Planning And Development of Sustainable Logistics Systems at a Macro-level

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The realization of a series of logistics activities, as support for goods flows, can result in serious negative consequences on sustainability if they are not planned properly. Road transportation’s dominant role in existing logistics systems has serious unsustainable effects on the society and environment. The only way in achieving regional sustainability of logistics systems is in the utilization of alternative transportation modes through the application of intermodal transportation (IT). The planning of IT systems is a complex task that consists of determining the appropriate structure of the network, identification of efficient IT terminal types, their number, location, and role in the system, defining connections between terminals, etc. All that is preceded by the selection of the system development scenario. This article indicates the significance of IT in achieving sustainability at a macro-level. The Dry Port (DP) concept is highlighted as an instrument of achieving sustainable IT system development. Six potentially sustainable development directions of IT systems through the concept of DP are defined and explained.

Key Words: sustainability, development, intermodal transportation, dry port

1. INTRODUCTION

The realization of goods flows is supported by a series of logistics activities – transportation, transshipment, warehousing, goods processing, order picking, etc. Inadequate planning of those activities can lead to serious negative effects on sustainability. The most visible negative effects on economic, environmental, and social sustainability are caused by transportation – a logistics activity with the most unsustainable effects [1]. In the existing logistics chains, road transportation has had a dominant role in the realization of goods flows, and this, for decades, has critical effects on sustainability. The negative consequences (inefficient utilization of transportation vehicles, high costs, air-pollutant emissions, noise and vibrations generation, traffic congestions, safety risks, etc.) are the most visible in road transportation mode.

The presence of road transportation in overall transportation can be reduced through the application of intermodal transportation (IT). „IT represents the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes.” [2]. The application of alternative transportation modes (rail, inland waterway, sea, and air), the utilization of standardized loading units, and flow consolidation through specialized logistics centres (IT terminals) are the main principles of IT. By reducing costs and achieving temporal savings through the application of IT [3], logistics systems become more efficient and sustainable.

The purpose of this article is to indicate the relationship between sustainable development and the planning of logistics systems at a macro-level. The goal is to highlight the importance of IT system planning in achieving regional sustainability. The article is organized into five sections. The next section describes the sustainability problems of logistics at a macro-level. Section 3 describes the role of IT in achieving sustainability, with the accent on the Dry Port (DP) concept as a potential IT development direction. Potential development scenarios, based on the DP concept, are defined and explained in section 4, which is followed by the conclusion.
2. SUSTAINABILITY PROBLEMS OF LOGISTICS AT A MACRO-LEVEL

Achieving sustainability in global supply chains is not only a destination but also a journey during which logistics systems go through different evolutionary phases by conducting innovations [4]. Although the achievement of sustainability of logistics systems at a macro-level is an ongoing topic, there are no sufficient efforts in intensive global partnerships on that matter [5]. It is necessary to form stable, long-term, and multidisciplinary partnerships to be able to work towards achieving sustainability [6].

The volumes of intercontinental goods flows are expected to double in the year 2025 compared to 2017 [7]. Having in mind that the biggest portion of these flows is the subject of container transport, it is expected that the volumes of intercontinental container flows would double as well. Logistics systems face many challenges caused by the need for capacity expansion for meeting the rising demands of container flows realization. The lack of appropriate logistics infrastructure for supporting those flows causes bottlenecks [8]. Technological, structural, and organizational changes are also required to ensure their efficient realization [9]. With the rise in intercontinental container flows volumes and the need for reducing sea transportation costs, there is an ongoing trend in developing and constructing freight ships with large capacities. This produces additional pressure on container seaport terminals that are unable to service such ships [10]. Seaport container terminals, as the main nodes in intercontinental flows, experience the most challenges in the realization of growing container flows volumes [11], where the operational inefficiency at seaport container terminals causes efficiency reduction also in their hinterland. Poor modal redistribution in the advantage of the road transportation mode causes movements of a large number of road freight vehicles on a daily basis, which results in increased unsustainable effects on the environment (air-pollutant emissions, noise and vibrations generation, traffic incidents, etc.). According to official EUROSTAT data, in the year 2019, road transportation participated in 76.3% of European goods flow realization, while the rail transportation mode was involved with 17.6% and inland waterway transportation only with 6.1% [12]. The consequence of this is the emission of an enormous amount of air pollution, noise, vibrations, while the increase of road freight vehicle numbers on roads, especially in seaport cities, causes traffic congestions and violates safety [13], increases traffic transit times, and energy consumption. CO₂ emissions of the transportation sector contribute to over 25% of global emissions. Road transportation participates in 72% of those emissions [14], where 30% is the consequence of using heavy-duty vehicles [15]. Road freight vehicles, in the year 2019, participated in 4.9% of all traffic accidents on European roads, but at the same time in 14.2% of all fatal accidents [16]. The development of IT systems would ensure better modal redistribution which would mitigate the negative effects of goods flows realization.

The achievement and development of a sustainable logistics system would result in the emergence of a new specialized type of logistics service providers – providers of sustainable logistics services [17]. Sustainable logistics systems combine all transportation modes and appropriately structured logistics services through the application of IT. To achieve regional and global sustainability of logistics chains, it is necessary to define the development scenarios for new, sustainable logistics systems, as well as strategies for their deployment [17].

3. THE DP CONCEPT IN THE FUNCTION OF IT SYSTEM SUSTAINABILITY

Achieving sustainable logistics systems at a macro-level is possible only through intensive planning and development of IT systems/networks. However, that is not a simple process because it includes a large number of stakeholders [18], complex problem structures [19], and many criteria [20] that the stakeholders use for potentiating the direction of actions. The development of IT systems must be preceded by the definition and selection of appropriate scenarios, in accordance with the specifics of the situation and stakeholder interests, with the aim set on acceptability and sustainability [9]. The selection of the appropriate IT development scenario has to be carried out in a multicritical environment, by solving conflicting goals.

IT system development scenarios are numerous [9], and differ in the network structure, the role of IT terminals, applied technologies, utilized transportation modes, included goods flows, etc. The existing literature, depending on the observed problems and applied approaches, analyzed a wide set of IT sustainability criteria/parameters: technical (efficiency, modal redistribution, flexibility, availability, service quality, etc.) [21–23], economic (development costs, operational costs, contribution to economic growth, etc.) [24–26], social (safety, competition, cooperation, etc.) [27–29], environmental (emissions of air pollution and energy consumption) [23, 24, 26], and regulatory/political (laws, international harmonization, institutions, etc.) [30, 31]. The treatment of the IT field varies in different regions of the world so the planning of sustainable IT systems at a regional level represents a serious challenge [22, 29, 32].
In regional goods flows, road transportation mode is dominant, the involvement of rail transportation is low, while the application of inland waterway transportation mode is almost nonexistent. To make the realization of regional goods flows sustainable, it is necessary to develop an IT system that relies more on the rail and inland waterway transportation modes. The development of IT systems is preceded by the selection of the development scenario. The DP concept is recognized in the literature as a sustainable development direction of IT systems that increases the participation of rail transportation.

IT terminals represent a distinct category of logistics centres and are the main elements of IT systems’ structure. It is possible to define a diverse set of different IT terminal categories from the viewpoint of their role, services, subsystems, technologies, dimensions, included flows, location, etc. [33]. DP terminals are one of those distinct categories, and they are one of the most analyzed categories in the context of IT system development.

A DP is a subsystem of a seaport container terminal, physically dislocated into the continent hinterland, with established regular shuttle connection (in most cases by rail) with its native seaport terminal, and offers almost all services of that terminal, only in the continent hinterland [34]. Shuttle lines are with fixed capacities and operate on regularly scheduled lines between DP terminals and seaport container terminals [35]. The DP concept improves the performance of seaport container terminals, ensures them with the required capacities, increases the volume of services that they can offer to the market, and so significantly improves their competitiveness, which also results in the attraction of greater container flows volumes [36]. The DP concept gained lots of popularity in the scientific community [37] so it was in the analysis focus in the context of regional and intercontinental seaport container terminals around the world [35,37–43]. DP implementation effects refer to the improvement of container flows’ realization efficiency which leads to the reduction of logistics costs and negative environmental impacts [43]. Razvojem DR terminala u uzdušnom pomorskom kontejnerskom terminala povećava se atraktivnost luke, a time i obim kontejnerskih tokova koji će prolaziti kroz region u kom se terminal nalazi. Samim time, može se tvrditi da je DP koncep efikasan katalizator održivog regionalnog razvoja [42].

Despite the numerous advantages and positive effects of the DP concept, there are still significant impediments to its wider practical application. Factors that affect and direct the DP concept integration into the IT systems the most are infrastructure, regulatory support, land ownership, and environment [44]. To make its implementation successful and sustainable, the DP concept requires infrastructural, institutional, and planning support, as well as the involvement of the private and public sectors [44].

The application of the DP concept is not universal and differs in different regions. Depending on the IT system state, the problems, goods flows’ structure and volumes, and the state of all aforementioned factors which dictate its application, the development direction of IT systems through the DP concept are diverse. The relationship between DP terminals and other entities in the IT system significantly impact the definition of development directions. This refers primarily to the relationship between DP terminals and their native seaports [45], between DP terminals and other links in the supply chain [41], and between DP terminals and the region on an administrative level [46].

4. IT SYSTEM DEVELOPMENT SCENARIOS THROUGH THE CONCEPT OF DP

The definition and selection of IT system development scenarios are one of the main tasks on the strategic planning level [9]. Considering that DP-based IT systems can have different structures, it is necessary to define the development direction appropriately. Six potential DP-based development scenarios for the system of IT are described in the following text. The scenarios differ in the network structure, the role of different terminal categories, the required level of logistics infrastructure development, involvement of different transportation modes, transformation degree of goods flows, included categories and volumes of goods flows, etc.

*Scenario 1 – Transformation of existing IT terminals into local DP terminals for seaport container terminals*

The idea of the scenario is the revitalization of existing IT terminals and their transformation into local DP terminals for seaport container terminals. This scenario requires only the modernization and reorganization of existing IT terminals as well as the establishment of rail shuttle connections with seaport container terminals. Also, the scenario requires the expansion of existing IT terminals’ capacities to be able to service a larger volume of container flows. This scenario utilizes road and rail transportation modes.

The advantages of the scenario are low realization costs and relatively simple implementation. The disadvantages are in being focused only on intercontinental goods flows, low network interconnection degree and synergy, small possibilities for cooperation among participants, a narrow catchment area of the system, high competition among DP terminals, etc. Another disadvantage is only partial demand coverage for the realization of container flows caused by the limited
expansion possibilities of the existing infrastructure. Furthermore, a large number of smaller, subsequently transformed, DP terminals does not result in optimal network configuration.

**Scenario 2 – Development of regional DP terminals for seaport container terminals**

This scenario is the well-known and analyzed concept of DP. It refers to the development of new, regional DP terminals for seaport container terminals [38,40]. The DP terminals would play the role of regional hubs/consolidation centres and would represent the key links of the network. Rail shuttle connections would be established on the relation DP-seaport terminals.

The advantage of the scenario is its capability for covering the increasing demands for container flows’ realization by developing new IT infrastructure and appropriate incorporation in the realization of intercontinental goods flows. The disadvantage of the scenario is its primary focus on intercontinental flows, so it is inappropriate for the realization of regional flows. Besides, a simple development of new DP terminals does not contribute to better cooperation and interconnection in the regional IT network.

**Scenario 3 – Development of a DP terminal network for seaport container terminals**

The scenario refers to the development of an interconnected network of DP terminals in which the existing IT terminals play the role of local consolidation centres for the newly-developed DP terminals [39]. This scenario is an upgrade of the previous. Shuttle rail connections would be established on the relation IT terminals – DP terminals, as well as on the relation DP terminals – seaport container terminals.

The advantage of this scenario is better network connectivity and the possibility for partial integration of regional flows. The disadvantage is still the dominant focus on intercontinental flows, a more complex network structure, and a more complex realization of regional flows.

**Scenario 4 – Transformation of existing IT terminals into local DP terminals for inland waterway container terminals**

The scenario focus is on the realization of regional goods flows and the integration of inland waterway transportation mode in their realization. Scenario refers to the revitalization of existing IT terminals and their transformation into local DP terminals for inland waterway container terminals. Rail shuttle connections would be established between DP terminals and inland waterway container terminals. This scenario does not cover the realization of intercontinental goods flows because it does not have appropriate connections of seaport container terminals with the developed IT network.

The advantages of the scenarios are low development costs and the integration of inland waterway transportation mode into the realization of regional goods flows. The disadvantages are the limited capacity of existing IT terminals, the lack of connections between inland waterway DP terminals, the dominant role of inland waterway transportation mode, which represents the main inflexibility of the scenario and prevents the attraction of greater goods flows’ volumes.

**Scenario 5 – Development of regional DP network for inland waterway container terminals**

The scenario refers to the development of a new DP-based network in the function of inland waterway container terminals [9]. The developed terminals have regional character and are with greater capacities. The existence of adequate rail connections between the developed DP terminals results in a wider catchment area and the possibility for attracting a greater volume of regional container flows. In this scenario, rail shuttle connections would be established between DP terminals and inland waterway container terminals, as well as between the DP terminals. As was the case in the previous scenario, the absence of adequate connections between seaport container terminals and the developed IT network, the scenario is not suitable for the realization of intercontinental goods flows.

The advantages of the scenario are a high degree of modal redistribution on rail and inland waterway transportation modes and the focus on regional IT development. The disadvantages of the scenario are relatively high development costs of new DP terminals and a complicated implementation caused by a complex network structure.

**Scenario 6 – Transformation of inland waterway container terminals into DP terminals for seaport container terminals**

This scenario represents an unexplored concept in the literature – the rehabilitation of existing inland waterway container terminals and their transformation into DP terminals for seaport container terminals. This would ensure the integration of inland waterway transportation mode into the realization of intercontinental goods flows. The inland waterway transportation mode would be connected through rail shuttle lines with seaborne transportation, on the relation seaport container terminals – inland waterway container terminals (DP terminals).

The advantage of the scenario is relatively low development costs because it does not require the development of new terminals. The disadvantage is the
dominant focus on the realization of intercontinental and lower attraction of regional goods flows.

**Scenario discussion**

The defined IT development scenarios are different, but still, some common characteristics exist. Scenarios 1, 2, and 6 are primarily oriented towards intercontinental goods flows, scenarios 4 and 5 are focused on serving regional goods flows, while scenario 3, although dominantly oriented towards intercontinental flows, can serve regional goods flows efficiently. Scenarios 1, 4, and 6 do not require substantial infrastructural investments because they do not refer to the development of new terminals, as is the case in scenarios 2, 3, and 5. Considering the modal redistribution of transport work, scenarios 1, 2, and 3 utilize only road and rail transportation (not considering the sea transportation to/from seaport container terminals), while scenarios 4, 5, and 6 also include the application of inland waterway transportation mode.

All the defined scenarios are characterized by different planning problems on all levels, and each deserves special attention and analysis. A special focus of future research should be set on the scenarios that refer to the development of DP terminals in the function of inland waterway container terminals because they promote intermodality in the best manner possible – by including road, rail, and inland waterway transportation modes. Furthermore, these scenarios deserve special attention because it is necessary to integrate regional goods flows into the existing IT systems. This is best achieved through the redevelopment of a regional IT system/network which is maximally flexible from the point of available transportation modes.

5. CONCLUSION

Sustainable realization of goods flows is an ongoing issue in the context of global and regional sustainable development. To achieve this, it is necessary to develop sustainable IT systems.

In this article, the problems of logistics systems' sustainability and the role of IT in their achievement are described. It is indicated that the DP concept stands out as a potential sustainable action direction in the planning of future, sustainable IT systems. Six different IT system development scenarios, through the concept of DP, are defined and described. The scenarios are defined according to the existing literature, approaches from the practice, but also on fresh ideas that were not yet analyzed but indicate sustainability.

The direction of future research could be in a more detailed analysis of the defined and the definition of new IT development scenarios. It is necessary to develop appropriate assessment and analysis models for examining the practical feasibility of these scenarios in different geographical areas. Special attention of future research should be set on the DP concept in the function of inland waterway container terminals because such solutions integrate inland waterway transportation mode into IT systems efficiently.

**REFERENCES**


**REZIME**

**PLANIRANJE I RAZVOJ ODRŽIVIH LOGISTIČkih SISTEMA NA MAKRO NIVOU**

Realizacija niza logističkih aktivnosti kao podrška robnim tokovima može imati ozbiljne negativne posledice po održivost, ukoliko nije dobro isplanirana. Dominantna uloga drumskog transporta u postojećim logističkim sistemima ima veoma izražene negativne posledice po održivost. Jedini način da se postigne regionalna održivost logističkih sistema je složen zadatak koji se sastoji od određivanja adekvatne strukture mreže, identifikacije efikasnih tipova IT terminala, njihovog broja, lokacije i uloge u sistemu, definisanja veza između terminala, itd. Svemu tome prethodi izbor scenarija razvoja sistema. U ovom radu je klasifikovano na značaj IT transporta u postizanju održivosti na makro nivou. Istaknut je Dry Port (DP) koncept kao instrument postizanja održivog razvoja sistema IT. Definisano je šest potencijalno održivih pravaca razvoja sistema IT kroz koncept DP.

**Ključne reči:** održivost, razvoj, intermodalni transport, dry port