road conditions, costs, time and distance into consideration) (3);
- deploying *Multi-agent system* and simulation of freight transport with regard to the current status followed by re-simulation (using the *Incentives Simulator for local authorities* module) regarding the changes proposed by

local authorities. Final data analysis makes it possible to generate a report (4) which supports decision making processes.

Simulation of the environment's reactions to the initiatives planned mainly allows for a quantitative comparison of the current state of matters with the chosen scenario. The comparison comprises the environmental effect of freight transport (emissions and noise) and includes forecasts pertaining to the means of transport used. For instance, a scenario which entails bonuses for those willing to buy an electric car while specific restrictions are introduced, making owners of vehicles with combustion engines pay additional charges for entering city centres, may force carriers to partially replace their fleets.

4. Advantages and expected impact

On account of its specificity and complexity, one may highlight a number of advantages of the system in question, such as the following:

- S-mileSys combines functions of multiple partial systems. Integration of various tools is the fundamental premise of the project and the system's main advantage;
- the system is easily accessible, as it requires no software to be installed on computers (it runs in a cloud and is accessed via a web-based interface); The only operation needed is one-time installation and configuration of a mobile application on the smartphones on board of the fleet vehicles;
- the system facilitates contacts between large transport companies (clients) and local carriers, thus enabling them to solve the first and last mile problem. Moreover, featuring a database of carriers, *Market Tool* enables pre-filtration of the database, and ultimately the system suggests all available options to clients (thus improving competitiveness of businesses);
- through application of criteria related to emission and noise, S-mileSys favours eco-friendly solutions in freight transport in urban areas;
- the advanced optimisation algorithms implemented in *Transport Planner Tool* and *Fleet Management Tool* improve transport efficiency (through minimisation of the number of vehicles used, emission, route length, time etc.);
- add-on modules (such as *Road condition tool*) increase the system's functionality (in this case, improving transport quality by choosing less burdensome routes);
- Big Data comprising information collected from all transfers provide local authorities with a rich source of data concerning distribution of freight traffic over the given city's road network, road pavement condition, total emission, noise, average speed, traffic loads etc. However, this aspect is usually neglected in contemporary solutions;
- based on the information thus collected, local authorities obtain a picture of the current status and are given opportunities to simulate situations following the changes they themselves propose.

However, it should be stressed that the system will gain peak efficiency once it grows in popularity and is commonly used. A task considered particularly difficult is to promote the system among local carriers that have already deployed other fleet management tools, since it always takes time to change one's habits. The more carriers subscribe to the S-mileSys system, the more data will be available to local authorities and the more competitive the services offered to clients will be.
Should S-mileSys be implemented on a broader scale within the chosen urban area, one may consequently expect an increase in terms of freight transport efficiency, emission reduction and air quality improvement. In a longer time horizon, the expected outcomes will include carriers changing their vehicle fleets into more environment-friendly ones (by fostering such solutions in the system and through the changes implemented by local authorities) as well as improved condition of roads, which will then translate into benefits for other users of the transport network (passenger transport).

5. Conclusions and further research

S-mileSys should clearly support large transport companies in operations performed within the first/last mile of transport. Points of cargo loading/unloading may be airports and sea ports as well as warehouses and logistics centres. Integration of tools increases the system's utility value. However, in order to reach full functionality, it requires being implemented by many carriers. To develop this holistic solution in border scale for freight transport services and delivery operations at selected area following steps were assumed:

- building database of airports, sea ports, railway stations as well as warehouses and logistics centres location (before implementation the S-mileSys at selected area);
- realization of numerous case studies profiled for selected large transport companies (as clients) and local carriers (as primary users) to promote the solution and building database of local carriers (in *Market Tool*);
- system implementation in local authorities (as priority users);
- start with special benefits programme together with local authorities (i.e. for carriers using more environmental friendly fleet).

An alternative solution (in case of only a few carriers will implement proposed system) may be data standardisation over numerous systems, in which case S-mileSys, being the subject of this paper, can extract data from other simultaneously deployed systems (e.g. for fleet management and monitoring), thus improving communication and expanding the range of data available to local authorities for analytical purposes.
It has been assumed that further research will comprise an attempt to integrate the system described in this paper with GTPlat (Celiński et al. (2017) and Sierpiński (2017)), being a system designed to assist passengers. Full integration of passenger and cargo transport will contribute to improved service effectiveness and better distribution of traffic streams over the transport network, while at the same time, a highly-developed simulation platform will allow for more comprehensive analyses pertaining to implementation of organisational and infrastructural changes in the existing transport system.

Acknowledgements

The present research has been financed from the means of the National Centre for Research and Development as a part of the international project within the scope of ERA-NET Transport III Programme “Smart platform to integrate different freight transport means, manage and foster first and last mile in supply chains (S-MILE)”.

6. References

Borkowski, P., 2017. Towards an Optimal Multimodal Travel Planner—Lessons from the European Experience. Advances in Intelligent Systems and Computing 505, 163–174.

Celiński, I., Sierpiński, G., Staniek, M., 2017. Sustainable development of the transport system through rationalization of transport tasks using a specialised travel planner, in: Transport Infrastructure and Systems. In: Gianluca Dell'Acqua, Fred Wegman (Eds.). CRC Press, Taylor & Francis Group, London, pp. 1071-1079.

Clean Power for Transport: A European alternative fuels strategy, COM(2013), 17.

Esztergár-Kiss, D., Csiszár, Cs., 2015, Evaluation of multimodal journey planners and definition of service levels. International Journal of Intelligent Transportation Systems Research 13, 154–165.

Földes, D., Csiszár, Cs., 2015, Route Plan Evaluation Method for Personalized Passenger Information Service Transport 30 (3), Special Issue on Smart and Sustainable Transport, 273-285.

Jacyna, M., Żak, J., Jacyna-Gołda, I., Merkisz, J., Merkisz-Guranowska, A., Pielucha, J., 2013. Selected aspects of the model of proecological transport system. Journal of KONES Powertrain and Transport 20, 193-202.

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

My Route Online Route Planner, http://www.myrouteonline.com

Pijoan, A., Oribe-Garcia, I., Kamara-Esteban, O., Genikomsakis, K.N., Borges, C. E., Alonso-Vicario, A., 2017, Regression based emission models for vehicle contribution to climate change. Advances in Intelligent Systems and Computing 505, 47–63.

Project Proposal, 2013, A platform to analyse and foster the use of Green Travelling options, The ERA-NET Transport III: Future Travelling.

Sierpiński, G., 2017. Technologically advanced and responsible travel planning assisted by GT Planner, in: Contemporary Challenges of Transport Systems and Traffic Engineering. In: Macioszek E., Sierpiński G. (Eds.). Lecture Notes in Network and Systems vol. 2, Springer, pp. 65-77.

Staniek, M., Sierpiński, G., 2016. 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 90, 11-21. ISSN: 0209-3324.

Sustainable Logistics and Supply Chains: Era-net Transport Flagship 2015 Call, 2015.

Tundys, T., 2017. The Impact and Role of Transportation on the Construction and Operations of the Green Supply Chain, in: Sustainable Transport Development, Innovation and Technology. Proceedings of the 2016 TranSopot Conference. In: Suchanek, M. (Ed.). Springer Proceedings in Business and Economics, Springer, Cham, Switzerland, pp. 15-26.

Urban Mobility – Research Theme Analysis Report, Communicating Transport Research and Innovation, 2016.

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.