TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
MECHANICS | MECHANIKA
1-M/2014

PAWEŁ WIĘCEK*, AUGUSTYN LORENC**

INTEGRATED, SUSTAINABLE APPROACH TO THE MANAGEMENT OF URBAN FREIGHT TRANSPORT – REVIEW OF THE WORLD'S SOLUTIONS

ZINTEGROWANE, ZRÓWNOWAŻONE PODEJŚCIE DO ZARZĄDZANIA MIEJSKIM TRANSPORTEM TOWARÓW – PRZEGLĄD ŚWIATOWYCH ROZWIĄZAŃ

A b s t r a c t

The purpose of this article is to propose the concept of an integrated system-wide approach to the management of urban freight transport. This work also addresses the aspects of environmental and social impacts from the road freight transport in a confrontation with modern and eco-efficient solutions in this area taken in cities areas the world.

Keywords: *freight transport*, *integrated transportation and logistics systems*, *city logistics*

S t r e s z c z e n i e

Celem niniejszego artykułu jest przedstawienie koncepcji zintegrowanego podejścia systemowego do zarządzania transportem towarów w obszarach miejskich. W szczególności poruszono problematykę niekorzystnych oddziaływań środowiskowych i społecznych, pochodzących od transportu drogowego towarów i dokonano przeglądu nowoczesnych i efektywnych ekologicznie rozwiązań w tym obszarze, podjętych w światowych metropoliach.

Słowa kluczowe: *zintegrowane systemy transportowe i logistyczne*, *logistyka miejska*

* M.Sc. Eng. Paweł Więcek, Institute of Management in Construction and Transport, Faculty of Civil Engineering, Cracow University of Technology.
** M.Sc. Eng. Augustyn Lorenc, Institute of Rail Vehicle, Faculty of Mechanical Engineering, Cracow University of Technology.

1. Introduction

Over the last few decades, the rapid development of science and technology began a process of fast population growth in the world. Man, who until now has been a neutral part of the perfectly balanced environment is, **now its** major threat. Along with economic growth and intensifying globalization processes, higher levels of the consumption of goods and services can be observed. This results in increasing freight traffic **which** adversely affects the environment and human surroundings. The common consumer lifestyle and the dynamically changing demand for goods and services poses producers and suppliers with high requirements in the field of transport and logistics activities. **Especially** in heavily urbanized area in the centers of large cities, they have to ensure a satisfactory level of customer service, **simultaneously taking into account the** environmental aspects.

2. The volume of road freight transport in Europe and its negative environmental impacts

According to the latest report of the Department of Economic and Social Affairs of the United Nations, strong urbanization processes taking place during the last century caused a significant increase in the number of residents in the cities. In 2009, nearly 3.5 billion of the total world's population lived in urban areas. Many forecasts suggest an extension of this number to about 4.5 billion by 2020 and to 6.3 billion by 2050 [16]. As a result of this trend, there is an urgent need for the supply of goods in different cities, which also translates into growing traffic congestion. Fig. 1 shows the amount of cargo transported within the European Union with regard to different modes of transport.

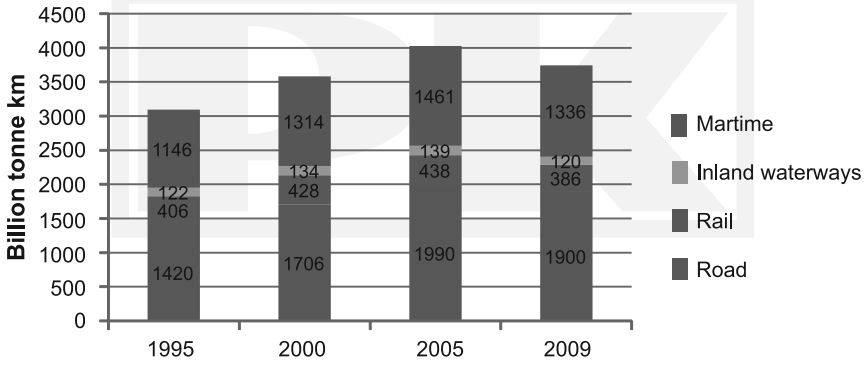

Fig. 1. Number of transported goods in the EU, depending on the modes of transport [4]

The interpretation of this graph shows that road transport continues to be the dominant branch in freight transport within the European Union. The main proof of this fact is that transport activity amounted to 1.9 billion tonne-kilometers in 2009. Also in Poland, road transport plays the most major role in the movement of freight and its level constantly increases, see Fig. 2.

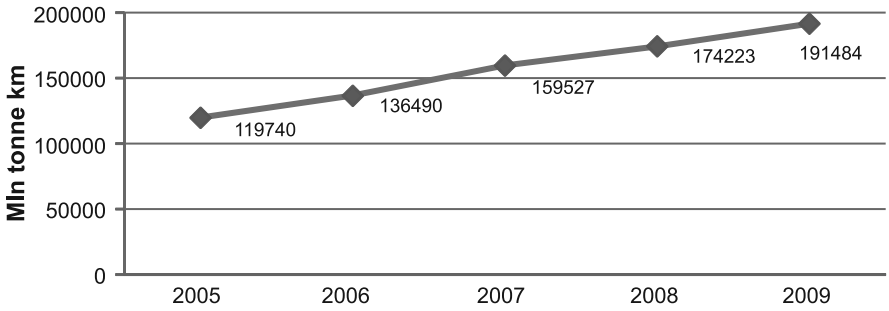

Fig. 2. Freight transport in Poland in the years 2005–2009 [6]

2.1. The impacts of freight transport on the environment

The growing traffic presents simulate certain inconveniences to the local population, contributing to congestion, deterioration of safety for pedestrians and private vehicles and lowering the quality of life in the city. Road transport is on the top of the list of different types of human activities that lead to environmental degradation. Its direct risks come under three separate categories: social impacts; economic impacts; environmental impacts, see Fig. 3.

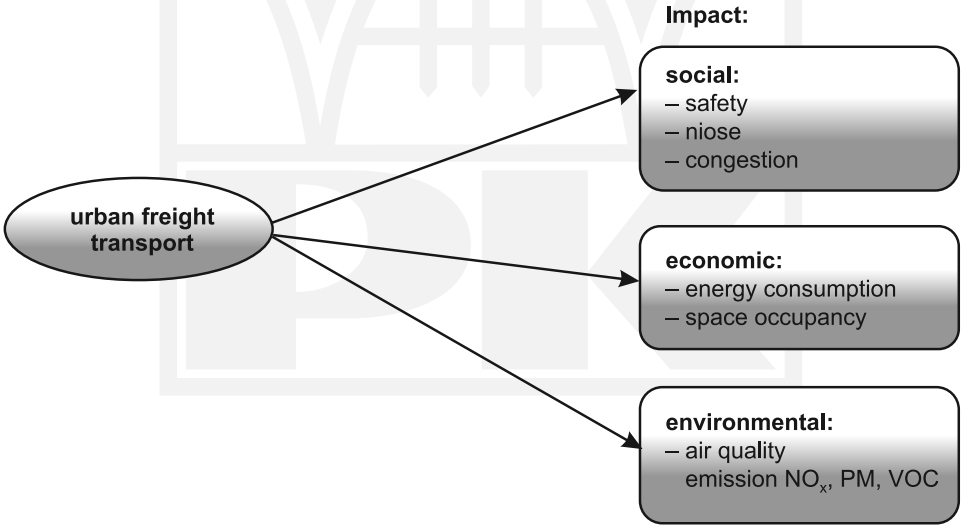

Fig. 3. Impacts of road transport on different environment

2.2. The impacts of freight transport on human health

The most serious impacts to human health is pollution emitted to the atmosphere by road transport. It contains mainly oxides of nitrogen, benzene and carbon, volatile organic compounds (VOC), and particularly dangerous emissions of particulate matter (PM).

Mixtures of these contaminants tend to change over time and space, depending on a number of features, such as close proximity to the road, the type and age of the vehicle, traffic patterns, and the presence of other sources of contamination. Short or long term exposure to these compounds in the air can lead to very adverse health effects immediately or in later years, in the form of the respiratory, nervous and cardiovascular diseases, as well as cancerous changes. According to measurements made by the WHO, vehicles still produce a large share of the emission of toxic compounds [9].

Other negative effects of road freight transport are related to noise and vibration. Nowadays, traffic noise is a serious threat to peace within the major cities and roads. It has a negative impact on health and human working conditions. It is believed that a noise level of upto 30 dB is harmless to the human body, but the level of 34–70 dB causes various concentration difficulties. Above these values, noise is dangerous to health. The above problems will be intensified, because of traffic level increase within the city. It is largely caused by motor vehicles from four main sources: the drive line system: engine; exhaust system: tires interacting with the substrate. In many passageways, noise magnitude depends mainly on commercial vehicles. Often, it is assumed that in terms of noise, one truck is equivalent to eight cars [8].

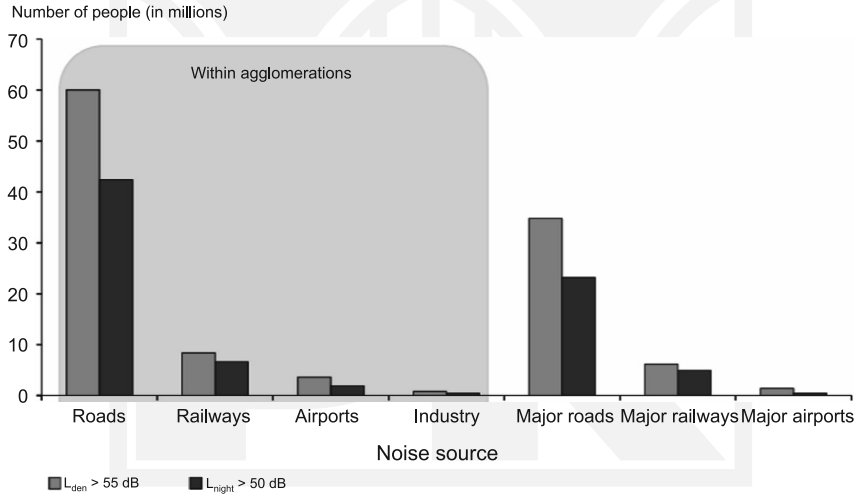

Fig. 4. Number of EU population living in urban area exposed to increased noise level [4]

According to the European Environment Agency, a large part of the EU's city population still live in conditions of exposure to elevated noise levels, see Fig. 3.

3. The proposal of an integrated approach to freight transport management in urban areas

The rising level of consumption of goods, the aforementioned negative environmental and social effects of transport, as well as increasing customer demand for logistics services currently make freight management problems in large metropolitan areas

a matter of particular importance. It is the result of the fact that effectively functioning freight transportation system conditioned to a high degree the economic development of cities. Transport activity within large urban complexes underlie the concept of city logistics.

This concept is defined as the process of total optimization of all transport and logistics activities by transport companies including the external environment, congestion and energy consumption in a market economy [14].

Current environmental awareness is a cause of increasing social demand for more sustainable and eco friendly urban transport. According to this evidence, an integrated approach to freight transport management in the city is becoming more and more popular in the world. The overall objective of this concept is to increase the efficiency of transport processes and the distribution of goods, expanding and enhancing services, simultaneously taking environmental issues into account.

The innovative basis for this approach is the fusion of each solution from three directions: logistical innovation, policy factors and technical improvements. It should be considered that each of those elements cannot be treated separately, but should interact with others in integrated way. This means consistent and complementary action of public and private entities in the supply chain network, despite their frequent conflicts of interest [11].

In a wider perspective, presented in a number of scientific papers, integrated and sustainable approach to logistics and transport activities is also recognized in the context of the entire supply chain, because in the long run, it allows for the achievement of even greater benefits. It is commonly believed that a sustainable eco-supply chain promotes efficiency and synergy among its participants, helps to increase eco-efficiency and quality of service while minimizing the economic and social costs [13]. Therefore, the approach to an integrated, sustainable transport of goods in urban areas in the context of the entire supply chain networks can be illustrated by the following graph. See Fig. 5.

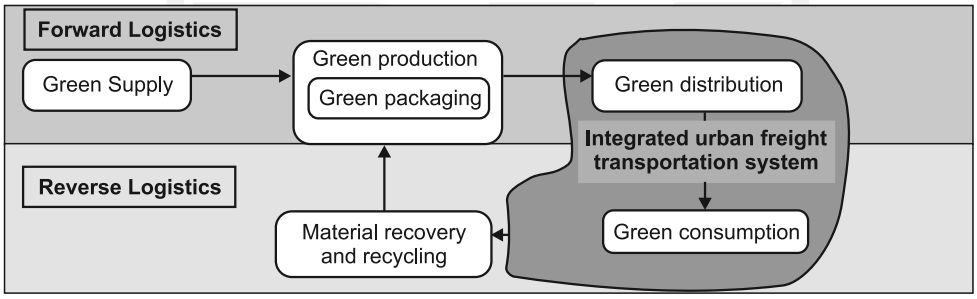

Fig. 5. Integrated, sustainable urban freight transportation system in the context of the whole supply chain network

In line with the vision of sustainable transport of goods, the activities carried out in this area requires the tasks of both forward and reverse logistics.

3.1. The integrated problems of logistics and freight transport in cities

In order to make the transportation system more sustainable and friendly to the environment as well as the urban population, it is essential to make a careful examination of the system's built and of its principles of operation in the context of identifying the problems and providing later solutions. A significant number of published work in this area indicates an important aspect, the presence of many groups of stakeholders, which include: shipping companies; storage companies; transport and courier operators; residents; municipal authorities. Each of these is in an attempt to achieve its objectives, which are often different. Therefore, the level of effectiveness of the logistics and transport operations is often reduced as a result of insufficient interactions between the actors of the system. The quality of the tasks carried out in the area of urban freight transport is also associated with solving various kinds of decision-making problems with different time horizon. The following levels can generally be identified:

- **strategic level**: Decisions made at this stage relate to the long-term issues consider the optimal transport and logistics network structure(centers of logistics and recycling, warehouses, fleet vehicles type) and other organizational and management tasks, which provide financial and economic efficiency. At this level, its initiatives and actions may be taken also by the municipal authorities.
- **tactical level**: Decisions at this level are related to the assessment of the efficiency and effectiveness of use of the transport infrastructure and reliability of supply. In this layer, transport companies take questions choice of equipment, vehicles, infrastructure for the exchange of information and data processing. At this stage there are analysis of the system behavior under uncertainty, incidents, changes in traffic and demand conditions, using mathematical and simulation tools.
- **operational level**: Activities carried out at this level are short term, they are often done from day to day. For example, the task of scheduling and time synchronization processes in warehouses, logistics centers; the issue of optimal allocation vehicles, choice of routes and the sequence of customers visited, including their time requirements.
- **the level of real-time control**: This layer provides some control over the tasks scheduled at the operational level. At this level, decisions and actions are made in real-time when there is a need for a dynamic response to a situation in which there are differences between the planned situation and the state of the transport system in reality. Activities at this stage depend to some extent on the decisions taken at a higher layer. They are sensitive to the quality of operational scheduling, where inefficiency predictions and forecasts can lead to costly changes planned activities through real-time layer.

3.1.1. The role of urban consolidation centers in an integrated urban freight transportation system

According to J. Allen, an important part of the functioning of an integrated and sustainable transport system for goods is an appropriate logistics network structure, taking into account the existence of urban goods distribution centers. Situated on the outskirts of the city, they are designed to manage their assigned areas. A consolidated flow of goods from different companies is brought to customers with smaller, low-emission vehicles. This type of center

offers the possibility of storing, sorting, consolidation of cargo groups and other services related to accounting, or legal advice through. Undertaken numerous projects including Italy, Sweden, it indicates a reduction in the total number of kilometers made by nearly 30%. The use of such a solution, however, requires complex cooperation between companies in the planning of tasks and procedures, as well as support for advanced information and telecommunications systems [2].

3.1.2. The aspects of information management in the transport of goods

A key element of an integrated transportation system is the acquisition, processing, management and exchange of data and information, not only within a single company, but also between all the actors in the supply network. Of particular note deserves a real time information, collected and kept updated. From the point of view of system performance, such data relates primarily to the current level of congestion, travel time, service and incidents. From the perspective of customer needs, there is information on the changes in demand, time windows, etc. This allows for effective planning, controling and monitoring of all the processes taking place in the transport and logistics network. To this end, the integrated use of the latest achievements in the field of electronics, telecommunications, advanced positioning systems, data processing and vehicle technologies is becoming more and more common. This gives a basis for the development of sophisticated applications and ICT systems (Information and Communication Technologies), used in the management of transport, logistics and fleet operations. See Table 1.

Table 1

ICT systems used in freight transport

Type:	**Tools and technologies used:**
On-board systems	– GPS, AVL, navigation and automatic vehicle location, – mobile internet, PDA (Personal Digital Assistants), – ADAS (Advanced Driver Assistance Systems) support of drivers's work, – RFID (Radio Frequency Identification) identification of freight, – Smart cards, electronic tachographs, storing information about the level of load, – on-board sensors, monitoring the condition of the vehicle, transported goods, speed, automatic toll collection.
Off-board systems	– CAD (Computer Aided Dispatch) computer support shipments, – FMS (Fleet Management Systems), comprehensive tools to control, fleet coordination, allocation of means of transport, optimization of capacity utilization, – EDI (Electronic data Interchange), standardized electronic exchange of transaction documents, – DSS, ES (Decision Support Systems, Expert Systems), decision-making tools to support the planning and management.

Management of information in an intelligent way, using ICT systems can have a positive effect on economic issues for transport and logistics companies. It may increase the competitiveness of services, reduce the number of kilometers traveled by vehicles, as

well as improve decision-making processes at various levels and companies capabilities of a dynamic response to changes in the network. It should also recognize the positive impact on enhancing road safety, reducing road traffic congestion and improving local air quality [7].

With regard to aspects mentioned in this paper, the proposed concept of an integrated, sustainable approach to transport goods in an urban area can be represented by a diagram. See Fig. 6.

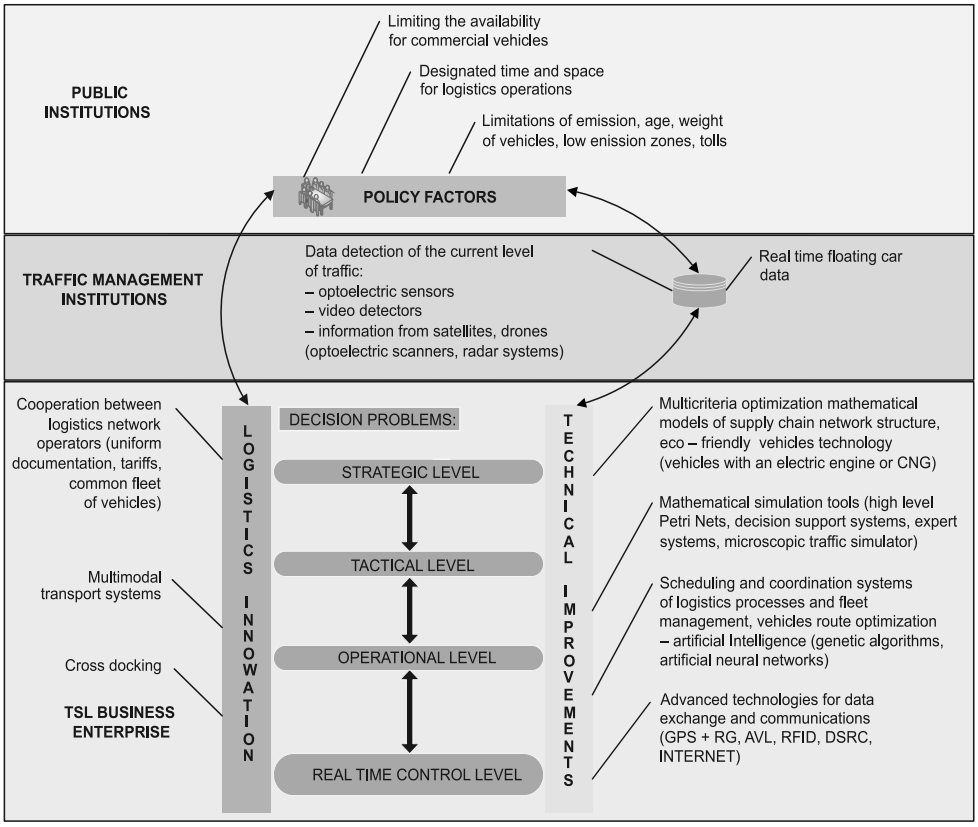

Fig. 6. The concept of integrated and sustainable approach to freight transport in urban areas

The above figure shows how this system can be seen in the context of decision making, tasks and innovation. The three most important factors determining the effectiveness of such an approach (logistics innovation, technical improvements and political factors) cooperate and interact with each other, ensuring a consistent system. The interconnection of these components results in apparent interaction and integration of entities engaged in transport and logistical activities at the organizational, infrastructure, telecommunications and information technology level. The functioning of the system under consideration can be described by using the following conceptual diagram (see Fig. 7).

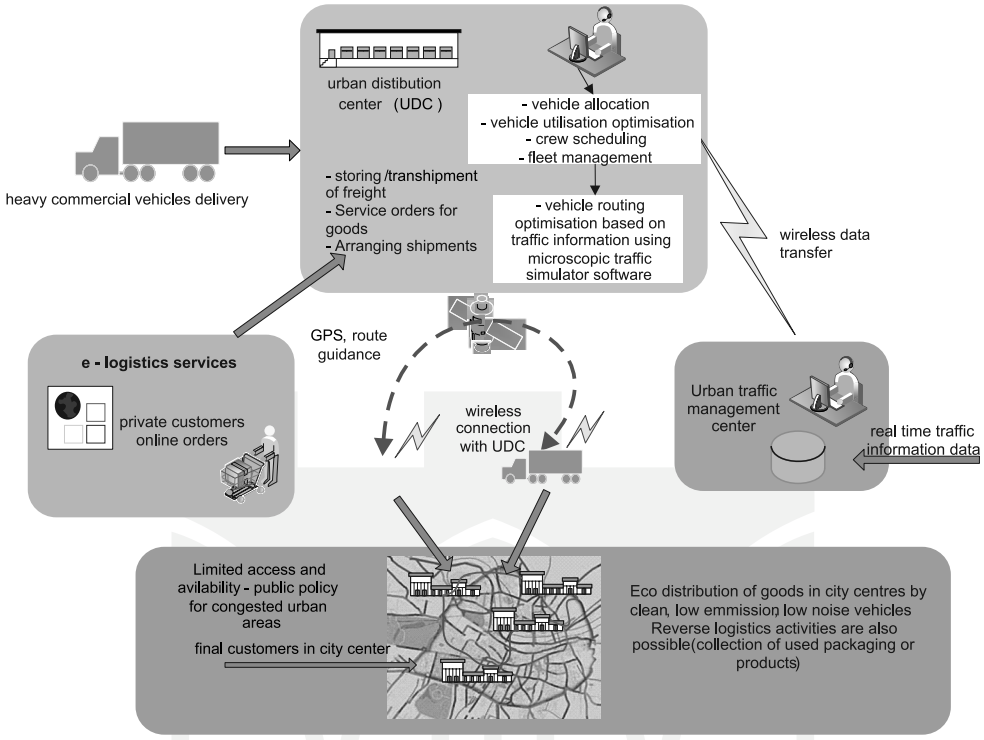

Fig. 7. Functional architecture of the proposed integrated sustainable freight transport system in urban areas

The result of the implementation of the presented approach to the transportation and distribution of goods in the city is a real opportunity to reduce the impact of unfavorable factors of transport for the immediate environment as well as a chance to limit operating costs and transport operators to increase the level and reliability of services.

4. Overview of the key solutions and projects in the field of integrated and sustainable urban freight transport

Social and environmental nuisances from increased freight traffic has gained special importance in practice. Evidenced by the wide range of initiatives in this area in recent years in many metropolitan areas in the world. J. Munuzuri in his work decides to distinguish basic categories of activities undertaken in this area. The most important of these include:

– **solutions for the infrastructure and coordination of traffic** (expansion, modernization and adaptation of existing infrastructure for the city logistics hubs to support the creation of combined transport),
– **solutions for optimal space management** (allocation of new land for logistical purposes, operations of loading or unloading),

– **solution in relation to the conditions of access** (entry and movement limitations of vehicles in the protected areas, the time limits in which vehicles are allowed to enter the zone).

The author draws special attention to the importance of combined actions and use of the benefits from different categories in achieving the desired objectives for an integrated and sustainable transport solution [10].

4.1. Solutions related to the management of urban areas accessibility

London – Low Emission Zone

In response to the deteriorating air quality due to high traffic, the city authorities in London decided to designate the zone of reduced emissions – LEZ. It is defined as a space into which permission to enter is given only to vehicles that meet the appropriate criteria and EURO emission standards. The main purpose of this solution is to reduce the area of impurities originating from the vehicle as well as promoting the use of environmentally-friendly vehicles. There is a daily charge for carriers whose vehicles do not meet the requirements, and move within the zones, or perform logistics operations. The restriction zone covers most of London and is specially marked. It includes trucks, vans, buses and light commercial vehicles entering the area. In order to control the emission criteria duty vehicles within the zone ANPR (Automatic Number Plate Reading) system is installed. It uses specialized cameras to monitor the area. The result of this project was a reduction in the total emissions of particulate matter (PM) of about 6.6% and a significant decrease in NO_x emission in 2012. In the restriction covered area, the forecasted drop of NO_x and PM emissions in 2012 amounted to 14 and 20% [15, 17].

Stockholm – vehicle tolls in the city center

Stockholm is the second city after London in which, after testing and the referendum decided to introduce a system of large-scale fees for vehicles traveling in the city center (private cars and vans). The main objective of the project started in 2006 was a global reduction in traffic and emissions. An important, element worth emphasizing is the cooperation and involvement of many stakeholders in the implementation of the system, including the Swedish Road Administration, local city government and IBM company responsible for providing technology. As in the case of LEZ in London, there is a camera system used to identify vehicles. The fee is made electronically. The current results of the system are the reduction of the overall level of traffic within the city by about 20% during peak hours and the reduction of travel time by 30%. There is a significant improvement in mobility and facilitation of the process of goods distribution [3].

Copenhagen – adjust availability of trucks in the city center

In the beginning of 2002, the Municipality of Copenhagen decided to implement a mandatory certification system for vehicles delivering goods within the city center. The aim of the project was to reduce the negative environmental impacts caused by the movement of goods in the center and at the same time making the narrow medieval streets of the city more accessible by increasing the capacity and reducing the number of delivery vehicles. The basis of the project was certified vehicles carrying logistics operations in the city

center. Three types of certificates (green, yellow, red) were established. The green certificate as the main type of license which indicates permission to enter the center and perform unloading or loading in specially reserved areas for commercial vehicles with a capacity of 2.5 to 18 tons, and using in the three-month period, an average of at least 60% of load capacity. Yellow is an option for operators who cannot meet the requirements of a green certificate. Red is dedicated to those providers only occasionally coming to the center and is valid for 1 day. Analysis of the results showed an increase in capacity utilization of vehicles, and this type of system only slightly contributed to a reduction in the level of traffic within the city center [5].

4.2. Solutions related to the infrastructure

Nijmegen – urban goods consolidation center

In 2008, Nijmegen, due to the deteriorating air quality and enhancing the movement of goods within the city, an initiative for the creation of a goods consolidation center appeared. The owner and administrator of the center was a company that provided logistics services for retail stores in the city center. The consolidation center can be used by operators who have declared their willingness to participate in the project. The distribution center was located on the outskirts of the city, where consolidated goods from suppliers were transported to customers through the individual stores with smaller vehicles powered by natural gas. Thus, heavy commercial vehicles had no need to enter the city center. In addition to the supply of goods to the store, the distribution center also offered a collection of packaging, storage and the ability to deliver items to private customers. During just the first year of the project, about 100 retailers joined, which resulted in a decrease in the total number of truck kilometers and a shortening of travel time by 5%. The total number of stops (unloading, loading) by logistics vehicles decreased by 7%. According to reports, this type of initiative also had a positive impact on improving the living conditions in the city by reducing pollution from vehicles and limiting noise [12].

Paris, Amsterdam – multimodal transport system for the distribution of goods

In recent years, due to increasing problems of congestion, the distribution process in many European cities has become more inconvenient. This is why more and more often, the concept of multi-modal integrated freight transport in urban areas is subjected to testing and analysis. There are some examples of initiatives and projects which try to reduce the role of road transport in favour of rail transport. At the beginning of 2008 in Paris, one of the retailers, Monoprix, decided to enter the solution, which is based on a combination of road and rail transport modes. A key element of the solution is to consolidate the flow of goods in the two warehouses located on the outskirts of the city. Then, using the automatic transshipment, pallets with goods are directly loaded on to a specially designed cargo train, which uses the public railway infrastructure, brings them into the city to the transshipment hub, from which, goods are delivered to 90 Monoprix stores shops, with a smaller fleet of low-emission vehicles. A diagram of the system is shown in Fig. 8.

The adopted solution resulted in limiting the negative effects of the urban distribution of goods throughout the Paris region. The most important is the reduction of total truck

distance traveled in Ile de France (700 000 km/year) which in turn helped in the saving of up to 70 000 liters of fuel and reducing CO_2 and NO_x emissions by 340.000 and 25 tones [1] respectively.

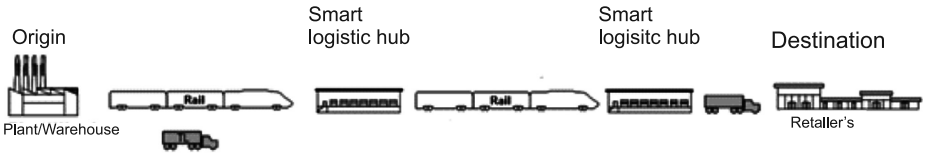

Fig. 8. Example of multimodal distribution system of goods retailer

A similar project in the use of rail transport as an alternative branch in the distribution of goods was carried out in Amsterdam in the period 2007–2008. The city had to replace about 2.500 to 5.000 vehicles entering the center every day by using special trams to carry the goods. On the outskirts of the city, where the tram lines end, special terminal nodes were prepared for handling the goods. Then, trams loaded with the goods travelled into the city, using four fixed routes to 15 points of transfer, where containers of goods were handled in small electrically powered vans and shipped to the stores (Fig. 9). A single tram was able to transport the amount of cargo comparable to that of four heavy goods vehicles with a capacity of 7.5 tones.

Fig. 9. Cargo tram project in Amsterdam [20]

Estimates of the project impact on the environment showed a reduction of particulate matters and nitrogen oxide by about 16%. Another element was the local noise reduction through the use of trams which are quieter than conventional vehicles [18].

4.3. Solutions for optimal space management

Barcelona – multi use lanes

In recent times, the urban space management in the context of goods distribution is becoming increasingly important. The fundamental objective in this case is the effective use of road infrastructure in urban areas, taking into account the specific needs of the distribution of goods. Road infrastructure management, in terms of time and space, was an issue for transport planners in Barcelona. In areas with intense traffic and large trade, in order to improve the availability and supply of goods, the municipal authorities decided to create additional lanes so called (multi use lanes) along the streets, dedicated to the appropriate groups of users over the time. Lanes are designed for ordinary vehicle traffic from 8–10 am. In the period between 10–17 pm, logistics operators can perform unloading of goods, and during the 17–21, loading operations. Then, till 8 am the next day, lanes can be used as a car park for local residents. These multi use lanes are specially marked with signs of VMS technology (Variable Message Signs), to display current information about the purpose of the lanes in the specified time. The second type of marking are bright lights that turn on when the lane is reserved for logistical operations. The main achievement of the implementation of the project was to reduce travel times for logistics operators by about 15% and bring about a significant improvement in operating conditions in these areas. Initiatives to improve the supply of goods in the area of effective space management have also been taken in other European cities such as Bordeaux, Aalborg and Bremen [19].

5. Summary

An integrated, sustainable system-wide approach to the transporting of goods in the urban area presented in this paper with a number of European projects and initiatives taking into account the assumptions of the concept, shown a strong current tendency to develop innovative ways to make the logistics and transport in Europe more environmental friendly. The working solutions are the response to the growing problems of congestion, goods movements, inefficiency of the goods distribution processes, the space deficit and the environmental and social nuisances in many cities. An important component of each of these solutions was an innovation, including the specificities of the city, use of modern technologies in the field of telecommunications, vehicle location, data processing and integration and also cooperation between many entities, developers and users of the system. Enhancing levels of urbanization, globalization and the consumption of goods are reflected in the growing demands on of logistics and transport activities. Therefore, further research and improvements in the integrated sustainable transport systems in urban areas are required to provide the expected benefits from businesses, public authorities and the local community.

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