Utilization of Internet application for visualization pollution in urban transport systems

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ABSTRACT

Transport is one of the main sectors of the economy, which has a significant impact on the economic development. Efficient transport systems are the basis of economic competitiveness. However development of transport, especially in the case of road transport, results many inconvenience, like negative environmental impact, accidents or increase of congestion in cities. From the perspective of sustainable development the most important one is pollution. Depending on the type of emitted substances, transport pollution is of local or global nature. Considering the emission of pollutants in urban areas, emitted toxic compounds mainly impact the local pollution the environment. This paper is focused on utilization of Internet tools for visualization of data regarding local pollutions in urban transport systems. This is the example of tool, which could be helpful in analysis of present functioning of UFT

KEYWORDS: urban freight transport, city logistics data visualization, freight transport management, sustainable development, local pollutions, transport environmental impact

1. Introduction

Economic growth in urban areas is connected with an increase in industrial production and trade turnover, which results in increasing goods flows and traffic in cities. In addition currently around 74% of Europe's population live in urban areas [11], and the urban share is expected to increase to 84% by 2050, adding further challenges to urban freight transport and last mile delivery solutions [8]. City freight delivery problems are caused by narrow streets on the one hand and still rising number of cars, passengers of public transport and pedestrians on the other hand. Due to increasing demands of the recipients, a urban freight transport also has the challenges associated with energy use, air quality (environment), increasing road congestion, road safety, disturbance and noise, and access restrictions combined with a general lack of loading and unloading space. In this framework, freight transport is a significant contributor to poor air quality and carbon generation in Europe.

Today urban areas face the challenge of making transport sustainable in environmental (CO_2, local air pollution, noise) and competitiveness (congestion, efficiency) terms while at the same time addressing social concerns. For that reason and also due to the increasing prices of petrol and natural gas, the stakeholders and users of urban freight transport are looking for other, new solutions as the alternatives for the internal combustion engine, such as eco-cars with electric drive.

Analysis of the local impact of freight transport on the environment associated with the emission of chemical compounds, directly affecting the health of people living in the city, such as nitrogen oxides, which have a similar impact on the human health as war gases, lead to lung damage and reduce the ability of blood to carry oxygen. The major problem in management of urban freight transport in the context of its environmental impact is the lack of data regarding the level of emitted pollution and availability of the information for final users.

2. The environmental impact of urban freight transport

Urban areas represent particular challenges for national and international freight transport, both in terms of logistical performance and environmental impacts (emissions, noise, accidents, congestion and land use). Urban freight is indispensable for the city's economy but at the same time freight deliveries significantly affect the attractiveness and quality of urban life. Typically, urban freight transport represents between 20 to 25% of road space contributing to between 10 to 20 % of urban road traffic [12]. The generally low load factor in distribution activities increase the total amount of freight-related traffic, and the commercial speed is usually low due to severe congestion in many urban areas.

Currently about 75 % of the European population live in town and cities [22]. It is predicted that by 2020 this number will increase to 83 %, and by 2050 about 2/3 of the world population will live in cities [16]. The key role of logistics in ensuring sustainable and competitive mobility in Europe is stressed in the mid-term review in White paper "Time to decide: 2010" [6]. A key part of the logistic challenges are connected to urban-interurban shipments and "last mile" distribution.

In the "Freight Transport Logistics Action Plan" [3], freight transport and logistics is said to possess an essential urban dimension. The Logistics Action Plan emphasises among other things that distribution in urban conurbations requires efficient interfaces between trunk deliveries over longer distances and distribution to the final destination over shorter distances. In addition, the distribution process between production centres and customers inside an urban area needs to be efficient and clean.

In the green paper, 'Towards a new culture for urban mobility' [7], the EC highlights the importance of the urban dimension of freight transport, and the need for efficient interfaces between long and short-distance freight transport. Possible solutions proposed include the use of smaller, more efficient and cleaner vehicles, improved load planning, consolidated distribution, zones with access regulations, and institutional reforms with increased integration of multiple stakeholders in local policy-making.

In the Action Plan on Urban Mobility [2] the Commission explains that it intends to provide help on how to optimize urban logistics efficiency, including improving the links between long-distance, inter-urban and urban freight transport, aiming to ensure efficient 'last mile' delivery (Action 19). Another focus in the Action Plan is how to better incorporate freight transport in local policies and plans, and how to better manage and monitor transport flows.

Also the energy consumption related to transport will increase by about 30% by 2030. The increasing growth of urban freight traffic has substantially affected the quality of life of urban residents. The negative impact on the environment resulting from rising traffic volume includes noise, pollution, congestion, accidents, use of non-renewable fossil fuels, loss of greenfield sites and open spaces as a result of transport infrastructure development and increasing amounts of waste products, such as tyres, oil and other materials. The external costs (including the environmental impact) caused by urban freight transport in European cities are estimated to several tens of billions of euros.

The analysis of environmental impact of UFT is mainly focused on pollution emission, which is depended directly on energy (usually fuel) consumption and noise emission level. The analysis of emissions from road transport usually takes into account the level of CO_2. This approach is justified in the global context only [1, 10, 20]. From the city perspective and influences on city dwellers (taking into account the chemical compounds directly related to the health status of the city population) most important are local pollutants, which include mainly:

- carbon monoxide (CO), which is an odourless and colourless gas with highly toxic properties,
- nitrogen dioxide (NO_2) - brown, highly toxic gas with a pungent odour;
- hydrocarbons (HC), which include carcinogenic compounds;
- particulate matter (PM) in the form of carbon-graphite compounds, ash and soot.

Finally, the increase of freight demand at urban areas as well as the environmental impact of freight traffic influence in significant manner on quality of life at urban areas [21].

The negative impacts of urban goods distribution are mainly caused by used vehicles (e.g. diesel-powered) and low system efficiency (e.g. low loading factor, low cooperation). So it seems to be most important to implement the local policies based on reduction of energy consumption in freight transport, decreasing the number of transported kilometres in urban areas by freight transport vehicles as well as using the environmentally friendly engines for the last mile freight delivering, reduction of pollutants (e.g. CO, CO_2, NO_x, particulate emissions) emitted by goods vehicles, increasing the number of low and/or zero emission freight vehicles circulating in urban areas (expected to be electrically powered), reduction of the number of freight vehicles in the urban areas (especially in city centres) by implementing restrictive measures for the most polluting and heavy freight vehicles, improving the cooperation at the local level among the relevant stakeholders, as well as removing non-technological barriers, promoting public-private initiatives etc.

The most effective activities of a sustainable transport policy in urban areas are considered the ones which reconcile the three dimensions of sustainability (economic, environmental and socio-cultural), whilst minimizing the costs associated with achieving the desired goals. The environmental aspect includes the pollution, especially greenhouse gases and carbon dioxide emissions (consumption of non-renewable fossil fuels contributes to the generation of waste such as tires, oil, etc.). The goals of sustainable mobility policies in the environment area mainly include [17]:

- combating climate change by reducing greenhouse gas emissions to the extent determined by the general reduction targets: by 2020 – 40%, 2030 – 50%, 80% by 2050 (145 million tons) compared to 1990, or alternatively: by 2020 – 20%, 2030 – 30%, 50% by 2050 with respect to 2005;
- taking into account the nature of the tolerance limits – limit the use of land for housing and transportation goals from the current 129 ha to 30 ha per day in 2020 and to 0 in 2050 (at that time recycling of land will only be possible);

- the use of renewable resources – by 2020 the use of non-renewable resources, not produced in accordance with the principles of sustainable development, should be reduced to zero;
- reducing the use of non-renewable virgin materials by 40% by 2020 and to 80% by 2050 compared to 1990-1994;
- reducing the health risks by maintaining the limit values adopted by the EU for fine dust nuisance and NO_2 and reducing road traffic noise in residential areas.

The most important problem in analysis of the environmental impact of urban freight transport is lack of data. The principal effectors of the barrier in obtaining data within the urban freight system include the following facts [19]:

- urban deliveries involve mainly private companies, which usually do not want to share data on their transactions, supplies and transported goods with their competitors and the public sector (it is, of course, observed not only in the case of transport within cities, but also in interurban, national, or international transport);
- there are no standardized research methods in the field of urban freight deliveries.

A certain solution to solve the above problems is the use of the independent system, which will make it possible to collect the data apart from the logistics operators and freight vehicles drivers. The basis of this kind of solution could be the telematics technologies based on motion detection and classification of vehicles. These systems allow for making measurements, which are non-invasive, undetectable for drivers and independent of freight companies [13].

The other problem related to the usability of data regarding urban freight transport environmental impact is the deliverable the information to final users. Taking to the account the mentioned above expectations of EC, it's valuable to share it on free of charge public system. It was one of the major assumptions of project GRASS (GReen And Sustainable freight transport Systems in cities), which is financed under the grant from Norway through the Norwegian Financial Mechanism 2009-2014 – Polish-Norwegian Research Programme. The major aim of GRASS project is to support municipalities in implementation of sustainable Urban Freight Transport measures in accordance with the expectations of different stakeholders groups and requirements regarding utilization of technologies that limit the negative impact on environment [9]. Project is realized by two partners – Maritime University of Szczecin (Department of Logistics and Transport Systems) from Szczecin, Poland and the Institute of Transport Economics from Oslo, Norway.

3. The web-based application for visualization the pollution in urban transport systems

3.1. Major assumptions for application in GRASS project

The objective of the work package named "Modelling of transport pollution propagation in urban areas", realized under the

GRASS project, is the preparing of the model of transport's pollution propagation at the urban area and implementation of it on free web-site for unlimited use by transport and logistics operators.

Based on the result of data collection process realized under the other project work packages, the model of urban freight transport pollution propagation was prepared. Pollution propagation model for road network is described by a number of variables related to the traffic of vehicles, the types of vehicles as well as the environmental and weather conditions. Therefore, during the traffic detection process it was necessary to classify vehicles into categories, which forms the basis for determining the characteristics of the emission. Two mobile traffic detectors Sierzega SR4 helped to divide vehicles into four categories: motorcycles (length to 20 dm), passenger cars (length between 20 and 60 dm), trucks (length between 60 and 95 dm) and long trucks (length between 95 and 255 dm). In addition, in order to simplify the system, modelling was performed for a constant average speed of vehicles in a given road section, which allows for assuming a constant emission intensity over the entire length of the road for the given vehicle category. Delimitation of the analysed area in Szczecin was focused on two factors:

- accumulation of entities in the particular area that generate increased demand for transport – according to data from the Regional Inspectorate for Environmental Protection, NO_2 concentration level in Szczecin is focused around the downtown area and the highest concentration of NO_2 exceeding 120 mg/m^3 occurs, among others, within the Centre and the Old Town;
- analysis of the number of commercial entities, taking to the account retail entities, HoReCa, service entities, production plants – the basis for this analysis were the results of the research described in [4] and survey realized at the chosen area of city centre.

Finally the 8 road section were chosen for the detailed analysis and involvement in the planned model and on-line tool (Fig. 1).

Fig. 1. The analysed road sections in the centre of Szczecin [own study]

3.2. The system architecture

Building information solutions the most important challenge is the proper identification of the needs. These needs, called requirements, allows to specify what a system should be, what

features it has to have. The requirements, in the first stage of collection, are typically stored by words. In complex systems such form is converted into the graphic form, using UML. The possibility of graphic representation of the functional requirements of the system, is undoubtedly one of the biggest advantages of UML. This article uses two structures of UML: DFD – data flow diagram (Fig. 2) and the use case diagram (Fig. 3).

Figure 2 shows a data flow diagram, which is a tool for describing, analysis and design of the system presented in the paper. In graphical way presents the basic relationships occurring in the information process, wherein the advantage of DFD is to simplify the used symbols. There are only 4 symbols: process (P1, P2, P3), data warehouse (matrices and visualization matrix configuration), data flow (arrows) and the terminator (the client).
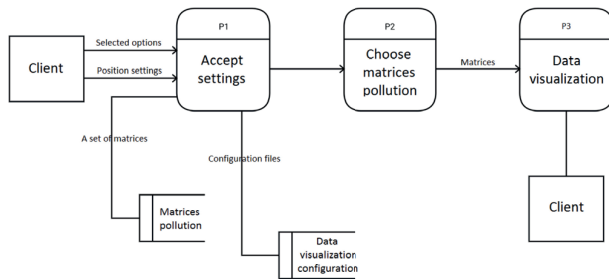

Fig. 2. The Data flow diagram of presented system [own study]

Use case diagram is a diagram that shows the functionality of the system and its surroundings (Fig. 3). It allows to graphical representation of the system properties in the way, as they are seen from the user side. They are used for imaging of services, which are visible from the outside of the system. Use case diagram, even though it is made up of several elements, it plays the most important role in the design of the system; in fact it describes the functional requirements, which the system must meet, and the environment in which it is located. This diagram is an aggregate of the function of services which the system is doing. Out of specification, this diagram allows the identification of system functionality, verification of progress in modelling and implementation, and also supports the communication between the participants.
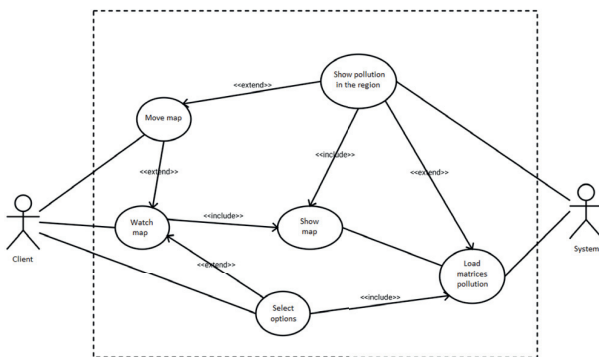

Fig. 3. The use case diagram of presented system [own study]

One of the most important features, which is described by the use case diagram, there is the flow of events - scenarios that show a set sequence of successively executed operations designed to achieve the functionality depicted by the specific use case. In the diagram shown in Fig. 3 use cases are: scroll the map, view the map, view the pollution in the region. Using these scenarios were able to present a basic set of operations, which reflects the expected sequence of events. The recipient of these events and the initiator is the actor. The actor is a role that holds user to the system and use cases. An actor can be a human, device or another system.

UML diagrams allowed the relevant grouping of events occurring in the system. The next important factor was to determine the requirements. It was assumed that the application will be made in web technology, enabling access to users from any device operating under the control of any operating system (prerequisite is to have installed a web browser). The application is designed to visualize the level of pollution generated by urban freight transport.

The web application, prepared under the introduced activities, has modular structure (Fig. 4). Each modules are connected according to the logical processes of data analysis and final information presentation on the web-site.
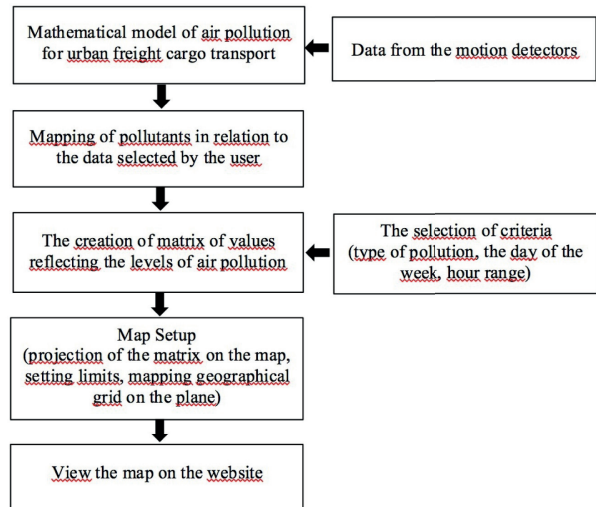

Fig. 4. The modular structure of the application [own study]

3.3. User interface

The main application window, with the exemplary results, is shown in Fig. 5. On the left side there are the values (types of pollutants - CO2, NOx, CO, days of the week, hour range and direction of the wind), which setting determines the results displayed on the map presented on the right side of the application window. Pollutants are depicted as small squares adjacent to streets, where the measurements were conducted. Each of the squares has a specific colour and presents the level of calculated contamination for a particular section of the street. The heart of the application is a mathematical model that calculates the values displayed on the map, based on data taken from detectors road.
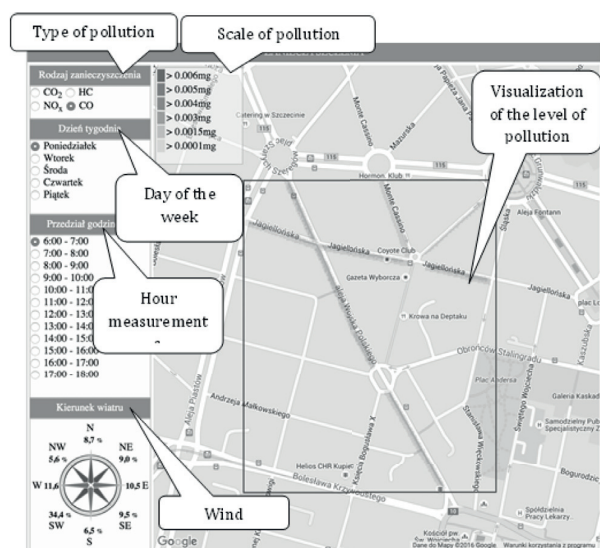
Fig. 5. The result of the application for the level of carbon monoxide (CO), metered Monday in the hours of 6:00-7:00 am [own study]

4. Conclusion

The analysis of environmental impact of transport systems in cities are mainly focused on the level of CO2. This approach is justified in the global context only. From the perspective of influences on city dwellers most important are local pollutants, which include among others carbon monoxide (CO), nitrogen dioxide (NO2), hydrocarbons (HC) and particulate matter (PM). It was the basic assumption for analysis introduced in this paper and realised under project GRASS. One of the major objectives of this project is to prepare a model of urban freight transport influences on city environment and preparing of the web application, which will provided information regarding some chosen pollution at analysed road sections in Szczecin city centre. The model covered simulation of the distribution of pollutants for vehicle traffic stream in a communication network of the city centre.

The results presented in this paper are based on the B-test version of application. In the next stages the final version will be prepare and available on web site grassproject.eu as the free of charge tool. This application could help to assess the environmental impact of UFT for analysed city area taking to the account different conditions, like kind of pollution, day and time as well as the average wind direction in Szczecin area.

Acknowledgements

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