# Planning and Development of Sustanable Logistics Systems at a Micro-level

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*The sustainability of urban areas is for decades a controversial point in the issues of sustainable development. Inefficient realization of logistics activities in urban areas results in numerous negative effects on sustainability. Especially unsustainable consequences are those of the dominant road transportation role in urban goods delivery. Achieving sustainability at a micro-level is possible only with the planning of city logistics (CL) systems through the development of different logistics centres categories, flow consolidation, cooperation, and intensive application of alternative transportation modes. The planning of CL systems is a complex task that involves several stakeholders with complex interrelationships and conflicting goals. This article indicates the importance of CL planning in achieving local, micro sustainability. Main stakeholders, criteria, and CL concepts are described in the article. In accordance with the existing literature in the field, new technologies, and approaches, seven potentially sustainable CL concepts are defined.*

**Key Words:** *sustainability, development, city logistics, concepts, cooperation, consolidation*

## 1. INTRODUCTION

Urban areas represent intersection nodes of goods flows. The realization of those goods flows is supported by a series of logistics activities – transportation, transhipment, warehousing, processing of goods, order picking, etc. Inadequate planning of logistics systems and inefficient realization of logistics activities results in numerous negative effects, which are most visible in urban areas. To achieve sustainable development, it is necessary to plan and develop sustainable logistics systems at macro [1] and micro levels.

Solving the sustainability problems of logistics in urban areas is in the responsibility domain of city logistics (CL). "CL refers to all strategies, technologies, and solutions of logistics which support all stakeholders and functions of urban space, regardless of their size, number, area, and borders, but in accordance with their individual and common interests and goals." [2].

The purpose of this article is to describe the sustainability problems on a micro-level and to point out the important role of CL in solving those problems. The focus is on defining potentially sustainable CL concepts that contribute to micro-level sustainability. The article is organized into five sections. The next section describes the sustainability problems at the micro-level and highlights the role of CL in their solving. Section 3 describes the stakeholders, criteria, and CL concepts. In section 4, potentially sustainable CL concepts, based on the development of different logistics centres categories, flow consolidation, cooperation, and the application of alternative transportation modes, are defined and explained. The last section presents concluding remarks.

## 2. LOGISTICS SUSTAINABILITY PROBLEMS AT A MICRO-LEVEL

The growing concerns of sustainability problems, urbanization, and technological innovations indicate the necessity for reassessing and harmonizing society opinions on the planning and development of cities [3]. Rapid urbanization during the last century has put the

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cities under great pressure because they did not manage to adapt to the forthcoming changes. Today, urban sustainability is compromised in every field, where inefficient energy consumption, large air-pollutant emissions, traffic congestions, water and ground pollution, biodiversity loss, poor accessibility and mobility, violated safety, etc., are only some of the most visible consequences of unsustainable growth [4].

Cities occupy only 3% of global space but are responsible for 75% of global energy consumption and air-pollutant emissions [5]. It is obvious that the treatment of urban areas' problems determines whether the world and the society would move towards a sustainable future [5,6]. The sustainability of urban areas is recognized by the European Union as an important topic, however only several cities of north and west Europe (such as Helsinki, Stockholm, Berlin, etc.), the Middle East (such as Masdara) and the Far East (such as Songdo) could state that they are on a path of sustainability [7].

Although logistics is not the only responsible side, the realization of logistics activities, especially transportation, is a significant cause for the negative effects on urban sustainability [8]. Traffic congestions, air pollution, inefficient realization of logistics processes, the increase in logistics costs, noise, etc., are some of the consequences caused by the neglect and inadequate approach in the planning of CL.

An everg-rowing demand for home delivery, personalization and individualization in production and consumption, and the frequency growth of small deliveries are present in CL for decades [9, 10]. Because of strict customer demands, the existing logistics systems are not capable of efficient activity realization. Flow consolidation levels are low, which results in low utilization of loading space capacities in delivery vehicles. The absence of cooperation in the field of CL results in a large number of empty vehicle trips in urban areas [11], which, together with the previously mentioned, causes additional unsustainable effects.

The main problem is the lack of planning activities and encompassing, long-term CL policies and practices [12]. Instead of treating logistics as a service to the local economy, local authorities have, in most cases, an antagonistic attitude towards the realization of logistics activities, especially transportation. By neglecting the real nature of CL problems, local authorities tend to drastically restrict and regulate logistics activities in urban areas [11, 13, 14].

## 3. STAKEHOLDERS, CRITERIA, AND CONCEPTS OF CL

For solving CL problems, it is important to consi der the opinions, goals, and interests of all stakeholder groups – logistics service providers, service users, local residents, and local authorities [15]. The relationships among those stakeholders are complex, with often conflicting goals [12]. The goal for logistics service providers is in the reduction of costs and the increase of profit of providing logistics services. The customers of logistics services (senders and receivers of goods) are interested in reliable, high-quality, and accessible logistics services, at an acceptable price. The interests of local residents refer to the reduction of negative effects caused by the realization of logistics activities, noise reduction, improvement of safety and mobility in urban areas. Local (urban) authorities aim at achieving better living conditions and promoting economic and ecological growth. Local authorities should play a key role in solving conflicting goals among CL stakeholders and stimulating cooperation [16–18].

The treatment direction of CL problems ideal for one stakeholder group is often unacceptable for others. Every stakeholder group gives more importance to those criteria which comply with their goals and opinions. Different criteria importance perceptions cause the necessity of defining enough-wide criteria set when solving CL problems so that all stakeholders' opinions and goals could be included. It is necessary to examine the opinions of stakeholders on the defined criteria in order to prioritize them. The literature analyzed a wide set of criteria and parameters used for solving CL problems: technical (efficiency, reliability, modal shift, goods flows transformation degree, etc.) [19–23], economic (operational costs, development costs, required subsidies, etc.) [19, 21, 24, 25], social (freeing of public space, city zone attractiveness, traffic congestions, accessibility, mobility, etc.) [14, 21, 23, 26] and environmental (air pollution, energy consumption, waste generation, etc.) [19, 21, 23–26].

Every urban area has its specific economic, demographic, and spatial characteristics. Therefore, the characteristics of goods flows, their generators, demands for logistics services, logistics platforms and systems, and service providers vary significantly in different urban areas [27]. Different social, economic and environmental circumstances cause different CL problems, but also define feasible solving directions.

According to different initiatives, measures, technologies, and approaches, it is possible to define a wide set of practical solutions/concepts of CL, and even within one concept, it is possible to define numerous different scenarios [28]. CL concepts are not universal – those proven to be good for some urban areas could be unfit and bad for other urban areas [29, 30].

There is a growing body of research that focuses on defining, analyzing, and the assessment of potentia-

lly sustainable CL concepts. The article [31] analyzes a wide set of performances of different drone-based CL concepts for goods delivery, while the article [32] ranks the sustainability drone-based CL concepts. CL concepts that consider the characteristics of urban areas and the environment are analyzed in [19]. The goal of the article was to find the most suitable CL concept for the city of Belgrade, for all stakeholders, considering all factors that describe the urban area. The concepts are defined according to different combinations of logistics centres, flow consolidation, and the application of environmentally friendly transportation modes. The problem of selecting the appropriate CL concept for the central business district of Belgrade is solved in [30]. Different multi-echelon systems, with different consolidation levels, and the application of different transportation technologies are considered. The application of Industry 4.0 technologies in defining potentially sustainable, smart CL concepts is analyzed in [33]. The article [34] focuses on the selection of sustainable CL concept for the last mile of delivery for the city of Pardubice, where electric scooters, parcel lockers, autonomous ground vehicles, drones, and pipeline systems are considered.

## 4. DEFINING SUSTAINABLE CL CONCEPTS

Temporal and spatial demand consolidation, according to some aspects of homogeneity, through consolidation centres, represents the foundation for planning and development of future CL systems [20]. Flow consolidation can take place at the outskirts of urban areas [35], or in the delivery zone, through micro-consolidation centres (MCC) [36]. Furthermore, the application of intermodal transportation (IT) and cooperation among participants (especially the carriers of logistics activities) have a significant role in the planning of those systems [20]. The development of appropriate logistics centre categories represents the core of the Physical Internet and it is an important prerequisite for achieving hyper-connected CL [16]. Hyper-connected CL relies on interconnected logistics networks, alternative transportation modes, standardization and cooperation among all participants [37]. Physical Internet and hyper-connected CL are relatively new ideas that represent a vision of sustainable CL systems [38], and their application depends directly on the identification, development, and application of sustainable CL solutions and concepts.

The following text defines and describes seven CL concepts that differ in the type and role of logistics centres, system structure, applied transportation technologies, logistics flows' transformation degree, modal redistribution of transport work, etc. It is assumed that in every concept one or more logistics centres at the outskirt of the urban area exist. Those centres enable flow consolidation and cooperation among participants in logistics chains.

CL concept 1 – Refers to the development of underground logistics systems for supplying flow generators. The system consists of peripheral logistics centres which have direct access to underground logistics systems. The concepts also include the development of adequate MCCs used for transhipment and transfer of goods at the surface in the delivery zone. The developed MCCs enable flow consolidation and modal shift in the close proximity of flow generators. Smaller delivery vehicles are used in the realization of the last delivery phase – from MCCs to flow generators. Considering the applied technology in the last phase, variety and volume of included goods flows, and logistics activities executors, it is possible to define different variants of this concept. Therefore, the last delivery phase can be executed by applying different categories of eco-vehicles (freight bicycles, cycles, electric vehicles, etc.) or through the idea of crowdsourcing (the engagement of ordinary people in the realization of logistics activities [39]). CL concepts, based on the application of underground logistics systems, are covered in [21, 40–42].

The advantages of this concept are the possibility for covering a wide set of goods flows, high efficiency of logistics processes, and extraordinary reduction of logistics activities' negative environmental impact. Its disadvantages are high investment costs, long development and construction period, and the impossibility of developing such systems in every, especially historical parts of urban areas.

CL concept 2 – Refers to the application of public passenger transportation vehicles for goods transfer to the delivery zone (Cargo-hitching). In this concept, the logistics system is integrated with the passenger transportation system in the city. The concept uses the existing rail infrastructure and regular tram lines for goods transportation to the delivery zone. Developed MCCs in the delivery zone enable the application of eco-vehicles and crowdsourcing in the last delivery phase. Cargo-hitching, as a CL concept, is covered in [43, 44].

The advantages of this concept are relative small infrastructure investments and relatively simple integration of rail transportation mode for goods transportation to the delivery zone. The disadvantages of the concept are the mixing of goods and passenger flows and limitation on the existing public transportation trip schedules.

CL concept 3 – Refers to the application of regular tram lines. In contrast to the previous concept, regular tram lines are established for the goods transportation on the relation peripheral logistics centres-MCCs. Modal shift on eco-vehicles (or the integration with the

crowdsourcing idea) takes place at MCCs for the realization of the last delivery phase (on the relation MCCs – flow generators). The application of cargo trams in CL concepts is covered in [23, 45].

The advantage of this concept is in the separation of goods and passenger flows which improves its efficiency and reliability. Its disadvantage is in the need for developing additional tram infrastructure for connecting with peripheral logistics centres.

CL concept 4 – Refers to the development of peripheral logistics centres interconnected with the rail transportation mode. A larger number of peripheral interconnected logistics centres are developed, which form a ring structure in the outer part of the logistics network. Flow generators are serviced directly from the peripheral logistics centres with eco-vehicles. Every logistics centre has its dedicated delivery zone, and with the rail connections, goods transfer among logistics centres is enabled. CL concepts based on interconnected logistics centres are covered in [35, 46].

The main concept advantages are the better possibility for transport work redistribution in the delivery zones of logistics centres. This improves the system efficiency and reduces costs and air-pollutant emissions. The disadvantages are in the need for developing rail infrastructure in the outer ring of the network and the requirement for developing a larger number of peripheral logistics centres.

CL concept 5 – Refers to the application of inland waterway transportation in the field of CL. The development of logistics centres at riverbanks enables the transfer of consolidated goods flows on inland waterway transportation mode and the use of inland waterways for goods transfer to the delivery zone. River transhipment stations are developed in the delivery zone, from which the last delivery phase is executed with eco-vehicles. Articles [47, 48] analyze the application of inland waterway transportation in CL.

The advantages of the concept are good modal redistribution, high efficiency, and the reduction of negative environmental impacts. The disadvantages are the limitation on the existing inland waterway infrastructure and a relatively narrow catchment area of river transhipment stations. Furthermore, the disadvantage is also in the requirement for developing a larger number of river transhipment stations, which could be a serious challenge in tourist and historical parts of cities (which often lie at riverbanks).

CL concept 6 – Applies inland waterway transportation mode in a combination with MCCs in the function of city-Dry Ports (DP) for river transhipment stations. DP terminals are a special category of IT terminals that are located in seaport container terminals' hinterland, have regular shuttle connections (road or rail) with those terminals, and offer almost all their services, but in the continent hinterland [49]. In this concept, the idea of DP terminals is transposed on the field of CL – a regular road connection between MCCs (city-DPs) and river transhipment stations is established. This concept is an upgrade of the previous one to widen the system catchment area by covering flow generators in the whole urban area. The development of MCCs in the function of city-DPs for river transhipment stations and the establishment of regular connections on the relation city-DPs – river transhipment stations enables efficient system transformation and the application of smaller delivery vehicles in the last delivery phase. The concept applies electric vehicles for transporting goods between city-DPs and river transhipment stations, whilst the last delivery phase is realized with smaller eco-friendly vehicles. The concept can represent a good solution in situations where there is only a limited number of river transhipment stations and a large delivery zone. No article in the existing literature analyzed CL concepts based on the application of inland waterway transportation and the development of MCCs in the function of city-DPs for river transhipment stations.

The advantages of this concept are exceptional effects on the reduction of negative environmental impacts, high efficiency in the realization of logistics processes, and good modal redistribution. Another advantage is in the fact that the realization of logistics activities does not occupy additional riverbank space which is in most cases dedicated for other urban and tourist contents. Also, an advantage is in the possibility of temporal goods warehousing in city-DPs which enables the realization of a greater number of deliveries during the day. The disadvantage of the concept is in the high complexity of the system and a complex operational delivery planning process.

CL concept 7 – Refers to the combined application of rail and inland waterway transportation modes. This concept combines the ideas of concepts 4 and 5. It refers to the development of logistics centres at peripheral locations, where some of them have access to the inland waterway. A rail connection is established among logistics centres to enable goods transfer. A portion of flow generators that are in the river catchment area is serviced through the combined application of inland waterway and road (smaller eco-vehicles) transportation modes. Those generators who are outside the inland waterway catchment area are served directly from the closes peripheral logistics centre (with larger-capacity eco-vehicles). This concept is not analyzed in the existing literature.

The advantages of the concept are in utilizing all three transportation modes, good system interconesti-

ons, high efficiency, and the reduction of negative environmental impacts. Its disadvantages are in the requirement for developing a larger number of peripheral logistics centres and additional rail infrastructure, as well as greater system complexity.

## 5. DISCUSSION

Every defined concept represents a distinct category of CL solutions and deserves more attention in scientific research. The first five concepts are covered in the existing literature, while concepts 6 and 7 are currently unexplored.

The analysis and modelling of CL concepts require answers to a wide set of planning questions of tactical and operational nature. The solving of tactical problems is especially important because those solutions direct the future exploitation of the developed system. In concepts that refer to a multi-echelon system structure with different categories of logistics centres and the application of alternative transportation modes and vehicle types, it is necessary to determine the most suitable network structure, the number and location of logistics centres, generator allocation on those logistics centres, operationally plan all the processes, etc.

## 6. CONCLUSION

The unsustainable development direction of society is most visible in urban areas. The realization of logistics activities in urban areas has significant negative effects on sustainability. To make the realization of logistics activities more sustainable, it is necessary to plan and develop sustainable CL systems.

In this article, the sustainability problems of logistics systems in urban areas and the role of CL in achieving local sustainability are described. All stakeholder groups, their attitudes, and goals are described, and the complexity in solving CL problems caused by complex relations among stakeholders is pointed out. The article highlights how flow consolidation through logistics centres, cooperation among participants, and the application of IT, represent the key elements in defining sustainable CL concepts.

Based on those elements, seven potentially sustainable CL concepts are defined. The concepts differ in the type and role of logistics centres, the system structure, applied transportation technologies, logistics flows' transformation degree, modal redistribution of transport work, etc.

The direction of future research could be in a more detailed analysis of the defined, and the definition of new CL concepts which are based on the development of different categories of logistics centres, cooperation and the application of IT. It is necessary to develop appropriate assessment and analysis models in order to examine the practical feasibility and the implementation effects of those concepts in different urban areas. Special attention of future research should be set on the concepts that promote the intensive application of alternative transportation modes.

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## REZIME

PLANIRANJE I RAZVOJ ODRŽIVIH LOGISTIČKIH SISTEMA NA MIKRO NIVOU

*Održivost urbanih sredina je već decenijama sporna tačka u pitanjima održivog razvoja. Neefikasna realizacija logističkih aktivnosti na područjima gradova ima mnogobrojne negativne efekte po održivost. Posebno neodržive posledice ima dominantna uloga drumskog transporta u isporuci robe na području grada. Postizanje održivosti na mikro nivou je moguće jedino sveobuhvatnim i jednovremenim planiranjem sistema city logistike (CL) kroz razvoj različitih kategorija logističkih centara, konsolidaciju tokova, kooperaciju i intenzivniju primenu alternativnih vidova transporta. Planiranje sistema CL je složen zadatak jer obuhvata više zainteresovanih strana sa kompleksnim međusobnim odnosima i konfliktnim ciljevima. U ovom radu je ukazano na značaj planiranja CL u postizanju lokalne, mikro održivosti. Opisane su zainteresovane strane, kriterijumi i koncepcije CL. Na osnovu postojeće literature u oblasti ali i novih tehnologija i pristupa, definisano je sedam potencijalno održivih koncepcija CL.*

**Ključne reči:** *održivost, razvoj, city logistika, koncepcije, kooperacija, konsolidacija, alternativni vid transporta*