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Potential for ITS/ICT solutions in urban freight management

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Abstract

The article presents a study on applying ITS solutions in planning and management of urban freight transport in Gdynia. The traffic management system Tristar which is under implementation and its related systems show a potential to assist in development of freight transport measures. Recommendations for urban freight policy development supplementing Gdynia's Sustainable Urban Mobility Plan were used as a basis for identification where ITS/ITC could be implemented. The first stage may involve modelling and analysis of freight vehicle traffic with new multilevel transport model for Gdynia. Other possible measures include, among others provision of dynamic information for vehicle routing and priorities for trucks on selected sections of road network. However, problems with access to reliable data describing delivery vehicle traffic were identified in this early stage as no practical rules for their collection had been developed. Additional problems appear in acquiring urban supply chain characteristics that require collaboration with the private sector. Such studies have not as yet been conducted in Poland. The identified factors indicate the need to precisely specify expected results and the areas of ITS application in Gdynia to prepare for their. Dynamic routing and scheduling with real time information appeared to be the most promising solution applying ITS, with temporary priorities for HGV providing services to the sea port in Gdynia in peak traffic and directing lorries implementation to free parking slots. Experience gained in these applications will be useful in developing other, complex solutions, e.g. in organising distribution in the city centre.

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Keywords: ITS and ICT; urban freight; city logistics; transport planning; transport managemet

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1. Introduction

Current trends in urban freight indicate potential for the introduction of advanced transport technologies as the way for more sustainable goods transport. Such solutions may include, among others, traffic management systems (in-vehicle and area related), access rights for different vehicle classes and traffic conditions, provision of open traffic information for accurate vehicle routing, and loading areas surveillance or vehicle monitoring (i.e. carrying dangerous goods or being overloaded). Proper implementation of modern transport technologies may result in a win-win situation, in which both the city authorities and freight operators equally reach their objectives improving the overall quality of services and transport system general efficiency.

However, the implementation of ITS/ICT (Intelligent Transport systems/Information and Communication Technology) solutions in urban freight transport necessarily require mature planning environment, clear objectives and eager involvement of various stakeholders from both the public and the private sector. Yet some of these requirements extend far beyond the city authorities competence and address the policy making on the national level. The above mentioned measures should be enforced as a part of a complex concept with a well designed system of supporting actions outstretching previously implemented solutions. Technology used should be proven and based on sound business cases engaging reliable private actors.

Although a traffic management system is currently under implementation in Gdynia urban freight still remains on a sidetrack. Thus, an urgent need has arisen to find out how these two domains may work together creating synergy effects for the city and actors involved. The city was selected as an example of ITS implementation because for several reason. The obvious one is the availability of first-hand experience from implementation of one of the most complex traffic management systems in Poland, covering not only single city, but the whole metropolitan area of Gdańsk, Gdynia and Sopot. The second reason is a possibility to evaluate how other measures, based on the traffic management system are implemented, supplementing its capabilities. This refers to the CIVITAS "Dynamo" project where, among other measures, a multilevel transport model is under development.

The main objective of this paper is to identify opportunities for ICT/ITS implementation in urban freight transport in the city of Gdynia. The research is based on the city's current experience in this field and the new developments stemming from an ongoing CIVITAS "Dynamo" project.

Section 1 of this paper gives an introduction to the problem and presents the research approach. In section 2 characteristics of ITS measures relevant for urban freight management are identified, as well as the requirements for data when freight modelling is considered. An example from the city of Gdansk is provided to illustrate typical problems in data acquisition, such as irregularity of road surveys and inadequate structure of available information. This problems occur also in Gdynia, which forms the TriCity agglomeration together with Gdansk and Sopot. This is the starting point for indicating ITS significance in the urban freight management process and its integrating and informative role. Section 3 links identified ITS measures with urban freight stakeholders concerns, giving an opportunity to introduce recommendations for Gdynia's Sustainable Urban Mobility Plan referring to freight transport.

In section 4 actual implementation of ITS solutions in Gdynia is presented, focusing on the Tristar traffic management system and multilevel transport model, which is under final stage of implementation as a comprehensive system supporting planning and decision making. These two system were analysed in terms of their feasibility to facilitate urban freight measure. Section 5 summaries the paper with conlusions.

2. ITS in urban freight transport

2.1. *Characteristic ITS/ICT solutions as instruments for managing freight transport*

ITS and ICT are a broad category of terms and measures which are structured in many ways according to available sources. As this paper is not intended as a literature review on this issue, only selected definitions are mentioned with emphasis on the planning process and local authorities perspective involved in freight issues. European Commission defines ITS as advanced applications providing innovative services related to the different modes of transport and traffic management. This capacious definition may be structured into more the following detailed traffic areas/cells and mobility management systems, user information systems, transport management systems, fleet and freight management systems, automatic payment systems, vehicle control systems increasing transport safety and emergencies and accident management systems (Gattuso & Pellicanò, 2014). ITS integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport systems. In general terms an ITS solutions in the urban freight may be classified according to the type of application, dimension of application (public-policy or private-operational) and user group (more public or private usage or used in both ways) (Karrer, Petz, & Ruesch, 2007). Other applicable categorization divides ITS into freight transport management systems and traffic management systems (Allen, Browne, & Thorne, 2007). Figure 1 shows combined classification of ITS measures developed to include its applications characteristics and the implementation area.

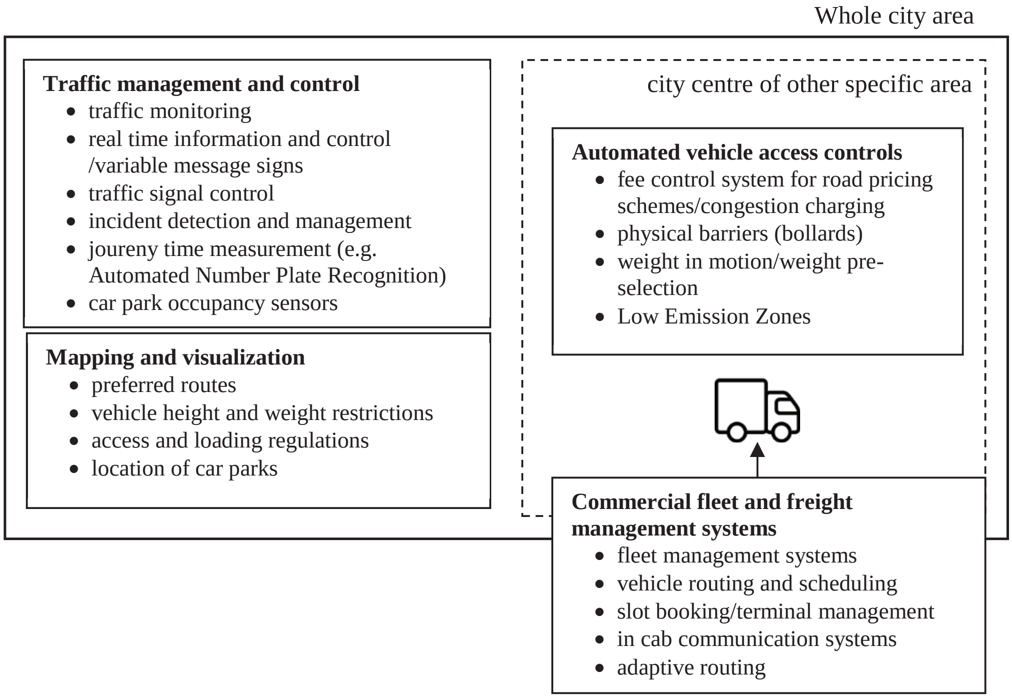

Fig. 1 ITS and ICT systems according to characteristics and areas of implementation

This categorization could be considered as a lead for possible planning and implementation procedure. However, it must be emphasized that the core of ITS comprises obtaining, processing and distributing information for better use of transport systems, infrastructure and services (Crainic, Gendreau, & Potvin, 2009). Therefore, quality of inputs to the freight planning system is crucial. This would allow to design robust measures based on reliable predictions and quantifiable outcomes. Several research activities were undertaken to identify barriers in effective planning of urban transport. Among many barriers identified by local authorities, issues related to lack of expertise in modelling transport activities were frequent. In detail, this includes lack of modelling staff and skills, poor management of data, lack of understanding of certain impacts and inability to model certain policy instruments (May, Page, & Hull, 2008). Another survey (Hatzopoulou & Miller, 2009) confirmed that the main challenges in modelling of transport activities include a lack of resources and expertise, low confidence in existing models, high needs for refining and calibration of existing models and high data requirements. From this perspective practical application of modelling in urban freight planning becomes significantly important as an integral component of the city's transport planning. Solutions applicable here may include both optimization and simulation methods (Taniguchi, Thompson, & Yamada, 2012). Simulation models, to which particular attention would be given in this paper, include:

- Models of vehicle routing and scheduling
- Multi objective optimization
- Intelligent agents
- System dynamics
- Multi-agent systems and game theory
- Traffic simulations

Modelling the traffic flows in order to improve an efficiency of transport system is often considered as important policy measure (Anand, Quak, van Duin, & Tavasszy, 2012). In the case of Gdynia, where an advanced traffic management system and traffic modelling solutions are under implementation, there is an opportunity to include urban freight traffic into this framework. However, in order to understand problems at traffic level, investigation of urban logistics chains is essential through the multidisciplinary approach (van Duin et al, 2007). In both cases properly introduced ITS solutions could provide added value to existing transport policy measures. Critical assessment of experiences with city logistics (Muñuzuri, Cortés, Guadix, & Onieva, 2012) provide valuable insight into areas where particular attention should be given to successful implementation of freight measures. These are evaluation of planned measures through data gathering and use of simulation tools to analyze the effect of policies and enforcement of regulations. Once again, these issues may be addressed with ITS with acceptable effort on the basis of existing infrastructure and systems, providing its adaptation to new applications is envisaged.

2.2. *Data crucial for planning the urban freight with a support of the ITS/ICT*

The availability and quality of data was identified as a critical factor influencing urban freight planning and implementation of ITS systems. It is important to identify then main types of freight flows present in different combinations in every city. Each type of movement related to goods transfer influences road traffic in a specific way, bringing also specific types of problems or external effects. Main groups of urban freight movements can be identified (Browne, Allen, Piotrowska, & Woodburn, 2007) as follows:

- Shipments of goods into an area to be consumed within that area
- Shipments out of an area of goods produced in that area
- Intra-urban collection and delivery and local shipment where the vehicle has its origin and destination within the same area
- Transient movements – goods passing through the area directly and goods undergoing temporary storage

Another two categories of movements should be included here to get the full picture of urban freight transport. One is urban management traffic related to urban management, ie.: public works and waste management (Patier & Routhier, 2008). The second group is often omitted and includes the movements described as service trips such as: window cleaning, catering, different types of services etc. (Allen, Browne, Cherrett, & McLeod, 2008).

To understand the nature of goods flows related to these types of movements more characteristics of vehicles movements should be gathered. In fact, only the combination of vehicles movement characteristics and their logistic characteristic may be considered to be optimal. However, there is a lack of ongoing public data collection about urban freight operations with the exception of standard vehicle traffic counts performed at the fairly regular intervals. Nonetheless, these counts provide limited information about logistic chains performance, as the following data has particular value (Allen, Browne, Anderson, & Jones, 2000), (Allen et al., 2008), (Cherrett et al., 2012):

- Total number of goods and service vehicle trips
- Total number of goods and service operating vehicles
- Average trip length of goods/service vehicles
- Fossil fuel consumption rate of goods and service vehicles
- Size and weight of vehicles used
- Number of goods and service vehicles parked on-street at peak hours
- Period of time for average delivery or service trip

- Time of goods and service vehicle operation
- Average travel speed within specified area

An important factor determining urban freight data availability is that information may be public or private. Traffic flows characteristics and other related information are the natural domain of public sector bodies responsible for transport planning, but detailed supply chain data, in most cases, belong to the private sector: retailers, logistics operators, transport companies etc. Merging these two sources may be beneficial for all the interested actors, however, there few sound examples of success in the field. Analysis of available urban freight data reveals the following important conclusions when implementation of ITS is under consideration (Browne, Allen, Steele, Cherrett, & McLeod, 2010):

- The survey time duration (the surveys are typically less than 24 hours per day so night deliveries are not counted, and do not always take place over an entire week), and deliveries made via side and rear roads are often not observed by surveyors
- The studies often involve a wide range of business types, sizes and ownership of establishments (i.e. Some studies focus on areas with small, independent shops while other focus on large establishments that are part of national chains), and relatively small sample sizes, so comparing averages can be misleading
- The surveys covered freight delivery and collection activity in urban establishments in terms of the number of vehicle trips, with no attempts to quantify tonnage, volumes, or monetary values of goods delivered and collected

General recommendations can be formulated (Rhodes et al., 2012) contributing to surmounting the data availability problems for urban traffic analysis and planning:

1. Addressed issues must be clearly defined. The planning and/or modelling objectives must be clearly defined prior to other steps. Next, these must be confronted with available data sources to indicate missing resources, followed by the development of a data collection plan organizing forthcoming efforts and providing a reference point for the team involved.
2. Only the directly required information should be collected. There is a tendency to get any information available. It is also advisable to assess internal capabilities for data analysis and processing to avoid getting outdated results of the analysis potential that are inadequate. This is especially important when regular data updates are planned.
3. It is advisable to seek out new partners or data sources. Many successful urban freight initiatives were based on public partnership with retail organizations, chambers of commerce, logistic operators, organizations, etc. An example of such a partnership may be Transport for London Freight Quality partnerships (Browne, Allen, Nemoto, Patier, & Visser, 2012) and other forms of public and private cooperation (Lindholm & Browne, 2013).

An additional problem hindering urban freight management is the dynamic fluctuation of transport needs, which varies not only from month to month but also from day to day and even hour to hour. In the case of freight transport, dynamic changes in passage demand and routes can be observed due to, e.g. the growing e-commerce service sector.

The range of data necessary to model freight shipment is also related to the applied modelling technique and methodology. Modelling the demand for freight transport accounting for locations generating heavy vehicle and delivery vehicle traffic (demand modelling – the first stage in the four step transport systems model developed for Gdynia) requires socio-economic data and spatial management data on the transport area, the points of departure and destination of the vehicle (the first model category based on travel from the place of origin of the transport area and to the destination in that transport area). This model category was developed in analogy to the four steps models for passenger traffic. Nevertheless, this approach may be applied in modelling some categories of freight transport/commercial transport such as e-commerce or express courier (Gonzalez-Feliu and Routhier, 2012). Other models (Gentile and Vigo, 2013) presents models developed by analogy to passenger travel, which allow counting the number of trips generated in the given transport area or location under study and next deduces an origin-destination matrix (O-D) of the goods.

The second category of models generating freight traffic takes into account trip chains or rounds in more detail, describing concurrently trip distribution between transport regions or defined locations in the transport network.

There are a number of areas where intelligent agents can assist in implementing urban logistics schemes such as; determining optimal paths for delivery vehicles in road networks, dynamic vehicle routing and scheduling, or service time durations. Developing intelligent agent software involves specifying a number of elements of the system, including the roles, interactions, types of agents, system goals, capabilities and services. Events are defined from the processing of percepts (information gained from the environment) and situated agents are capable of performing actions or tasks (Taniguchi et al., 2012). ITS technologies are indispensible in modelling, relying on intelligent agent software or the multi agents method, providing options for tracking vehicles and locating them in time and space to model their behaviour. These models use the round as a unit and are also based on a sequential format (Gonzalez-Feliu & Routhier, 2012). Information on traffic of different classes of vehicles (including lorries and delivery trucks) are required in modelling traffic assignment as well as the time of travel in particular sections of the transport network (data required for model calibration and verification). This data are available from comprehensive traffic study (those including travel time measurement at various times of the day/week) or more comprehensive data from ITS detection systems.

However, modellers face difficulty caused by limited freight data suitable for model validation at the aggregation level. Another source of problems is that public data sources used for model estimation have a considerable amount of observations that are suppressed due to data disclosure policies. So this missing information is synthetically imputed, rather than estimated based on data sampling. This can cause bias on the estimated model parameters and therefore unreliable predictions of freight demand (Oliveira-Neto, 2012). Also estimating the responses of freight carriers to policy measures implemented by municipality is difficult for modellers due to behaviour of these stakeholders within the framework of coordination and competition in market economy.

These issues show the need for systematic and dynamic transport structure management in towns and cities to improve transport efficacy with limited side effects. Managing transport in urban areas should rely on two basic pillars – the infrastructure (technical) and organisational measure. Both require planning measures, which must be supported by knowledge of transport process characteristics, and an option for testing solutions that may contribute to better transport management. The analysis of change scenarios is a planning component that can be performed using transport model systems. The development of transport models, in turn, requires the collection of multi fold data, often difficult to acquire or unavailable without the latest measuring technologies or access to IT sources earlier not used (e.g. private data). The identification of patterns reflecting dynamic demand changes for various transport modes and requires many costly studies and data. This is also the case of freight transport, which often requires detailed information at the transport region level, and even quite often, at road section level (e.g. in the case of parking delivery vehicles) or about a given location (analysis of deliveries to, varied in terms of size, commercial facilities).

2.3. *Example of problems related to data acquisition based on the city of Gdansk experience*

Gdansk is the major city of the TriCity agglomeration with ca. 460 thousands of inhabitants. Other cities are Gdynia (248 thou. inhab.) and Sopot (38 thou. inhab.). In 2009, comprehensive traffic studies were carried out in Gdańsk (such studies are performed every circa 5 years) that included also freight transport (covering vehicle flow in the entire TriCity, so their relevance for modelling heavy transport in Gdynia was limited. Stage I involved screening tests by phone to identify the profile of transport companies and their carriage capacity (as there is no such database). Stage II involved questionnaire surveys about the behaviour of lorries and delivery vehicles in companies. Drivers were asked to provide information about:

- Journeys on the day before the survey (origin – destination, time of departure / arrival)
- Degree of using the vehicle's carrying capacity
- Kind of freight
- Average trip time

Information on trips was additionally collected during cordon studies on inlet roads to the studied area. Questionnaire surveys of drivers comprised a list of earlier prepared questions. Four types of vehicles were covered by the cordon questionnaire study: passenger cars, delivery vehicles, lorries, lorries with articulated trailer, trailers.

The questions referred to trip origin and destination, the goal, frequency of trips and sojourn time to the cordon location (in the case of vehicles leaving or in transit through Gdańsk). In the case of lorries and delivery vehicles additional questions were asked about the kind of cargo carried, mass and admissible vehicle capacity. The hour of survey performance, the number of persons in the vehicle and the place of vehicle registration were also noted.

The size of the studied group was satisfactory, however, the responses referred to the day prior to the survey (2551 out of 23780 delivery vehicles registered in Gdańsk took part in the survey, i.e. 11%, and 649 drivers among the 13345 registered lorries, i.e. 5%, the trip questionnaire sample during the cordon survey reads circa 5%). Nevertheless, in terms of delivery transport, modelling information is missing such as: vehicle dwell times, specific location of stops for loading or unloading the vehicle (especially on-street stopping locations are potentially liable to cause more traffic delays to other road users in urban areas). Comprehensive traffic studies (also covering freight transport) in Gdynia are not performed due to costs and lack of legal duty. In legal terms there is no specific standard or KBR range. Thus, there is no comprehensive freight related data collection system, and lorry traffic is randomly assessed in studies, forecasts and feasibility studies conducted for smaller city areas (city cells), often on the grounds of local traffic counts or carriage data provided from time to time by institutions and companies.

Statistical data on freight handling volumes (big enterprises) provide another data source for modelling heavy traffic in TriCity and assessing the number of delivery vehicles. More detailed information is provided by supply companies (sporadically and very reluctantly). Taking into account the way and selectiveness of performed studies the results may be heavily flawed. They do not provide sufficient grounds for day to day or hour to hour modelling, i.e. modelling accounting for dynamic changes in transport behaviour. Application of ITC/ITS for the development of a new study methodology and models mitigates the gaps indicated above.

3. Integration of the ITS/ICT with freight transport planning system in relation to Gdynia's experience on this field

3.1. Identifying the potential fields of ITS application in reference to urban freight stakeholders problems

Intelligent transport systems are considered to be key enablers of achieving objectives of public policies related to transport activity in cities (European Commision, 2013). However, this cannot be realized in isolation from the freight transport market user requirements as they are the final users of implemented solutions (Urban ITS Expert Group, 2013). General objectives of sustainable urban freight transport systems were identified in the previous section. As a result main problems related to urban freight could have been identified. Consequently, the main considerations of freight operators and receivers should be verified and how ITS may close a gap between these domains. Characteristics of stakeholders objectives were the subject of several studies which yielded comprehensive reference material to define the role of ITS in this framework (Anderson, Allen, & Browne, 2005), (Dablanc, 2009), (SUGAR, 2011), (Russo & Comi, 2012), (European Commision, 2012), (Macharis, Verlinde 2012).

Figure 2 shows how ITS systems may contribute to realization of urban freight stakeholders' objectives and alleviation of their problems with operation efficiency. The figure illustrates the potential frequency of applying ITS solutions in solving problems and satisfying reported demands of the public sector and logistic operators. The intensity of these relations reflects the number of connections between elements, and symbolically the district radius of ITS solutions.

Benefits from implementation of ITS solutions as a response to aforementioned issues related to urban freight integrate the private sector (freight operators and receivers) and public sector (local authorities acting on behalf of the urban community). The private sector may benefit by improving its efficiency and productivity, as well as reliability of services. These gains could be achieved by (RITA, 2005):

- Better management of people and equipment
- Reduction of non-productive waiting time
- Better schedule adherence
- Operational flexibility
- Reduction of errors and order processing times

When private sector increases its operational efficiency with ITS systems a win-win scenario is created from the perspective of local authorities. In general, possible benefits are the opposite to freight problems identified previously. As an excessive demand for freight movements is reduced all traffic related effects are very likely to decrease. The cost-benefit ratio of ITS implementation in urban freight is to increase when the scope of information obtained from the transport system allows to effectively address more users. One of the critical factors determining success here is the definition of common technical standards ITS solutions acceptable by freight stakeholders (European Commision, 2015).

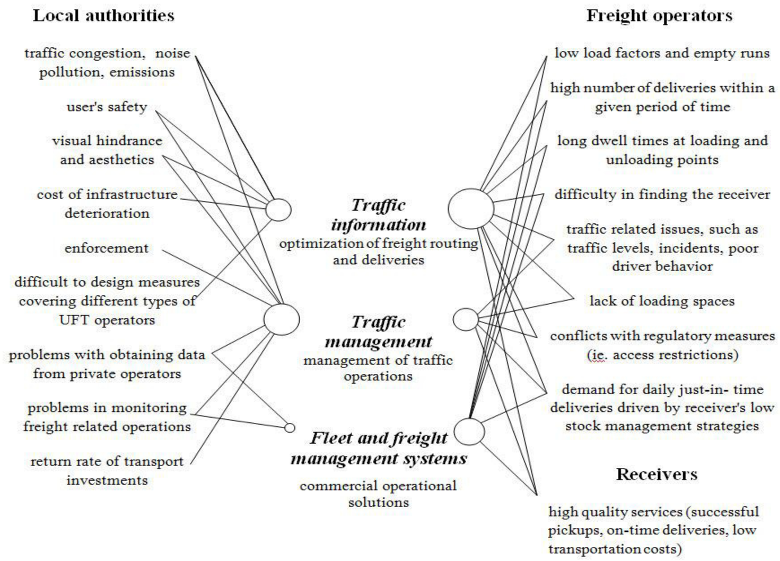

Fig.2. ITS contribution to addressing of urban freight stakeholders concerns

3.2. Areas where ITS/ICT may contribute to the development of urban freight measures in Gdynia

ITC/ITS methods and measures are applied by the public sector (municipal authorities) and the private sector (carriers, forwarders), to achieve specified and sometimes controversial objectives. Contentious expectations of these sectors appear when municipal authorities wish to reduce the impact of heavy traffic on the life standard of inhabitants (fumes, noise, traffic safety, higher costs of road construction/maintenance), evoking measures aimed at reducing or eliminating heavy traffic in urban areas, what is connected with longer trip time of these vehicles (this refers to source traffic, target and transit of heavy vehicle traffic). Two aspects relate to the case of smaller delivery vehicles, one is the growing traffic jams in the street network caused by the large share of delivery vehicles in road traffic, which in some street segments may exceed 10% - 15% share in traffic at various time of the day. Traffic growth in rush hours, even by a few percent, may be the reason for exhausting the critical capacity of the urban road network and result in traffic jams. The parking of delivery vehicles, which restrict mobility space for inhabitants (motorised urban dwellers, pedestrians and cyclists), is another problem. Restrictions in delivery vehicle traffic and parking have, on the other hand, a negative impact on delivery transport operators, causing perturbations in delivery schedules (empty runs or not fully loaded, time lost for loading and unloading in the case of problems in finding parking space, failure to meet client expectations in terms of delivery time).

Measures available for intervention in urban freight transport performance may be categorized according to three general objectives (Kaszubowski, 2014):

- Optimization of freight vehicles flows and demand for infrastructure provision
- Reduction of excessive demand for freight services
- Transfer of operations to a more sustainable mode of freight transport

Under each objective there are different types of urban freight measures. Review of existing literature gives a comprehensive overview on this matter (Muñuzuri, Larrañeta, Onieva, & Cortés, 2005), (Russo & Comi, 2010), (Russo & Comi, 2012), (Lindholm, 2012), (European Commision, 2012). If the basic structure of the available measures is required, they can be classified with relation to infrastructure and regulations (governance). With the previously identified areas of ITS contributions addressing urban freight stakeholders issues it is possible to picture how ITS measures could be used to increase efficiency of urban freight measures pursuing each of the aforementioned intervention objectives. Figure 3 describes selected examples of these interrelations. The number of presented measures was intentionally restricted to keep the scheme informative.

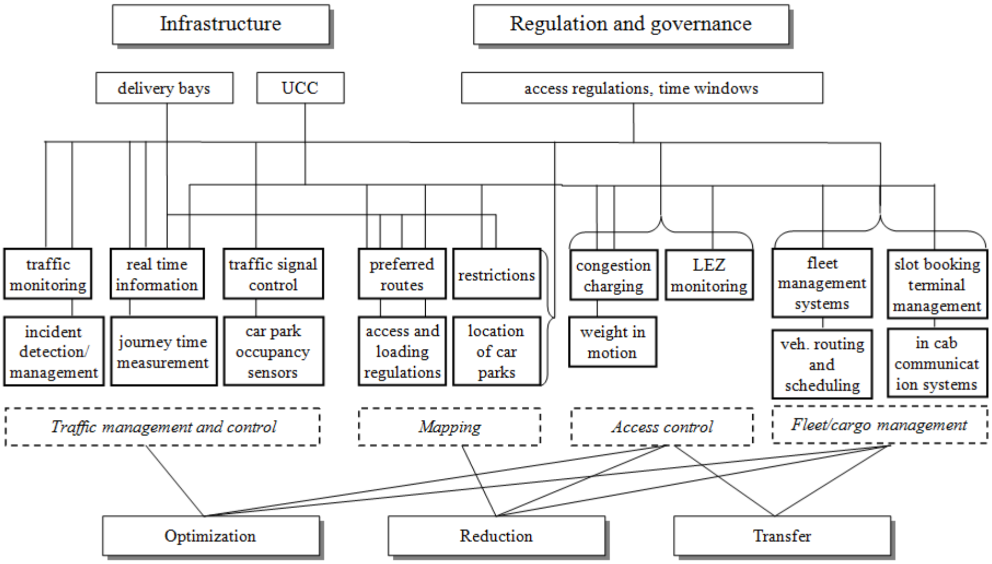

Fig.3. Example of ITS implementation supporting urban freight measures.

Analysing the figure bottom up we see the potential application of various ITS instrument groups compliant with the objectives of management tools for urban freight transport. This is followed by a presentation of how selected solutions (e.g. urban consolidation centre or access regulation) may be supplemented by ITS tools to improve effectiveness. The diagram shows that ITS solutions may be applied at the same time to develop various instruments for managing freight transport. Their actual usefulness, however, will depend on the accessibility of earlier specified data, and what is still more important knowledge of how to apply them. Without a skilful identification of expected results, the merging of standard solutions and ITS tools may fail to find justification.

Despite a variety of areas where ITS application can provide significant benefits to urban freight measures, its implementation must be closely related to the actual maturity of a city planning system and its objectives related to managing urban freight. This would safeguard proper balance between ITS systems requirements and the city's implementation potential. In the case of Gdynia's transport policy, freight issues are considered mainly from a perspective of heavy goods traffic and its adverse impacts. However, there is a strong emphasis on the solutions based on currently developed traffic management system TRISTAR. This provides an unique opportunity to propose an expansion the transport policy with urban freight measures supported by selected ITS solutions.

Urban freight self-assessment in Gdynia confirmed that the city is at the basic planning stage(Kaszubowski, 2016). It imposes that first a capacity building efforts are required to develop a ground for more advanced actions. Based on this conclusion recommendations for urban freight policy were prepared as a part of Sustainable Urban Mobility Plan under development within the CIVITAS Dynamo project as far as mid 2016. Table 1 presents measures related to two proposed objectives of the SUMP: sustainable and efficient urban distribution and modern technologies in urban freight (Kaszubowski, 2016).

Table 1. Measures under Gdynia's draft SUMP urban freight objectives

Regulatory system supporting urban delivery
• verification of the city's institutional potential in urban freight planning and creation of communication channels and principles between responsible departments • development of methodology for freight data gathering and processing according to existing and forecasted changes in planning and management capacity of the city, ie.: utilization of transport modelling solutions and traffic management system TRISTAR • road network classification according to main freight generators and traffic characteristic • unification of weight and/size regulations, starting from the city center and main transit road network to the seaport • methodology for planning of dedicated delivery zones
Integration of urban freight stakeholders
• identification of the UFT stakeholders, establishing a form of roundtable hosted by the city to identify their concerns and developing common understanding of freight related problems
ICT/ITS for optimization of freight traffic
• utilization of potential of traffic management system and related transport modelling solutions to improve planning and forecasting of UFT measures • guidance and enforcement for freight vehicles, especially HGV's (including weight-in-motion) • real time traffic information for better route planning, including congestion and incidents
Low emission transport solutions
• verification of conditions (requirements and benefits) of low emission zone introduction • identification of potential solutions to support uptake of new technologies, ie.: incentives for operators based on conducive regulations

Two measures form the core of ITS/ICT system supporting development of urban freight management system in Gdynia: the traffic management system TRISTAR and multilevel transport model for Gdynia. This approach is based on evaluation of existing city's planning capacity and possibility to expand existing and implemented systems with new functionalities providing an opportunity to better address urban freight issues.

4. Application of ITS/ICT instruments in Gdynia – status quo and development plans

4.1. TRISTAR traffic management system

The use of modern technologies can improve the operational area of traffic management, and can also support the planning and design of transport systems solutions relevant for current traffic organization. Given the above benefits the Tri-City authorities have taken steps to implement ITS measures. Gdynia, Sopot, and Gdansk are three Polish cities located very close to one another on the Baltic Sea coast. They form an agglomeration referred to as Tri-City with a population of 750 000 inhabitants. The Tri-City has nearly 1 400 km of roads, 300 signalized intersections and over 2 000 daytime public transport lines (buses, trams, trolleybuses and local trains). The Tri-City faces transport-related problems that are typical of large agglomerations. In the modal split the share of public transport has decreased in recent years and the share of cars has increased. Currently, the modal split in non-pedestrian travel is 50%/50% and the car owner ship rate is approx. 500 cars/1 000 inhabitants. The objectives are: to improve the traffic conditions by providing traffic management tools and to increase the share of public transport by improving its competitiveness thanks to the use of ITS technologies. This infrastructure and system software will be further developed also to meet the requirements of urban freight transport management. The first stages of implementing the system are in progress embracing the TriCity street mains including circa 150 intersections and pedestrian crossings with traffic lights, communication utility infrastructure (including cable pipeline and fibre-optic cable) stretching circa 100 km, assembly of circa 60 visual surveillance cameras, circa 60 cameras for identifying vehicles, circa 70 information displays at commuting stops, over 20 variable-message signs, and installation of positioning transmitters and on-board computers in public transport vehicles (Oskarbski, 2011), (Oskarbski, 2014).

The target system will be expanded to include all intersections equipped with traffic signals and integrated with the planned systems on express roads (TriCity Bypass, South Bypass) as well as airports, rail, and TriCity sea harbours. Two Traffic Management Centres have been established (in Gdańsk and Gdynia) collecting, processing and distributing data. The first stage of implementing the TRISTAR functional structure is given in Fig. 4. (Oskarbski, 2011), (Oskarbski, 2014).

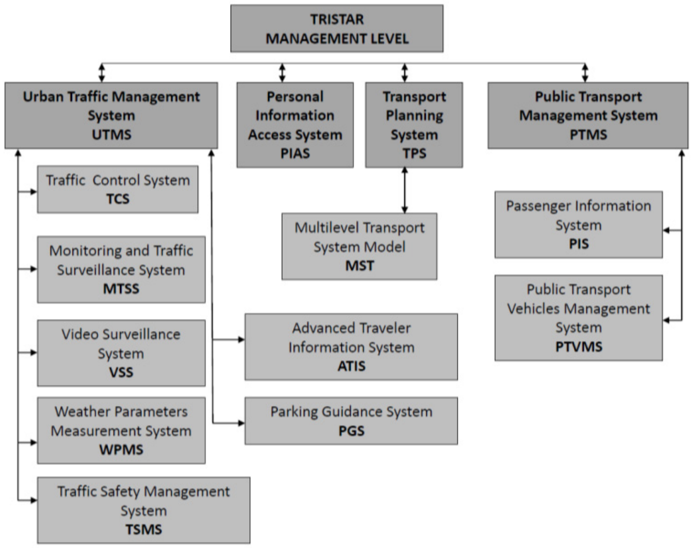

Figure 4 –Functional structure of the first stage of TRISTAR implementation

On the grounds of the present architecture of the TRISTAR traffic management system in Gdynia the following solutions for urban freight management are possible:

- Dynamic vehicle routing and scheduling with real time information of travel times may be upgraded by providing additional TRISTAR data identifying e.g. traffic congestion and incidents and prevent growing congestion
- Application of vehicle-to-infrastructure (V2I) communication would supply freight operators and drivers with information on traffic obstructions. The techniques above may be applied in freight vehicles and provide drivers with additional information (e.g. Route to a chosen destination for goods delivery, unloading, etc.), the information contributed by delivery vehicles used to streamline the travel time calculation algorithm for particular street sections. The latter will contribute to reducing traffic congestions, shorten travel time along particular street sections of both freight transport and other vehicles
- Granting priority to freight vehicles in the period of peak traffic in selected areas, ie.: an access to the Gdynia's seaport (e.g. arrival of ferries, or directly following loading of a greater number of vehicles) to quickly restore normal traffic conditions,
- Inclusion of the delivery fleet in the system will generate data (trip time along particular street sections), supply the system with more data collected along the route not only in fixed measuring stations, elevate indication accuracy and result in more effective traffic control
- Installation of meteorological sensors in vehicles and feeding their readouts to the TRISTAR system would provide information on weather conditions and related hazards not only locally but in the entire network used by delivery vehicles. Implementation of such modules is projected. Winter maintenance service vehicles are projected as the first in the pipeline
- There is an option to further develop the system to direct vehicles to free parking slots for freight vehicles in buffer parking lots on city outskirts and even provide information about single free parking slots for freight vehicles e.g. parking by the curb. Such measures would reduce arduousness in vehicle and pedestrian traffic

caused by freight vehicles parked in places forbidden, and ease traffic congestions caused by drivers searching for a free parking space
- Including delivery vehicles in TSMS (incident detection) to acquire more data and facilitate incident detection, improve the safety standard for all drivers and to reduce time required to restore regular traffic conditions

The aforementioned applications based on the TRISTAR system are characterised by different level of technology requirements and complexity, defining possibility of their implementation. Dynamic vehicle routing with real time information and scheduling and parking guidance system for freight vehicles are potentially the most rational measures in terms of required time and effort. In technical terms their implementation would be an expansion of existing capabilities of the traffic management system. However, there are obvious requirements, such as identification of the most appropriate data sharing system and verification of influence of parking facilities on a surrounding area and traffic conditions. The same applies to the priorities to freight vehicles on selected parts of the city's road network. Such priorities can be applied as a predefined traffic organisation programme, similar to solutions prepared in advance for a city-wide cultural events or similar situations. The main area of this type of intervention would be an access route to the port in Gdynia, heavily congested with the long distance traffic. This measure has a considerable implementation potential because is based on existing data about traffic and can be supplemented with other ITS/ICT solutions, such as variable message signs.

Other solutions are more complex and reach beyond current state of art, but are worth to consider because the traffic management system is based on the constant evolution principle. This refers to a concept of the vehicle-to-infrastructure applications. This technology is a subject to intensive research as potentially beneficial to the safety and efficiency in road traffic management. Potential benefits from gathering the data from vehicle's on-board communication devices with smart road infrastructure are, among others: prior recognition of potential traffic jam, dynamic traffic and traffic light control. However, this technology requires provision of advanced systems both in vehicles and infrastructure, making V2I a complex cahllenge.

4.2. The role of Multilevel Transport System Model as a tool supporting planning and evaluation of urban freight measures

One of the modules of the TRISTAR system is Transport Planning System (TPS) supported by information obtained from other modules of the system. TPS will be integrated with a Multilevel Transport System Model (MST) to enhance accuracy in planning efficiency and design studies as well as in temporary changes to traffic arrangements in connection with road works, special events and changes in traffic in real time, for example, when an accident occurs. MST will, inter alia (Oskarbski et al., 2014b):

- Enable data delivery to various tasks performed in operating transport systems and facilities, facilitating optimal decision-making
- Provide data for planning work, feasibility studies of transport facilities, revising traffic arrangement plans, taking into account geometric solutions at intersections and interchanges and advanced traffic control
- Set up data and information for updating Gdynia’s (in the first step) sustainable urban mobility plan (sump) and provide detailed analyses and verification of effects on mobility management initiated by sump proposals and measures
- Provide simulation tools to popularise proposed solutions for improving transport system of the city

The application of ITC/ITS allows for the development of new study methodology and models that account for earlier gaps, however it is worth noting that changes must also refer to the organisation and content of databases in companies and vehicles operating on the territory of the TriCity, as well as adopting a data supplementing method, and the appointing of a unit collecting such data. These technologies must be used in both the urban infrastructure and in vehicles.

The objectives of the draft SUMP for Gdynia regarding urban freight presented in section 3.2 impose significant changes into current planning practice regarding transport planning. They are crucial not only to start addressing freight in a coherent way, but first to understand the specifics of freight transport within in the city. This was the factor underlying inclusion of selected preparatory measures in the SUMP's freight part, such as development of data gathering methodology and identification of existing information resources within the city's departments.

Multilevel Transport Model will be applied on three levels which provide modelling options for varied degrees of detail, currently mostly for individual vehicles and public transport. Strategic level of the model includes the provision of data to develop a transport policy, the implementation of planning studies and network studies. At the strategic level a macroscopic model based on the VISUM software will be applied.

Tactical level includes the provision of data to develop decision-making papers (network and corridor studies, feasibility studies), development projects of traffic arrangement, traffic control and evaluation of planning solutions effectiveness as well as for traffic management purposes. At the tactical level, a mezoscopic model will be applied based on the VISUM and SATURN programs as well as BALANCE offline program implemented within TRISTAR system. The model will be powered and calibrated with data from TRISTAR traffic management system, linking both ITS solutions into one transport planning and management environment.

The macroscopic and the mesoscopic models will provide the basis for the elaboration of the microscopic model (simulations), which will be supplied with current or historical data from the TRISTAR data warehouse and traffic control system BALANCE (Oskarbski, 2014). The microscopic model will be used at the operational level which includes; the provision of data to develop specific projects of traffic arrangements, traffic control programs, projects of transportation services for selected objects, and will primarily serve visualisation of transport facility operations.

MST will make analysis of freight traffic in Gdynia possible taking into account environmental and social factors such as:

- Delivery time and location availability (particularly in the city centre)
- Delivery access in terms of vehicle carriage capacity
- Indication of parking options for delivery vehicles in the city centre
- Option for permanent or temporary closing of specified street sections to traffic/parking of delivery vehicles
- Developing of an information system for organisers of delivery traffic

The development of more comprehensive freight transport models relying on data acquired from carriers is justified. Reliable shipment statistical data (described in item 2.3.) provides an option for developing better quality models of freight transport demand under step one of the 4 stage procedure, and on these grounds for estimating the matrix of freight vehicle trips (such an approach is justified in modelling heavy traffic (transit freight, industry supply and sea-port activities), when shipment dynamics is difficult to account for (though this depends on data delivery frequency by carriers, industry and sea-port operators). The development of a reliable model also requires regular comprehensive traffic studies, including freight vehicles and operators, (the present legislation does not project the duty to conduct such studies, which due to high costs fail to encourage study performance by cities). Such studies should be performed every 5 years, and as such would provide valuable input and validation data for freight models. In the case of commercial distribution, commercial services, e-commerce, express courier and communal services (waste removal/road maintenance) it would be relevant to apply an approach based on modelling trip patters (rounds/trip chains). This would allow the model to account for fixed routes

5. Conclusions

The article was to identify options and barriers for applying ITS systems in urban freight transport planning and management in Gdynia. The starting point was the assumption that ITS plays an integrating role in planning transport. In freight transport it refers mainly to integrating policy instruments and measures taking into account priorities for different modes of transport resulting from urban transport policy assumptions. The identification of ITS/ICT solutions applied in freight transport, and comparing their requirements with the conditions in Gdynia, revealed a basic issue that may impede ITS implementation. This problem is the quality and accessibility of freight carried data covering apart from just traditional information about vehicle traffic, the specific demand and supply of freight and shipment services. In Gdynia, the structure of heavy vehicle (lorries) traffic was analysed under a comprehensive traffic study but the study methods used did not ensure reliable data. Therefore, it is not possible to use an important area of ITS application, i.e. urban freight transport modelling to identify areas of concern, and on these grounds to plan rational solutions accounting for the earlier mentioned integration requirement, e.g. other transport modes.

Gdynia today uses a multilevel transport system model (MST) for transport planning, which form foundations that should be further developed. The model was developed according to the traditional 4 stage method of modelling freight transport systems, which may be modified, inter alia, in scope of freight traffic (primarily for demand modelling. and traffic assignment) by applying modelling methods accounting for freight trip chains (e.g. by using intelligent or multi agents that guarantee top quality reproduction). The development of such a model requires specific information on routes and stops of freight vehicles in time intervals what can only be done by using ITS methods or by introducing a duty to run logs by drivers, whose extent of duties seems to make this impossible, with the results of the latter likely to be heavily burdened by human factor errors. Data originating from vehicles could be verified using the TRISTAR system and applications (e.g. readouts of ANPR cameras, and traffic measuring station that classifies vehicles). This approach is possible in modelling urban traffic management of the street network in the area of operation and planning. Knowledge of the traffic load in particular street segments (intersections and in between sections) and its descriptive parameters (e.g. traffic speed) conditions adequate designing of solutions for traffic control, information for travellers and traffic management in case of an incident or the detection of an incident. It also provides reliable foundations for short and long term traffic forecasts. The main problem in introducing this solution is the wanting cooperation of the authorities and freight operators. Such collaboration and dialogue helping to solve technical issues (positioning devices in vehicles, compatibility of devices, communication and integration of databases), problems connected with reluctance of freight operators to disclose data, and legal problems related to preferences for freight operators, may bring benefits to all stakeholders.

Implementation of the above solutions integrating various areas of ITS application including urban freight transport in the early stages may result in comprehensive integration with potential freight management measures. This comprehensive approach will facilitate better planning in terms of expectations and additional effects in the realisation and operation stages.

The merging of TRISTAR data and data delivered by freight fleets will accelerate incident detection and facilitate quick arranging of detours (for all vehicles) and contribute to more dynamic and reliable information flow for drivers. Development of the TRISTAR system in conformity with the requirements of urban freight management contribute to the success in implementing the assumptions of the urban transport policy targeted at raising efficiency of the transport system. ITS solutions as presented in the paper can be an integral part of planning and implementing urban freight management measures contributing to better results in each of the three identified application groups: optimization of freight flows, reduction of demand for freight services and transfer of operations to sustainable modes of transport.

References

Allen, J., Browne, M., Anderson, S., & Jones, P. (2000). *A framework for considering policies to encourage sustainable urban freight traffic and goods and service flows*. *EPSRC Summary Report. University of Westminster, Transport Studies Group, London.*

Allen, J., Browne, M., Cherrett, T., & McLeod, F. (2008). *Review of UK Urban Freight Studies. Green Logistics Project Work Module 9*.

Allen, J., Browne, M., & Thorne, G. (2007). *BESTUFS II: Good Practice Guide on Urban Freight Transport*.

Anand, N., Quak, H., van Duin, R., & Tavasszy, L. (2012). City Logistics Modeling Efforts: Trends and Gaps - A Review. *Procedia - Social and Behavioral Sciences*, *39*, 101–115.

Anderson, S., Allen, J., & Browne, M. (2005). Urban logistics—how can it meet policy makers' sustainability objectives? *Journal of Transport Geography*, *13*(1), 71–81.

Browne, M., Allen, J., Nemoto, T., Patier, D., & Visser, J. (2012). Reducing Social and Environmental Impacts of Urban Freight Transport: A Review of Some Major Cities. *Procedia - Social and Behavioral Sciences*, *39*, 19–33.

Browne, M., Allen, J., Piotrowska, M., & Woodburn, A. (2007). *Literature Review WM9 : Part I - Urban Freight Transport Carried out as part of Work Module 1 Green Logistics Project Final version*. *Green Logistics Project Work Module 1 Final Report, Transport Studies Group, University of Westminster*.

Browne, M., Allen, J., Steele, S., Cherrett, T., & McLeod, F. (2010). Analysing the results of UK urban freight studies. *Procedia - Social and Behavioral Sciences*, *2*(3), 5956–5966.

Cherrett, T., Allen, J., McLeod, F., Maynard, S., Hickford, A., & Browne, M. (2012). Understanding urban freight activity – key issues for freight planning. *Journal of Transport Geography*, *24*, 22–32.

Crainic, T. G., Gendreau, M., & Potvin, J. Y. (2009). Intelligent freight-transportation systems: Assessment and the contribution of operations research. *Transportation Research Part C: Emerging Technologies*, *17*(6),

Dablanc, L. (2009). *Freight Transport for Development Toolkit: Urban Freight*. Washington, DC. European Commision. (2012). *Study on Urban Freight Transport*.

European Commision. (2013). *Mobilising Intelligent Transport Systems for EU cities* (No. SWD(2013) 527 final).

European Commision. (2015). *Daft Paper - Standardisation request addressed to CEN, Cenelec and ETSI on harmonised European standards in support of the implementation of Intelligent Transport Systems in urban areas*.

Gattuso, D., & Pellicanò, D. S. (2014). Advanced Methodological Researches Concerning ITS in Freight Transport. *Procedia - Social and Behavioral Sciences*, *111*, 994–1003.

Gonzalez-Feliu, J., & Routhier, J.-L. (2012). Modeling Urban Goods Movement: How to be Oriented with so Many Approaches? *Procedia - Social and Behavioral Sciences*, *39*, 89–100.

Hatzopoulou, M., & Miller, E. J. (2009). Transport policy evaluation in metropolitan areas: The role of modelling in decision-making. *Transportation Research Part A: Policy and Practice*, *43*(4), 323–338.

Karrer, R., Petz, C., & Ruesch, M. (2007). *Intelligent Transport Systems (ITS). BESTUFS II Deliverable D2.3: Best Practice Update 2007 / Part II*.

Kaszubowski, D. (2014). Determination of objectives for urban freight policy. *LogForum 10(4)*, *10*(4), 409–422.

Kaszubowski, D. (2016). Recommendations for Urban Freight Policy Development in Gdynia. *Transportation Research Procedia*, *12*(June 2015), 886–899.

Lindholm, M. (2012). How Local Authority Decision Makers Address Freight Transport in the Urban Area. *Procedia - Social and Behavioral Sciences*, *39*, 134–145. http://doi.org/10.1016/j.sbspro.2012.03.096

Lindholm, M., & Browne, M. (2013). Local Authority Cooperation with Urban Freight Stakeholders: A Comparison of Partnership Approaches. *EJTIR*, *13*(13), 20–38.

May, A. D., Page, M., & Hull, A. (2008). Developing a set of decision-support tools for sustainable urban transport in the UK. *Transport Policy*, *15*(2008), 328–340. http://doi.org/10.1016/j.tranpol.2008.12.010

Muñuzuri, J., Cortés, P., Guadix, J., & Onieva, L. (2012). City logistics in Spain: Why it might never work. *Cities*, *29*, 133–141.

Muñuzuri, J., Larrañeta, J., Onieva, L., & Cortés, P. (2005). Solutions applicable by local administrations for urban logistics improvement. *Cities*, *22*(1), 15–28.

Patier, D., & Routhier, J.-L. (2008). How to Improve the Capture of Uran Goods Movement Data? In *8th International conference on Survey Methods in Transport* (pp. 1–38).

Rhodes, S., Berndt, M., Bingham, P., Bryan, J., Cherrett, T., Plumeau, P., & Weisbrod, R. (2012). *Guide for Understanding Urban Goods Movements. NCFRP Report 14*.

Oskarbski, J., 2011. Perspectives of Telematics Implementation in Tricity Transport Systems Management and Planning. Communications in Computer and Information Science. Modern Transport Telematics, 239/2011. Springer Berlin Heidelberg

Oskarbski, J., 2011b. Perspectives of Telematics Implementation in TriCity Transport Systems Management and Planning. Communications in Computer and Information Science. (Modern Transport Telematics), 239/2011

Oskarbski, J., Jamroz, K., 2014. Multi-level transport systems model for traffic management activities – presented at 10th ITS European Congress, Helsinki.

Oskarbski, J., Jamroz, K., Birr, K., 2014. Application of multi-level transport model for the TRISTAR system – DTA-5th International Symposium on Dynamic Traffic Assignment, June 17th – 19th, Salerno, Italy

Russo, F., & Comi, A. (2010). A classification of city logistics measures and connected impacts. *Procedia - Social and Behavioral Sciences*, *2*(3),

Russo, F., & Comi, A. (2012). City Characteristics and Urban Goods Movements: A Way to Environmental Transportation System in a Sustainable City. *Procedia - Social and Behavioral Sciences*, *39*, 61–73.

SUGAR. (2011). *City Logistics Best Practicies: A Handbook for Authorities*. Bologna.

Taniguchi, E., Thompson, R. G., & Yamada, T. (2012). Emerging Techniques for Enhancing the Practical Application of City Logistics Models. *Procedia - Social and Behavioral Sciences*, *39*, 3–18.

Urban ITS Expert Group. (2013). Guidelines for ITS Deployment in Urban Areas: Traffic Management.
Van Duin JHR, Quak H. City logistics: a chaos between research and policy making? A review. Urban Transport XIII-Urban Transport and the Environment in the 21st Century 2007: 135-146.