
MODELING THE STRUCTURE OF THE LOGISTICS CENTERS

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Abstract: *Growing competition in the global market imposes the need for proper planning of logistics processes and development of logistics networks, where logistics centers (LCs) as nodes in these network play a key role. LCs can have different structures defined by various elements characteristics, and accordingly different efficiencies. In order to identify those that would represent benchmarks for other LCs it is necessary to define the broadest set of possible structures. However, in practice a number of structures is limited, which doesn't mean there might not be some which would be competitive or more efficient than the existing ones. Therefore the goal of this paper is the modeling of potential LC structures, based on the identified dependencies between the elements characteristics and the existing structures' efficiencies. The model is tested in a case study of modeling a potential intermodal terminal structure as one of the possible LC forms.*

Keywords: *modeling, structure, logistics center, intermodal terminal, efficiency.*

1. INTRODUCTION

Due to the growing competition in the global market, adequate planning of logistics processes is crucial for defining successful business strategies. Economic development and globalization have contributed to a significant increase in the volume of goods flows between the producers and the consumers, and hence the need for planning and design of the logistics networks through which these flows would realize in the most efficient way. Logistics centers (LC), as the nodes in these networks that connect all the other participants (suppliers, manufacturers, retailers, users etc.) and different modes of transport, are the subject of numerous studies concerning their number and location (e.g. Ming-Bao et al., 2007), the structure of functions (e.g. Rimiené & Grundey, 2007), connectivity (e.g. Peng & Zhong, 2008), etc. LCs can appear in different forms and under different names, such as freight terminals, freight villages, city logistic terminals, distribution centers, free-trade zones, hub terminals, dry port terminals, intermodal terminals (IT), etc. (Zečević, 2006). Regardless of their forms and names, their structures are defined on the basis of the same structural elements, such as modes of transport, types of goods, transport technologies, the structure of functions and subsystems, etc., which may have different characteristics and modalities .

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The subject of this paper are the LC structures that need to be identified in order to create preconditions for their comparison and research on their basic characteristics, performance, efficiency, etc., in order to identify those that can serve as the benchmarks for other LCs within the groups with the mutually comparable characteristics. As the research of this type requires real data on the LC operation, they can only be implemented for centers that really exist. This, however, does not mean that there might not be structures that would be competitive with the existing ones and as such the benchmark candidates. According to this the goal of this paper is the modeling of the potential structures of the LC, based on the connections identified between the characteristics of the structural elements of the existing logistics centers and their efficiencies.

The paper is organized as follows. The following describes what the structures of the LC are, how they are defined and what they depend on. The next section describes the methodology for modeling the potential LC structures, after which it is demonstrated in the case study of modeling the potential structure of the IT, as one of the LC forms. Finally, the concluding remarks and the future research directions are provided.

2. STRUCTURE OF THE LOGISTICS CENTERS

Logistic centers represent the systems that can be different in terms of structural elements. Starting from some earlier attempts to classify these elements (Bichou & Gray, 2005), this paper classifies the elements for defining the LC structure into four levels (Figure 1): organizational, operational, physical/spatial and technological. Each of the elements can have different characteristics (modalities). By combining them in different environments and under different conditions, different LC structures can be obtained. Elements can also be used to group the defined LC structures, regardless of the different forms and names. Therefore, the groups of small, large, medium, etc. LCs can be formed in relation to the size, groups of road-rail, road-river-rail, rail-maritime, etc., LCs can be formed in relation to the modes of transport, groups of hub, corridor, liner, etc. LCs can be formed in relation to the status in the network, etc. Examples of some of the structures, that can be found in one or more of these groups, are: "small" road-rail LC that realizes the basic functions, "medium" road-rail-river LC that realizes basic and complementary functions, "large" road-maritime LC that realizes basic, supplementary and accompanying functions, etc.

These different combinations of LC structure arise as a result of a number of factors which according to their character and type of influence can be classified as: internal factors, factors of the logistic flows requirements and environmental factors (Heljedal, 2013; Bergqvist et al., 2010; Roso, 2008; Zečević, 2006). According to Zečević (2006) internal factors include: technological, spatial, financial, location and ownership/organizational performances; Factors of the logistics flows requirements include: logistics strategies, flows characteristics, quality requirements, goods characteristics and network/transport chain characteristics; Environmental factors are: spatial/economic plans, economic/organizational characteristics, laws, social factors, geographical characteristics, infrastructure characteristics, traffic and logistics characteristics, geological characteristics, climatic features and ecological factors. Factors actually define and shape the basic requirements that LC structures have to implement. Factors may affect one or more elements of the structure and may accordingly have a different significance. The excessive complexity and variety of modalities of the elements can lead

to the fact that not all elements can be considered when defining the LC structures. In these situations, factors can be used to select the key elements upon which the LC structures mostly depend.

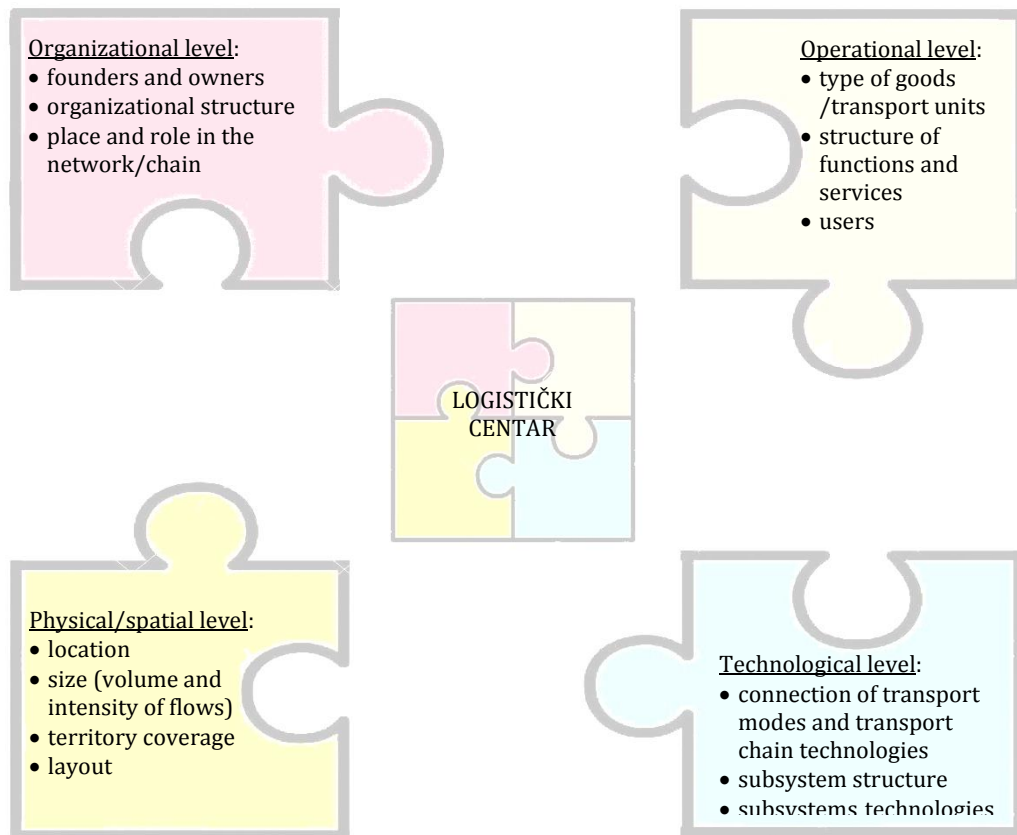


Figure 1. Elements for defining the LC structure

3. METHODOLOGY OF MODELING THE POTENTIAL LC STRUCTURES

Modeling the potential LC structures imply the formation of structures that in practice do not yet exist, or are not yet identified and described, but which might be competitive with the existing structures. The methodology presented in this paper implies the formation of potential structures based on the existing ones. The model is based on the establishment of links between the characteristics of the LC structural elements and their efficiencies. The model actually investigates the differences in the efficiencies of various LC structures and links them to the differences in the characteristics of their structural elements, on the basis of which it forms the new (potential) structures and gives their relative efficiencies. The methodology is explained in more details below, and the schematic representation of the methodology is given in Figure 2.

The first step (Step 1) in the methodology involves the selection of comparable structures from a set of existing ones, which differ on from another by the characteristics of one of the structural elements. The next step (Step 2) is the selection of the reference existing structure, i.e. the structure that will serve as the basis for modeling the potential structure. For the selected comparable structures and reference structure, i.e. for the specific (real-life) LCs as their representatives, it is necessary to determine their efficiencies (Step 3). As the subject of this paper is not to determine the efficiencies, the methodology will go

from the assumption that they have already been calculated. Efficiency can usually be obtained using one of the most commonly used tools such as: DEA (Data Envelopment Analysis) method (e.g., Serebrisky et al., 2016; Ding et al., 2015), SFA method (*Stochastic Frontier Analysis*) (e.g. Wiegmans & Witte, 2017, Cullinane et al., 2006), FDH (Free Disposal Hull) method (e.g. Wang et al., 2003), or mathematical models specifically defined for the particular problem being solved (e.g. Blonigen & Wilson, 2008).

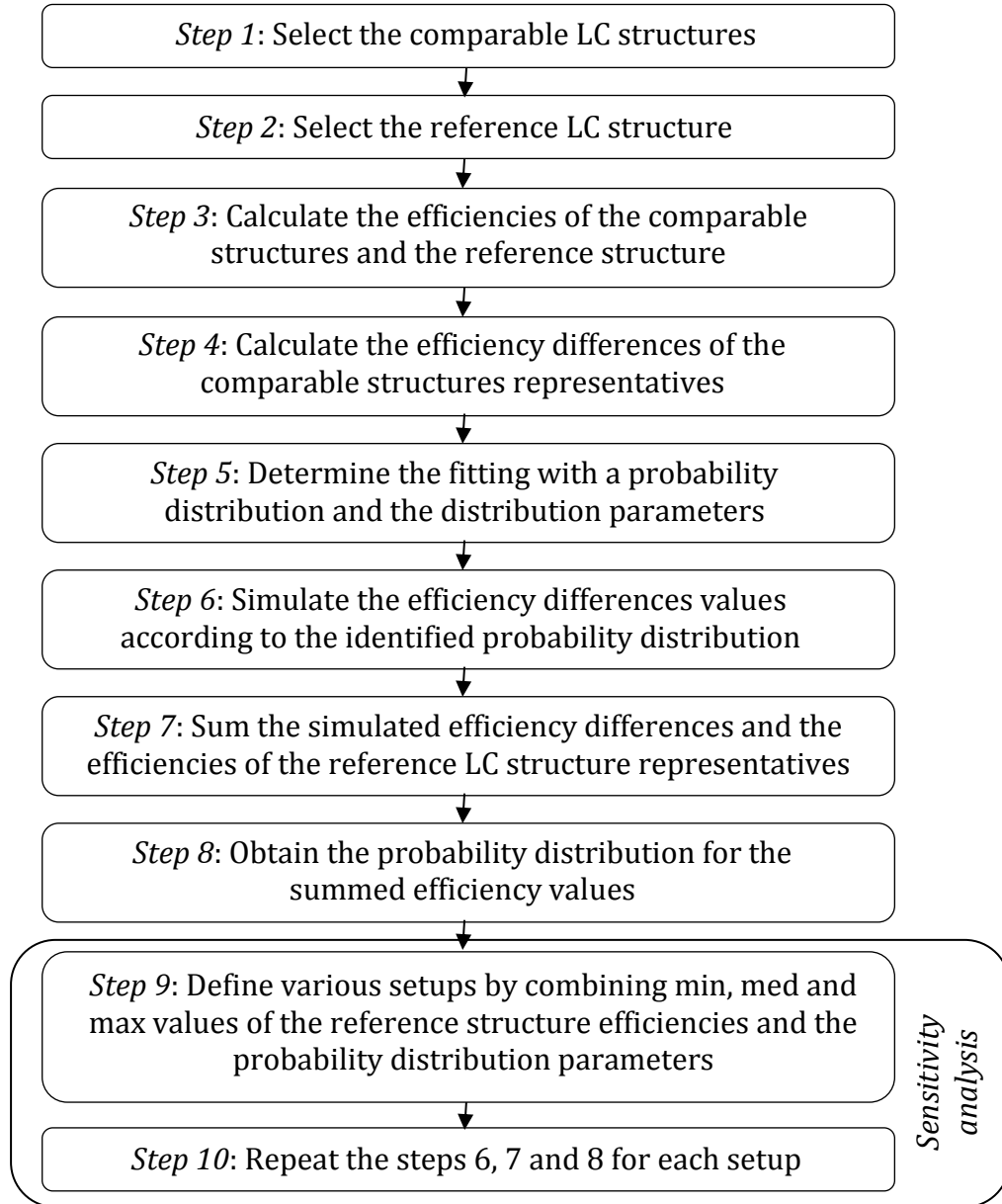


Figure 2. Schematic representation of the methodology for modeling the potential LC structures

On the basis of the obtained efficiency values, differences in the efficiency of representatives of different comparable structures are calculated (Step 4). For the obtained differences in the efficiencies, the fitting with one of the probability distribution function is checked and the parameters of this distribution are determined (Step 5). For the obtained probability distribution parameters the values of the efficiency differences

are simulated (Step 6) and added to the efficiency values of the representatives of the reference LC structure (Step 7). For the obtained values, the probability distribution for the efficiencies of the LC potential structures have been formed (Step 8).

In order to perform the sensitivity analysis of the obtained results, additional settings for modeling the efficiency of potential structures are formed (Step 9). Each setting implies a different combination of the initial efficiency of the reference structure, on the basis of which the potential structure is modeled, and the parameters of the probability distribution of the efficiency difference values. In each setting, the minimum (min), medium (med) or maximum (max) values of the initial efficiencies of the reference LC's structure representatives are taken, as well as the minimum, medium or maximum values of the simulated efficiency differences, obtained by varying the parameters for the probability distribution based on which these values are obtained. For each setting, steps 6, 7 and 8 are repeated, and the probability distributions for the potential LC structure efficiency values are obtained (Step 10). As a measure for comparing the efficiency of the existing and the potential LC structures, the mean value of the obtained or simulated efficiencies can be used.

4. CASE STUDY: MODELING POTENTIAL LC STRUCTURES

The applicability of the proposed methodology for modeling the potential LC structures will be demonstrated in the case of defining the structure of the potential intermodal terminal (IT) as one of the types of LCs. IT represents a place for storage and transshipment of intermodal transport units between different modes of transport (UNECE, 2009). Based on the described elements for defining the LC structure, different IT structures can be defined. The case study to be elaborated in this paper is based on the researches by Tadić et al. (Unpublished manuscript), which define different IT structures, identify real-life European representatives for each structure and calculate the values of their efficiencies. It is also determined that the key elements, based on which the IT structures can be defined, are: size, connection of transport modes, place and role in the network and the structure of functions.

Starting from the IT structures defined in the studies of Tadić et al. (Unpublished manuscript), the first steps in applying the methodology proposed in this paper include the selection of the comparable structures and the reference structure of IT. For the comparable structures, "medium" ITs which according to the structure of functions belong to the category B, i.e. perform the basic functions (reception, transshipment, disposal and shipping of transport means and ITUs) and supplementary functions (e.g. ITUs charging and discharging, storing the goods, maintaining ITUs, etc.) (Tadić et al., Unpublished manuscript), and all "medium" ITs that belong to the category C, which in addition to the aforementioned, performs the accompanying functions (e.g. ITUs collection and dispatching, collection and distribution work with non-containerized cargo, vehicles and handling equipment maintenance, etc.) (Tadić et al., Unpublished manuscript) (Step 1). For the reference IT structure, the "medium" road-rail corridor terminal belonging to the category B according to the structure of functions is selected (Step 2). The goal was identify the effects of expanding the terminal functions structure on their efficiency, and to use this relationship to model the "middle" road-rail corridor terminal that would belong to the category C in terms of the structure of functions. The next step would be to calculate the efficiencies of the representatives of the

aforementioned IT structures (Step 3), which was done in the researches of Tadić et al. (Unpublished manuscript), therefore for the purposes of this paper only differences in their efficiencies have been calculated (Step 4) For the obtained values the fitting with some of the probability distribution have been checked. A normal probability distribution with the parameters $\mu = 0.12$ and $\sigma = 0.219$ (Figure 3) was obtained, where μ is the mean, and σ is the standard deviation (Step 5). Checking the fitting with one of the probability distribution is performed using the EasyFit software (MathWave Technologies).

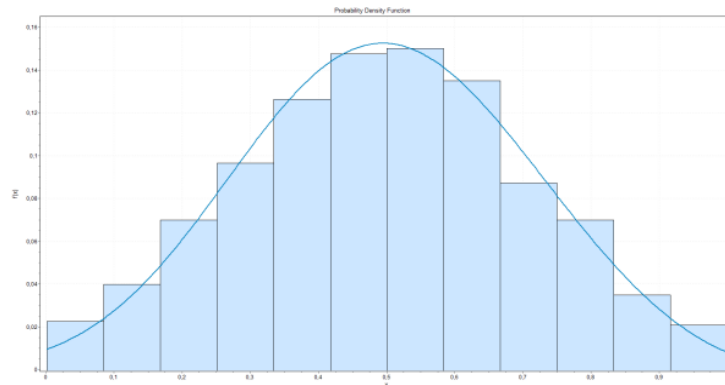


Figure 3. Check of the fitting with a probability distribution (source: EasyFit)

The values of the efficiency differences are simulated in the Excel program package for the obtained parameters. 1500 values in 1000 iterations were simulated (Step 6), and the values obtained were summarized with the efficiency values of the IT structure representatives (Step 7). In this way, the efficiency values for the "medium" road-rail corridor terminal belonging to the category C in terms of the structure of functions are obtained. The probability distribution for these values is shown in Figure 4 (designated as the "basic") (Step 8).

In order to perform the sensitivity analysis, eight more settings were created, in which the minimum, medium and maximum values of the efficiencies of the IT reference structure representatives were combined (min = 0.343; med = 0.423; max = 0.476) with the different mean values ($\mu_{min} = 0.08$, $\mu_{med} = 0.12$, $\mu_{max} = 0.16$) (Step 9). For each of the defined settings, steps 6, 7 and 8 were repeated and the probability distributions shown in Figure 4 were obtained (Step 10).

For the "basic" setting, the average value of the efficiency of the potential structure of IT was 0.535. Considering the sensitivity analysis, in the defined settings, the following mean values of efficiencies were obtained 0.435 (min-min), 0.509 (wed-min), 0.544 (max-min), 0.478 (min-wed), 0.591 (max-wed), 0.497 (min-max), 0.568 (wed-max) and 0.611 (max-max). The values do not deviate significantly from the values for the "basic" setting (± 0.1), which means that this result is acceptable. On the basis of the obtained results, the analyzed potential IT structure would be more efficient than most of the existing structures that belong to the subgroup of "medium" ITs.

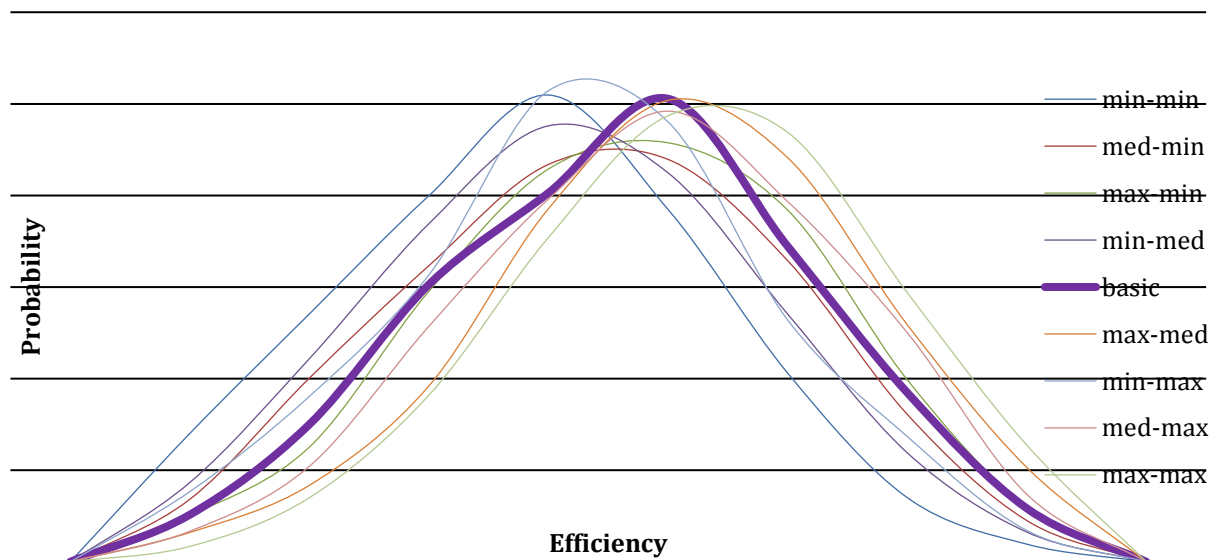


Figure 4. Simulated efficiency values for the modeled IT structure

3. CONCLUSION

Defining the LC structures allows their mutual comparison, analysis of their characteristics, performance, efficiency, etc., in order to find the most efficient ones that would serve as the benchmarks for the other existing LCs that have the potential to develop into these structures, or as a model for developing new LCs. In order for this process to be successful, it is necessary to form the widest possible set of structures, whereby it is necessary to take care not to neglect some structures that may still not exist in practice or have not been identified yet, but which could be competitive or even more efficient than some of the existing structures. Therefore, in this paper, a methodology was developed for modeling the potential LC structures and determining their efficiency, which was demonstrated on the case of modeling the potential structure of IT, as one of the possible forms of LC. Solving the case study has proven that the model is applicable and can produce potential IT structures that are competitive in terminal groups with mutually comparable characteristics. The model is also applicable to modeling other LC structures, regardless of their forms and names. Future research could address the identification of all possible structures, both for ITs and other LCs, in order to create as many structures as possible and to find the most efficient ones.

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