DEFINING THE TYPICAL STRUCTURES OF THE INTERMODAL TERMINALS

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Abstract: *Intermodal transport enables energy, costs and time savings, improves the quality of services and supports sustainable development. The basic element of the intermodal transport system is the intermodal terminal (IT) whose efficiency largely depends on its' structure defined by a combination of different characteristics and modalities of elements, such as the structure of functions and services, sub-system technologies, size, location, layout, etc. Accordingly, the subject of this paper is the development of a methodology for defining typical IT structures based on a wide range of structural elements and factors that affect elements and define their significance. The methodology also included the multi-criteria decision-making (MCDM) model that combines the fuzzy Delphi method, used for evaluating the strength of the factor's influence on the elements, and the fuzzy VIKOR (VišeKriterijumska Optimizacija i kompromisno Rešenje, srb) method, used for ranking and selecting the key elements for defining the IT structure. The aim of this paper was to identify typical IT structures as a prerequisite for their further analysis and selection of those that would represent benchmarks for other terminals with mutually comparable characteristics. The following are identified as the key elements for defining the IT structure: modes of transport connecting the IT, place and role of the IT in the network/chain, size of the IT and the structure of the functions and services that IT performs. Based on the possible combinations of their modalities and research which included over 180 real-life ITs in Europe, 36 typical IT structures are defined.*

Keywords*: intermodal transport, intermodal terminal, typical structure, fuzzy Delphi, fuzzy VIKOR.*

1. INTRODUCTION

Economic globalization and market liberalization have led to the separation of the places of production and consumption, which has resulted in the significant growth of the world trade and intercontinental goods flows. The realization of these flows mainly involves the use of different transport modes, as well as the need to interconnect them. On the other hand, the transport sector faces serious problems as it generates negative economic, social, environmental and other impacts, mainly due to the intensive growth of the road freight transport (Krstić et al., 2019a; Zečević et al., 2017a). Given that the

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traditional methods of development and improvement of individual modes of transport are not able to tackle with these problems (Barysienė, 2012), the solution is sought in the integration of different transport modes through the intensified development of the intermodal transport, with the aim of shifting freight flows from road to the alternative transport modes (EC, 2011). Intermodal transport represent the transport of goods in one and the same loading unit or vehicle using multiple transport modes, where there is no transshipment of goods between the transport modes (ECMT, 1993). The main goal is the application of the different transport modes in order to reduce the overall costs and improve the quality of services. Energy, cost and time savings, less environmental pollution and other positive effects of intermodal transport have been attracting the growing attention in the developed European countries (Caris et al., 2013). The European Union (EU) set the objectives to shift the 30% of the road freight transport at distances over 300 km to the more environmental friendly transport modes (rail, water) by 2030, and 50% by 2050 (EC, 2011). These goals can only be achieved through more intensive development of the intermodal transport.

One of the basic intermodal transport subsystems are intermodal terminals (IT), which represent places for storing and transporting intermodal transport units (ITU) between the different transport modes (UNECE, 2009). ITs represent very important nodes of the transport network that serve as the links between the different transport modes and can have different structures obtained by combining different elements such as the structure of functions, services and subsystems, the place and role in the network, subsystem technology, location, size and layout, etc. In the literature, there are papers in which attempts have been made to define the typical terminal structures (e.g. Kutin et al., 2017; Park & Medda, 2010; Roso et al., 2009; Woxenius, 2007, Sirikijpanichku & Fereira, 2005). However, in these papers the terminal structures are predominantly defined only in relation to one or a few elements. Theoretically, by combining different modalities and characteristics of structural elements, large number of different terminal structures can be formed, but in practice exist typical structures, largely depending on several key elements. The subject and main contribution of this paper is the development of a methodology for defining typical IT structures that involves identifying a wide sets of structural elements and factors that influence these elements, as well as the multi-criteria decision-making (MCDM) model based on which the evaluation and selection of the key elements have been performed. The developed MCDM model is based on the integration of the Delphi and VIKOR (*VišeKriterijumska Optimizacija i kompromisno Rešenje*, srb) methods in the fuzzy environment, where the fuzzy Delphi method was used to define the strength of the factor's influence on the elements, and the fuzzy VIKOR method for ranking and selecting the key elements on the basis of which the typical terminal structures are defined. The goal of defining the typical IT structures is to create preconditions for comparing their basic characteristics, performance, efficiency, etc., in order to identify those that can serve as the benchmarks for other ITs that have the potential to develop into these structures or as a model for the development of future ITs.

The paper is organized as follows. First, the elements for defining the IT structure, as well as the factors influencing these elements and their significance, are identified and described. Afterwards, the MCDM model is described, based on which the structural elements are ranked and the key elements selected. By combining the various characteristics and modalities of the identified key elements and by researching 180 ITs

across Europe, typical IT structures are defined. Finally, concluding remarks and future research directions are provided.

2. ELEMENTS AND FACTORS FOR DEFYNING THE IT STRUCTURE

As already mentioned, the IT structure is defined by a combination of different elements. The combinations are affected by many factors which define and shape the basic requirements that a terminal of a certain structure must perform. Factors may affect one or more elements of the structure and may have a different significance. The following lists and explains the elements for defining the structure, as well as the factors affecting them.

2.1 Elements for defining the IT structure

The elements for defining the IT structure can be classified into four levels (Krstić et al., 2019b): organizational, operational, physical/spatial and technological. Organizational level consists of elements such as: founders and owners (E_1), organizational structure (E_2) and place and role in the network chain (E_3). ***The founders and owners*** represent the investors, i.e. the owners of the capital used for the construction of the IT. In the literature there are various classifications of financing models (Beth, 1985; Alderton, 1999) and according to the ownership of the capital, financing can be (Cullinane & Song, 2002): public, privat or public-private partnership (PPP). In practice, ITs are most often established on the basis of the PPP (Tadić & Zečević, 2010). ***The organizational structure***, i.e. the management model implies distribution of responsibilities, allocation of resources and management of relationships, behavior and activities in the IT in order to achieve the desired business outcome. This topic was elaborated by Vieira & Neto (2016), Bichou & Gray (2005), Monios (2015), and others, while the particularly interesting is the classification of management models based on the relationship between the owner and operator of the terminal, i.e. who employs the personnel, who owns the infrastructure and superstructure and who manages them, i.e. who makes operational decisions (Krstić et al., 2019b). Transport systems are characterized by the movement of goods through the networks where ITs represent nodes of the logistics, i.e. transport networks, in which processes of transshipment, changes in transport means and modes, storage, consolidation, sorting, and others are realized depending on ***the place and role in the network*** (Tadić & Zečević, 2012). According to this element the ITs can be classified in different ways (Park & Medda, 2010; Woxenius, 1997), and the basic classification is on the maritime and inland ITs (Krstić et al., 2019b).

Operational level consists of the following elements: type of cargo/transport unit (E_4), structure of functions and services (E_5) and IT users (E_6). Although by the definition only ITUs are being manipulated in the IT, in practice different ***types of cargo and transport units*** may appear (Notteboom & Rodrigue, 2009; Middendorf, 1998). IT, depending on the size, volume and intensity of flows, user requests and other influences, may have different ***structure of functions and services***. In the literature there are different classifications of the IT functions (e.g. de Villiers, 2015; Wiegmans et al., 1999), and according to Zečević (2006) ITs can be divided into four categories: A, B, C and D, expanding the range of services from basic (receiving, transshipping, loading and shipping of transport means and ITUs) to VAL (Value Added Logistics) services. ***IT users***

are the customers of the services which can be physical or legal entities (more often legal entities), owners or organizers of freight and transport flows passing through the IT (Zečević, 2006). They can be divided into those whose core business is logistics and organization of goods transport, and those to whom this is not the core business (Krstić et al., 2019b; Wiegmans et al., 1999).

Physical/spatial level includes the following elements: location (E_7), size (volume and intensity of flows) (E_8), territory coverage (E_9) and spatial organization - layout (E_{10}). The successful functioning of IT depends to a large extent on its *location* (Zečević et al., 2017a), which should be considered in terms of the macro (Teye, 2017) and the micro environment (Zečević, 2006). Considering *the size* different classifications of the ITs may appear, based on different measuring units: the volume of flows that pass through the IT, the land area of the IT, the number of present transport modes, etc. (Notteboom & Rodrigue, 2009; ITIP, 2001; Wiegmans et al., 1999). IT can have different *territory coverage*, i.e. *catchment areas*. Catchment area is the space of origin/destination of the goods and-transport flows which at one stage pass through the IT (Zečević, 2006). One IT can have different catchment areas for different goods and transport flows, transport chain technologies and different service types (Zečević, 2006). IT can appear in different variations in relation to the *spatial organization* of subsystems. While planning the IT layout, a number of parameters, potential constraints and potential stochastic interactions between the subsystems, potential technologies, volume and flow structure, present modes of transport, etc. must be taken into account. (Zhang et al., 2016; de Villiers, 2015; Roy & de Koster, 2013). The basic IT layout classification can be done according to the present modes of transport (Krstić et al., 2019b).

Technological level includes the elements: connection of transport modes and transport chain technologies (E_{11}), subsystems structure (E_{12}) and basic subsystems technologies of the IT (E_{13}). IT can connect different *modes of transport* (water, rail, road and much less air) and *technologies for the realization of transport chains* (Notteboom & Rodrigue, 2009; Nazari, 2005). *IT subsystems* are functionally rounded units within the systems that are responsible for the partial or complete realization of one or more functions. Various examples of the subsystems structure can be found in the literature (Kemme, 2013; Brinkmann, 2011; Steenken et al., 2004), and each subsystem enables the realization of certain requirements, i.e. terminal services, by using the technological elements. However, the *technologies of the basic subsystems* of transport (Steenken et al., 2004), storage (Kalmar, 2011) and transshipment (Krstić et al., 2019a) have the greatest influence on the other structure elements.

2.2 Factors influencing the definition of the IT structure

Based on the character and type of influence, the factors can be classified as: internal factors, factors of logistics flows requirements and environmental factors. The above factors influence the structural elements of IT, and these influences, as well as the links between the factors and elements are shown in Table 1. Based on the literature review (Heljedal, 2013, Bergqvist et al., 2010; Roso, 2008; Zečević, 2006) the following lists and explains all factors.

Table 1. Relations between the factors and the elements for defining the IT structure

	Founders /owners	Organizational structure	Place/role in network	Type of cargo/ITU	Functions and services	Users	Location	Size	territory coverage	Layout	Transport modes	Subsystems structure	Subsystems technology
Technological performance				•	•					•	•	•	•
Spatial performance							•	•		•		•	•
Financial performance	•	•	•		•	•	•	•	•		•		•
Location performance			•			•	•	•	•	•	•		
Ownership/organizational performance	•	•	•			•							
Logistics strategies	•	•	•		•	•	•		•		•		
Flow features			•				•	•	•		•		
Quality requirements			•		•	•	•	•	•	•	•	•	•
Cargo features				•	•	•	•	•		•	•	•	•
Network and transport chains features			•		•	•	•	•	•		•	•	•
Spatial and business plans							•	•	•	•	•		
Economic/organizational features	•	•	•			•	•	•	•				
Laws	•	•					•				•		
Social factors				•			•				•		•
Geographical features							•	•		•	•		•
Infrastructure features							•	•	•	•			•
Traffic and logistics features			•		•	•	•	•	•		•		•
Geological features							•	•		•			
Climatic features				•			•			•	•		•
Environmental factors				•			•			•	•		•

Internal factors include certain IT performances (technological, spatial, financial, location and ownership/organizational) which define the requirements for arrangement of the certain structure functioning. **Technological performances** (F_1) define the requirements in terms of the efficiency of processes and activities and achieving the appropriate values of performance indicators (storage capacity, speed and intensity of transshipment, time of holding the vehicles in the system, etc.), as well as the basic characteristics of IT subsystems technologies. **Spatial performances** (F_2) define the requirements for the surface sizes of the IT, as well as their basic characteristics in terms of shape, geometry, position, connectivity, availability, etc., so that all physical components of the IT are adequately fitted and efficiently functioning. **Financial performances** (F_3) refer to defining the requirements regarding the necessary finances, sources and method of financing, profitability of investments, i.e. fund return possibilities, etc. Each terminal subsystem requires certain investments, generates costs and allows revenues, and its justification interacts with a large number of variables from the environment (Zečević et al., 2006). The financial justification performances affect the majority of the IT structural elements (Table 1). **Location performances** (F_4) refer to the definition of requirements for the macro and micro location of the IT, as its position in relation to important economic, traffic, social and other content. **Ownership/organizational performances** (F_5) define the basic characteristics, requirements, advantages and disadvantages of different models of establishment, management and organization of ITs, in order to select the appropriate model in the planning process. Adequate definition of these performances for different IT structures is aimed at achieving a high level of their efficiency.

Factors of logistics flows requirements include the requirements generated by goods and transport flows that pass through the IT, as well as the requirements of the participants in these flows. Logistics strategies, flow features, quality requirements, goods features, networks and transport chains features belong to this group of factors. **Logistics strategies** (F_6) define the requirements for realization of logistics activities and may affect founders and owners, organizational structure, structure of functions and services, terminal users, but also the place and role of the IT in the network/chain, location, territory coverage and transport modes and transport chain technologies (Table 1). **Flow features** (F_7), i.e. rules of flows creation, place and time of the beginning/end of flows, main features, i.e. whether flows are stationary or non-stationary, deterministic or stochastic, continuous or discontinuous, homogenous or heterogeneous, etc. affect the place and role of the terminal in the network/chain, location and size of the terminal, territory coverage, transport modes and transport chain technologies (Table 1). **Quality requirements** (F_8) refer to requirements regarding the features of the IT services, such as reliability, flexibility, availability, accuracy, information exchange, etc., thus directly affecting multiple structural elements of the terminal (Table 1). **Cargo features** (F_9) such as: type of cargo, package options, quantity, physical state, degree of cargo danger, deterioration, sensitivity, etc., mostly affect the definition of IT structure in terms of the type of cargo/transport units, but also on other structural elements. **Networks and transport chains features** (F_{10}), i.e. the size and structure of the logistics network, available transport modes, etc., set the requirements that terminals have to fulfill in order to enable their efficient functioning in the network and servicing different transport modes. This factor has the greatest impact on the place and role of the terminal in the network/chain, and transport modes and transport chain technologies.

Environmental factors represent various external factors which, according to their character, can be regulatory/social (spatial and business plans, economic/organizational features, laws and social factors), and physical (geographical, infrastructure, traffic and logistic, geological, climatic and ecological features). **Spatial and business plans** (F_{11}) refer to urban plans, spatial planning plans, general and detailed regulation plans, economy development strategies etc., which can have a significant impact on the various elements of the IT structure, above all on the location, size and layout of the terminal (Table 1). **Economic/organizational features** (F_{12}), refer to the presence of economic systems in the field of logistics, management, information technologies, etc. which affect the organizational structure, founders and owners, coverage of the territory, users, location, place in the network and size. **Laws** (F_{13}) in the field of traffic and transportation, spatial planning, financing and management of economic entities, environmental protection, etc. can significantly affect the IT structural elements, above all founders and owners, organizational structure, location and layout of the terminal, etc. **Social factors** (F_{14}) refer to the influence of the local population on defining the structure of the terminal. Residents have certain requirements related to the realization of goods and transport flows, i.e. on the effects of their realization, which can significantly affect the location, type of cargo, transport modes and transport chain technologies, subsystems technologies and other elements of the IT structure (Table 1). **Geographical features** (F_{15}) refer to the relief of the land, the topology and slope of the terrain, the proximity of river flows and other features that may have an impact on the IT structural elements, primarily on the location, size and layout of the terminal, transport modes and transport chain technologies, as well as subsystems technologies..

Infrastructure features (F_{16}) refer to the presence, level of construction and state of the utility infrastructure (water supply, sewage, gas pipeline, etc.), which can significantly affect primarily the location, size and layout of the terminal, as well as the subsystems technologies ***Traffic and logistics features*** (F_{17}) refer to the characteristics of the transport infrastructure, such as the degree of construction, density of the traffic network, condition or the quality of the infrastructure, etc. which affects the possibility of using different transport modes and accessing the significant transport routes. This factor has the greatest impact on transport modes and transport chain technologies, but also on the place and role in the network, subsystems technologies and users. ***Geological features*** (F_{18}) refer to basic soil characteristics such as the soil composition, erosion, landslides, groundwater, etc., which may affect terminal structure elements such as: location, size, and layout. ***Climatic features*** (F_{19}) refer to the effects of temperature, humidity, average rainfall, water flows of nearby rivers (i.e. flood risk), etc. which may affect the IT structural elements, primarily location and layout (Table 1). ***Environmental features*** (F_{20}) include influences that can lead to the negative effects on the environment and are caused by the goods and transport flows. This factor mostly affects the location, transport modes and transport chain technologies, as well as the layout, type of cargo and subsystems technologies.

3. SELECTION OF THE KEY ELEMENTS FOR DEFINING THE IT STRUCTURE

In the previous section, the elements for defining the IT structure and the factors that influence these elements are explained. Not all the elements have the same significance and influence on the definition and design of the IT structures, therefore it is necessary to distinguish the most important, key elements. To accomplish this task, a hybrid model based on the fuzzy Delphi and the fuzzy VIKOR method is proposed. These are MCDM methods, but in this paper instead of criteria, factors will be evaluated, and instead of alternative elements for defining the IT structure. The basic characteristics of the methods, the reasons and steps of their application, as well as the process of ranking the elements are explained below.

3.1 Hybrid fuzzy Delphi-VIKOR model for ranking the elements of the IT structure

The first part of the model uses fuzzy Delphi method in order to gather the information and from a broader set factors extract those which are, according to the decision makers (DM), i.e. members of the stakeholders, relevant for ranking the structure elements. The traditional Delphi method was first proposed by Dalkey & Helmer (1963), and it has been widely applied in various areas. The aim of the method is to collect data from the field of expertise of the participants. The method is defined as a process of group communication through which the convergence of thoughts about a particular real problem is achieved. It is suitable for achieving the consensus through a series of questionnaires by which the data from a group of selected participants (DMs) are collected in multiple iterations. The Delphi method is characterized by the anonymity, iteration, controlled feedback, statistical group response, and stability in responses among the DMs on a specific issue (Shen et al., 2011). However, although the Delphi method provides a chance to completely integrate diverse DMs' opinions, it is time-consuming, costly, and has a lower questionnaire return rate because it tries to obtain converged results through repetitive surveys. In addition, the problems of imprecise,

vague and ambiguous evaluations of the DMs, due to incomplete information or inability of their treatment in a decision environment, are also present. As one of the possible ways to overcome the problems and limitations of the Delphi method, Murry et al. (1985) suggested the involvement of the fuzzy set theory (Zadeh, 1965) which can efficiently deal with the vagueness in thinking and expressing preferences of DMs. Since its first application, fuzzy Delphi method has been applied in many MCDM problems from various fields, either alone or in a combination with other methods (e.g. Tadić et al., 2019; Tadić et al., 2018; Zečević et al., 2017a; Tadić et al., 2016b; Mikaeil et al., 2013; Daim et al., 2012, Shen et al., 2011). The fuzzy Delphi method can obtain converged responses of the DMs with fewer survey rounds, or even in a single round, and effectively conduct the ambiguity and uncertainty of the DMs' evaluations (Klir & Folger, 1988). In the process of the group decision-making it integrates the opinions of all DMs with the aim of achieving the consensus with significant time and cost savings (Mikaeil et al., 2013).

The second part of the model refers to the application of the fuzzy VIKOR method for the evaluation and ranking of the elements for defining the IT structure in relation to the impact factors. The VIKOR method is chosen due to its advantages over some other methods (Caterino et al., 2008). The VIKOR method (Opricovic, 1998) is an MCDM method that can help the DMs to optimize the complex systems, i.e. to solve discrete decision-making problems with conflicting criteria. The method performs ranking of the alternatives on the basis of criterion functions and the selection of a compromise solution that is closest to the ideal alternative. The solution is considered to be a compromise because it is obtained by mutual concessions, i.e. it provides a maximum group utility and a minimum individual regret of the opponent. In order to solve the problem of imprecision in expressing DMs' preferences, Opricovic (2007) extended the VIKOR method in fuzzy environment, and since then it has been successfully applied in many fields, alone or in combination with other methods (e.g. Zečević et al., 2017a; Zečević et al., 2017b; Tadić et al., 2017; Tadić et al., 2016a; Tadić et al., 2015; Tadić et al., 2014; Zečević et al., 2014; Chang, 2014, Opricovic, 2011). The following explains the application steps, and the schematic representation is given in Figure 1.

Step 1: Define the structure of the evaluation model. It is necessary to identify the problem and the stakeholders interested in its solution, define the sets of IT structural elements and the factors for their evaluation.

Step 2: Define the fuzzy scale for the evaluation of the factors and elements by the DMs. Nine-point linguistic scale with the corresponding triangular fuzzy numbers is defined in this paper and shown in Table 2.

Table 2. Linguistic terms and corresponding fuzzy values

Linguistic term	Abbreviations	Fuzzy scale
None	N	(1, 1, 2)
Very Low	VL	(1, 2, 3)
Low	L	(2, 3, 4)
Fairly Low	FL	(3, 4, 5)
Medium	M	(4, 5, 6)
Fairly High	FH	(5, 6, 7)
High	H	(6, 7, 8)
Very High	VH	(7, 8, 9)
Extremely High	EH	(8, 9, 10)

Step 3: Evaluate and select the factors for the evaluation of the elements by applying the fuzzy Delphi method (Hsu & Yang, 2000).

Step 3.1: Obtain the evaluations of the factors by the DMs and transform them in the triangular fuzzy numbers by applying the relations given in Table 2.
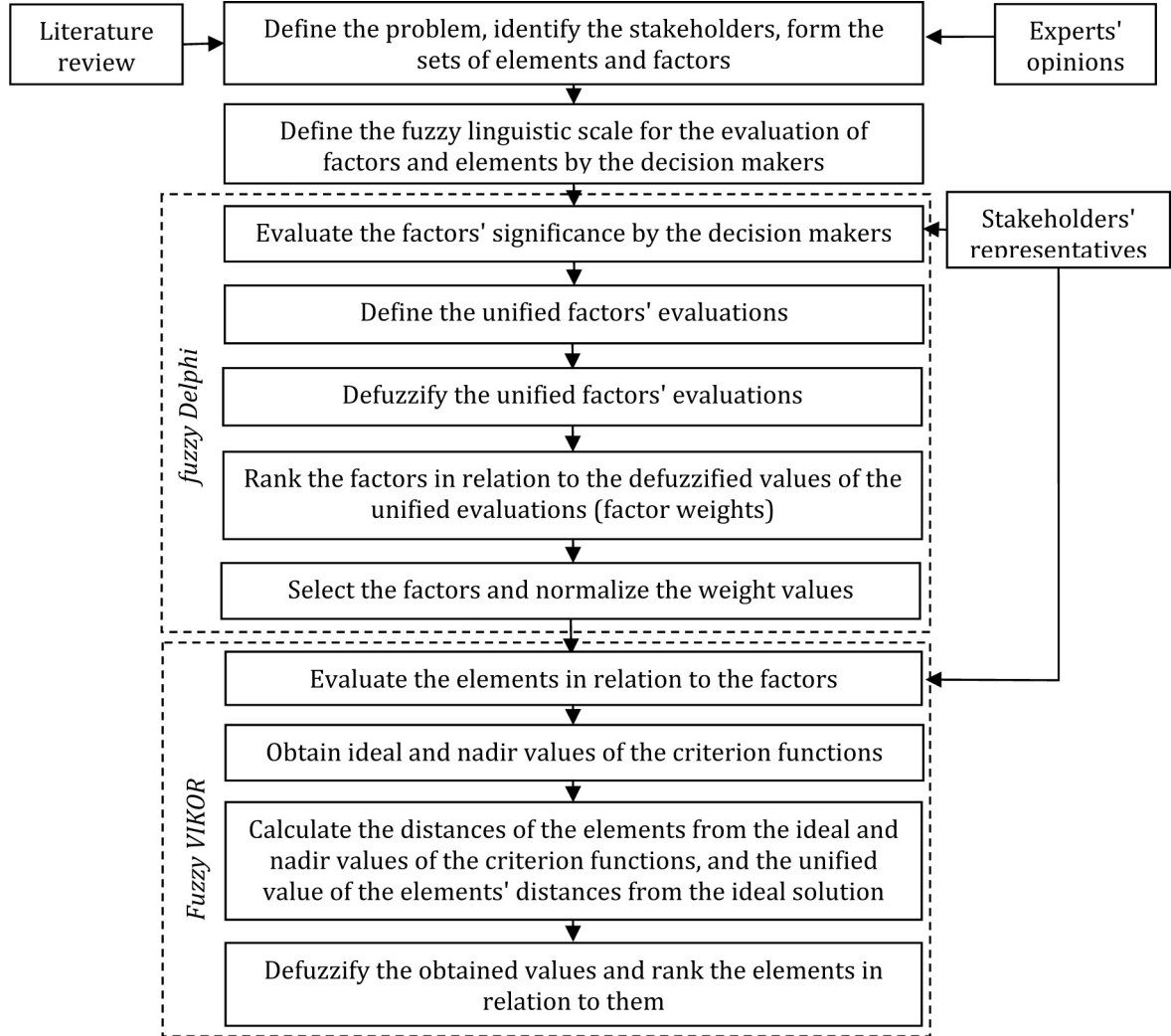

Figure 1. Schematic representation of the proposed fuzzy Delphi-fuzzy VIKOR model

Step 3.2: Define the unified evaluations of the factors. The general approach for establishing unified evaluations is as follows:

$$\tilde{\delta} = (\alpha, \beta, \gamma) \qquad (1)$$

$$\alpha = Min(l_k), \quad k = 1, \dots, n \qquad (2)$$

$$\beta = \left(\prod_{k=1}^{n} m_k\right)^{1/n}, \quad k = 1, \dots, n \qquad (3)$$

$$\gamma = Max(r_k), \quad k = 1, \dots, n \qquad (4)$$

where α, β and γ are the left, medium and right values of the unified fuzzy value $\tilde{\delta}$, respectively, and $\alpha \leq \beta \leq \gamma$. l_k, m_k and r_k are the left, medium and right values of the triangular fuzzy evaluation which indicates the importance of the factor in relation to the stakeholder k. n is the number of the considered stakeholders.

As it is necessary in this step to unify the evaluations of the sub-criteria with respect to each stakeholder, by applying the equations (1-4) for the fuzzy evaluations $\tilde{b}_{jk} = \left(l_{jk}, m_{jk}, r_{jk}\right)$ of the importance of the factor j with respect to the stakeholder k, unified fuzzy evaluations $\tilde{\delta}_j = \left(\alpha_j, \beta_j, \gamma_j\right)$ for the factors j, $j=1,...,f$, are obtained, where f is the number of factors.

Step 3.3: Defuzzify the values. For the defuzzyfication of the triangular fuzzy values, in this paper is used the equation with the general form (Kutlu & Ekmekcioglu, 2012):

$$crisp(P) = (\alpha + 4\beta + \gamma)/6 \qquad (5)$$

where *crisp(P)* represents the defuzzyfied value of some fuzzy value $\tilde{P} = (\alpha, \beta, \gamma)$. Accordingly, defuzzyfied value of the unified evaluation *crisp(δ_j)* s obtained by applying equation (5) for the unified fuzzy evaluation $\tilde{\delta}_j = \left(\alpha_j, \beta_j, \gamma_j\right)$. These defuzzyfied values represent the weights of the factors (w_j) as well as the values based on which the selection of the factors that require further consideration is performed.

Step 3.4: Select the factors. The appropriate set of factors for the evaluation of elements is obtained by setting the threshold θ. The sifting principles are as follows:

if $crisp(\delta_j) > \theta$ factor *j* is acceptable,

if $crisp(\delta_j) < \theta$ factor j is unacceptable.

The threshold depends on the way the questionnaire is formed, and the scale used for the evaluation (Shen et al., 2010).

Step 3.5: Normalize the weight values. The obtained factor weights need to be normalized by applying the following equation:

$$w_j^N = \frac{w_j}{\sum_{j=1}^s w_j}, \quad j = 1, \dots, s \qquad (6)$$

where w_j^N is the normalized factor weight, and s is the total number of selected factors.

Step 4: Evaluate the elements and rank them by applying the fuzzy VIKOR method. DMs evaluate the elements (*i*) in relation to the factors (*j*) and their evaluations are then converted into the triangular fuzzy numbers using the relations given in table 2. The values of the elements are obtained by applying the fuzzy VIKOR method. The procedure is adapted from Opricovic (2011), and computational steps are described below.

Step 4.1: Form the fuzzy performance matrix ($\widetilde{D}$) members of which are the triangular fuzzy numbers representing the unified evaluations of the elements, in relation to the factors:

$$\widetilde{D} = \begin{array}{c} \\ E_1 \\ E_2 \\ \vdots \\ E_o \end{array} \begin{array}{cccc} F_1 & F_2 & \dots & F_s \\ \left[\begin{array}{cccc} \tilde{e}_{11} & \tilde{e}_{12} & \dots & \tilde{e}_{1s} \\ \tilde{e}_{21} & \tilde{e}_{22} & \dots & \tilde{e}_{2s} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{e}_{o1} & \tilde{e}_{o1} & \dots & \tilde{e}_{os} \end{array}\right] \end{array} \qquad (7)$$

where E_i denotes the element *i*, *i = 1,...,o*, *o* represents the total number of elements; F_j represents the factor *j*, *j = 1,...,s*; $\tilde{e}_{ij} = \left(l_{ij}, m_{ij}, r_{ij}\right)$ denotes the triangular fuzzy evaluations of the element E_i in relation to the factor F_j.

Step 4.2: Obtain the ideal $\tilde{e}_j^* = (l_j^*, m_j^*, r_j^*)$ and the nadir $\tilde{e}_j^{\circ} = (l_j^{\circ}, m_j^{\circ}, r_j^{\circ})$ values of the criterion functions, i.e. of the evaluations of the elements in relation to the factors:

$$\tilde{e}_j^* = \max_i \tilde{e}_{ij}, \quad \tilde{e}_j^{\circ} = \min_i \tilde{e}_{ij}, \quad za \; j \in J^b \tag{8}$$

$$\tilde{e}_j^* = \min_i \tilde{e}_{ij}, \quad \tilde{e}_j^{\circ} = \max_i \tilde{e}_{ij}, \quad za \; j \in J^c \tag{9}$$

where J^b and J^c are the sets of factors representing benefits (higher evaluations by these factors lead to higher ranking of the element) and costs (lower evaluations lead to higher ranking), respectively.

Step 4.3: Calculate the normalized fuzzy difference $\tilde{d}_{ij}$:

$$\tilde{d}_{ij} = \frac{\tilde{e}_j^* \ominus \tilde{e}_{ij}}{r_j^* - l_j^{\circ}} \quad za \; j \in J^b \tag{10}$$

$$\tilde{d}_{ij} = \frac{\tilde{e}_{ij} \ominus \tilde{e}_j^*}{r_j^{\circ} - l_j^*} \quad za \; j \in J^c \tag{11}$$

Step 4.4: Calculate the values $\tilde{S}_i = (S_i^l, S_i^m, S_i^r)$, which represent the fuzzy weighted distance of the element E_i from $\tilde{e}_j^*$ and the values $\tilde{R}_i = (R_i^l, R_i^m, R_i^r)$, which represent the fuzzy weighted distance of the element E_i from $\tilde{e}_j^{\circ}$, by applying the following equations:

$$\tilde{S}_i = \sum_{j=1}^{s} w_j \otimes \tilde{d}_{ij} \tag{12}$$

$$\tilde{R}_i = \max_j w_j \otimes \tilde{d}_{ij} \tag{13}$$

Step 4.5: Calculate the values $\tilde{Q}_i = (Q_i^l, Q_i^m, Q_i^r)$, i.e. the overall distances of the elements from the ideal solution, by the equation:

$$\tilde{Q}_i = v \frac{\tilde{S}_i \ominus \tilde{S}^*}{S^{\circ r} - S^{*l}} \oplus (1 - v) \frac{\tilde{R}_i \ominus \tilde{R}^*}{R^{\circ r} - R^{*l}} \tag{14}$$

where $\tilde{S}^* = \min_i \tilde{S}_i$, S^{*l} is the lower value of the triangular fuzzy number $\tilde{S}^*$, $S^{\circ r} = \max_i S_i^r$, $\tilde{R}^* = \min_i \tilde{R}_i$, R^{*l} is the lower value of the triangular fuzzy number $\tilde{R}^*$ i $R^{\circ r} = \max_i R_i^r$. The value v is introduced as a weight for the strategy of "the majority of criteria" (or "the maximum group utility"), whereas $1 – v$ is the weight of the individual regret.

Step 4.6: Defuzzify the values $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$ by applying the equation (5).

Step 4.7: Rank the elements according to the increasing crisp values. The results are three ranking lists $\{E\}_S$, $\{E\}_R$ and $\{E\}_Q$ obtained by the values *crisp(S)*, *crisp(R)* and *crisp(Q)*, respectively.

Step 4.8: Propose as a compromise solution the element $E^{(1)}$ which is the best ranked by the value of Q, if the following two conditions are satisfied: Co.1. "Acceptable Advantage": $Adv \geq DQ$ where $Adv = [Q(E^{(2)}) - Q(E^{(1)})]/[Q(E^{(o)}) - Q(E^{(1)})]$ is the advantage rate of the element $E^{(1)}$ in relation to the element ranked as the second $E^{(2)}$ in the list $\{E\}_Q$, and $DQ = 1/(o – 1)$ is the threshold from which the advantage rate (Adv) has to be higher. Co.2. "Acceptable stability in decision making": The element $E^{(1)}$ must also be the best ranked by S or/and R. If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of: CS1. The elements $E^{(1)}$ and $E^{(2)}$ if only the condition Co.2 is not satisfied, or CS2. The elements $E^{(1)}, E^{(2)}, …, E^{(0)}$ if the

condition Co.1 is not satisfied; $E^{(O)}$ is determined by the relation $\left[Q(E^{(O)}) - Q(E^{(1)})\right]/$ $\left[Q(E^{(o)}) - Q(E^{(1)})\right] < DQ$ for maximum E - the total number of the elements (the positions of these elements are "in closeness"), where $E^{(O)}$ is the last ranked element in relation to Q, and $E^{(o)}$ is the element with the highest index value.

3.2 Application of the hybrid fuzzy Delphi-VIKOR model for ranking and selection of the key elements of the IT structure

The proposed hybrid fuzzy Delphi-VIKOR model is used to rank the elements of the IT structure based on the previously described factors. The first step in applying the model is to evaluate the importance of factors by the DMs belonging to different stakeholder groups (founders/owners and operators - Fo., users - Us., and administration and residents - Ad.). The founders/owners and operators as the main goal have the maximization of profit as a result of successful IT operation, users goal is to get the quality service at a reasonable price, and administration and residents goal is the economic development of the region (city, state) and the preservation of the environment. The relations given in Table 2 are used for the evaluations of the factors. Using the equations (1 - 4) evaluations of the DMs are unified, after which they are defuzzyfied using the equation (5). Defuzzyfied values are then used for factor ranking and selection of those that have a significant effect on IT structure elements. Value of 4.5 for the θ is adopted. Defuzzyfied values of the selected factors were then normalized using the equation (6) and these values were used in the second part of the model as the weights of the factors for the evaluation of the structural elements. The evaluations of the DMs, unified evaluations, defuzzyfied factor values, and the final normalized weights of the factors are given in Table 3. From Table 3 it can be seen that 6 factors are labeled as unacceptable, which means that they will not be considered when ranking the elements for defining the IT structure.

Table 3. Evaluation and selection of the factors for IT structure elements ranking

Factor	Fo.	Us.	Ad.	Unified	Defuzzified	Selection	Normalized
F_1	(7,8,9)	(6,7,8)	(2,3,4)	(2.00,4.82,9.00)	5,047	Selected	0,063
F_2	(7,8,9)	(5,6,7)	(2,3,4)	(2.00,4.58,9.00)	4,886	Selected	0,061
F_3	(8,9,10)	(4,5,6)	(2,3,4)	(2.00,4.48,10.00)	4,988	Selected	0,062
F_4	(6,7,8)	(6,7,8)	(5,6,7)	(5.00,6.26,8.00)	6,338	Selected	0,079
F_5	(8,9,10)	(2,3,4)	(1,2,3)	(1.00,3.00,10.00)	3,833	Unacceptable	/
F_6	(6,7,8)	(7,8,9)	(3,4,5)	(3.00,5.52,9.00)	5,679	Selected	0,071
F_7	(6,7,8)	(6,7,8)	(1,2,3)	(1.00,3.66,8.00)	3,940	Unacceptable	/
F_8	(3,4,5)	(8,9,10)	(2,3,4)	(2.00,4.16,10.00)	4,773	Selected	0,059
F_9	(5,6,7)	(5,6,7)	(3,4,5)	(3.00,4.76,7.00)	4,841	Selected	0,060
F_{10}	(8,9,10)	(7,8,9)	(4,5,6)	(4.00,6.60,10.00)	6,736	Selected	0,084
F_{11}	(6,7,8)	(3,4,5)	(7,8,9)	(3.00,5.81,9.00)	5,873	Selected	0,073
F_{12}	(6,7,8)	(4,5,6)	(7,8,9)	(4.00,6.26,9.00)	6,338	Selected	0,079
F_{13}	(7,8,9)	(4,5,6)	(7,8,9)	(4.00,6.54,9.00)	6,528	Selected	0,081
F_{14}	(2,3,4)	(2,3,4)	(8,9,10)	(2.00,4.16,10.00)	4,773	Selected	0,059
F_{15}	(3,4,5)	(2,3,4)	(5,6,7)	(2.00,3.91,7.00)	4,110	Unacceptable	/
F_{16}	(7,8,9)	(6,7,8)	(5,6,7)	(5.00,6.54,9.00)	6,695	Selected	0,083
F_{17}	(7,8,9)	(7,8,9)	(5,6,7)	(5.00,6.84,9.00)	6,893	Selected	0,086
F_{18}	(2,3,4)	(2,3,4)	(3,4,5)	(2.00,3.00,5.00)	3,167	Unacceptable	/
F_{19}	(1,2,3)	(1,2,3)	(4,5,6)	(1.00,2.52,6.00)	2,847	Unacceptable	/
F_{20}	(1,1,2)	(1,1,2)	(8,9,10)	(1.00,2.00,10.00)	3,167	Unacceptable	/

The next step is to rank the elements of the structure using the VIKOR method. First, the elements of the structure are evaluated in relation to the factors using the relations given in Table 2. These evaluations are given in Table 4.

Table 4. Evaluations of the IT structure elements in relation to the factors

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}
F_1	N	N	N	VH	VH	N	N	N	N	VH	VH	FH	EH
F_2	N	N	N	N	N	N	FH	VH	N	EH	N	FH	VH
F_3	VH	FH	VH	N	VH	L	L	VH	L	N	H	N	M
F_4	N	N	EH	N	N	FH	EH	VH	EH	M	EH	N	N
F_6	VL	VL	EH	N	VH	FL	FL	N	VL	N	M	N	N
F_8	N	N	VH	N	EH	EH	L	H	VL	VL	FH	FH	VH
F_9	N	N	N	EH	H	FL	FL	FH	N	M	L	M	VH
F_{10}	N	N	EH	N	VH	M	FH	VH	H	N	FH	L	L
F_{11}	N	N	N	N	N	N	H	VH	L	VL	FH	N	N
F_{12}	VH	L	EH	N	N	FL	L	FH	M	N	N	N	N
F_{13}	M	M	N	N	N	N	M	N	N	N	FL	N	N
F_{14}	N	N	N	FL	N	N	L	N	N	N	FH	N	L
F_{16}	N	N	N	N	N	N	H	H	M	VH	N	N	VH
F_{17}	N	N	EH	N	H	VH	H	H	M	N	EH	N	H

Evaluations shown in Table 3 are transformed into triangular fuzzy numbers and based on them the ideal $\tilde{e}_j^* = \left(l_j^*, m_j^*, r_j^* \right)$ and the nadir $\tilde{e}_j^\circ = \left(l_j^\circ, m_j^\circ, r_j^\circ \right)$ values of the criterion functions are obtained by applying the equation (8), whereas all factors are taken as the "benefit" factors. After that the values of the normalized fuzzy differences $\tilde{d}_{ij}$ are calculated using the equation (10). The values of the maximum group utility $\tilde{S}_i = \left(S_i^l, S_i^m, S_i^r \right)$ and the minimum individual regret $\tilde{R}_i = \left(R_i^l, R_i^m, R_i^r \right)$ are obtained by applying the equations (12) and (13), respectively. The overall distances of the elements from the ideal solution $\tilde{Q}_i = \left(Q_i^l, Q_i^m, Q_i^r \right)$ are obtained by applying the equation (14) whereas the value $v=0.5$ is taken for the coefficient of the weight of the maximum group utility. The obtained values for $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$, are then defuzzyfied by applying the equation (5). Based on these defuzzyfied values three ranking lists are formed $\{E\}_S$, $\{E\}_R$ and $\{E\}_Q$, and presented in Table 5.

Table 5. Ranking of the elements in relation to the S, R and Q values

		E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}
$\tilde{S}$	S_l	0.435	0.494	0.095	0.486	0.250	0.367	0.127	0.102	0.339	0.378	0.039	0.477	0.289
	S_m	0.686	0.745	0.346	0.737	0.501	0.618	0.378	0.353	0.590	0.629	0.290	0.727	0.540
	S_r	0.852	0.911	0.540	0.888	0.681	0.809	0.622	0.561	0.793	0.809	0.525	0.889	0.731
	Crisp(S)	0.672	0.731	0.337	0.720	0.489	0.608	0.377	0.346	0.582	0.617	0.287	0.713	0.530
	Rank	10	13	2	12	5	8	4	3	7	9	1	11	6
$\tilde{R}$	R_l	0.057	0.057	0.046	0.057	0.056	0.057	0.042	0.047	0.042	0.057	0.053	0.057	0.057
	R_m	0.076	0.076	0.065	0.076	0.074	0.076	0.056	0.065	0.065	0.076	0.070	0.076	0.076
	R_r	0.086	0.086	0.081	0.086	0.083	0.086	0.070	0.081	0.081	0.086	0.079	0.086	0.086
	Crisp(R)	0.075	0.075	0.064	0.075	0.072	0.075	0.056	0.065	0.064	0.075	0.069	0.075	0.075
	Rank	8	9	4	13	6	7	1	3	2	11	5	12	10
$\tilde{Q}$	Q_l	-0.05	-0.03	-0.21	-0.03	-0.14	-0.08	-0.20	-0.20	-0.10	-0.08	-0.23	-0.04	-0.12
	Q_m	0.172	0.197	0.018	0.194	0.090	0.142	0.028	0.021	0.125	0.147	-0.01	0.190	0.108
	Q_r	0.367	0.393	0.229	0.383	0.292	0.348	0.260	0.238	0.339	0.349	0.222	0.384	0.314
	Crisp(Q)	0.167	0.193	0.016	0.188	0.086	0.139	0.030	0.020	0.123	0.143	-0.01	0.184	0.105
	Rank	10	13	2	12	5	8	4	3	7	9	1	11	6

As the key elements for defining the IT structure, transport modes (E_{11}), place and role in the network/chain (E_3), terminal size (E_8) and structure of functions and services (E_6) are selected. They are ranked as the first, second, third and fifth, respectively. Terminal location (E_7) and subsystems technologies (E_{13}), although ranked as the fourth and sixth, as well as the lower ranked elements, have not been selected as the key ones for the following reasons. For the terminal location (E_7), founders and owners (E_1) and management models (E_2), the rule of appearing in the combination with the other key elements was not determined. Further classification in relation to these elements would lead to an excessive number of IT structures, therefore they could not be referred to as the typical structures. On the other hand, by combining the remained elements with the key ones would not lead to further division and classification. These are the elements with strong dependence on some of the key elements, such as: territory coverage (E_9) (depends on the location and role of the terminal in the network), layout of the terminal (E_{10}) (depends on the present modes of transport), subsystems structure (E_{12}) (depends on the structure of functions and services) and subsystems technologies (E_{13}) (mainly depends on the terminal size and the subsystems structure, or indirectly on the structure of functions).

4. TYPICAL STRUCTURES OF THE INTERMODAL TERMINALS

Based on the identified key structural elements and research that included over 180 real-life ITs in Europe, typical structures (TS) of the intermodal terminals have been identified in this paper. The basic classification of the TS group was made in relation to the terminal size (E_8) as (Krstić et al., 2019b): "small" with an annual capacity of up to 100,000 TEUs (Twenty-foot Equivalent Unit), "medium" with a capacity of 100,000 to 200,000 TEUs, "large" with a capacity between 200,000 and 400,000 TEUs, "very large" with a capacity between 400,000 and 1,200,000 TEUs and "mega" with a capacity of over 1,200,000 TEUs. Subsequently, within the defined groups, a further TS classification was made in relation to other key elements. In relation to transport modes (E_{11}) terminals can be divided into uni-modal (only one transport mode is present, usually road, and the main role is usually consolidation of flows), bimodal (connecting two transport modes, most often appear in the form of road-rail, maritime-road and river-road ITs), tri-modal (connecting three transport modes, most often appear in the forms of maritime-rail-road and river-rail-road ITs) and quadri-modal (most commonly connecting road, rail, river and maritime modes of transport) (Notteboom & Rodrigue, 2009). In relation to the place and role in the network/chain (E_3) ITs can be divided into two basic groups: maritime and inland terminals. Maritime terminals appear in nine basic types (Park & Medda, 2010): terminals in dominant ports, terminals in superior ports, terminals in indirect ports, terminals in versatile ports, terminals in ordinary ports, terminals in development ports, terminals in specialized ports, terminals in industrial ports and terminals in peripheral ports. On the other hand, inland ITs can be classified into five basic tyoes (Woxenius, 1997): direct connection terminals, corridor terminals, hub & spoke terminals, fixed-line terminals and assigned route terminals. Regarding the structure of functions and services (E_5), ITs can be divided into four categories (Zečević, 2006): A, B, C and D. Terminals of category A perform the basic functions (reception, transshipment, disposal and shipping of transport means and ITUs), B perform basic and supplementary functions (e.g. ITUs charging and discharging, storing the goods, maintaining ITUs, etc.), C, 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.), and D, in addition to all aforementioned, perform additional functions in order to achieve the complete logistics service (e.g., services with the special ITUs, educational and advisory services, planning and organization of door-to-door transport, VAL (Value Added Logistics) services, etc.). By combining the various characteristics and modalities of the ITs with respect to the identified key elements, the 36 typical IT structures given in Table 6 are defined.

Table 6. Overview of the typical IT structures in relation to the key elements

Typical structure	Terminal size	Transport modes	Place and role in the network	Functions structure
TS_1	"small"	road	direct	A
TS_2	"small"	road-rail	line	B
TS_3	"small"	road-rail	corridor	B
TS_4	"small"	road-rail	hub	C
TS_5	"small"	road-river	line	B
TS_6	"small"	road-river	corridor	B
TS_7	"small"	road-river	hub	C
TS_8	"small"	road-rail-river	corridor	C
TS_9	"small"	road-rail-river	hub	D
TS_{10}	"medium"	road-rail	line	B
TS_{11}	"medium"	road-rail	corridor	C
TS_{12}	"medium"	road-rail	hub	C
TS_{13}	"medium"	road-river	corridor	C
TS_{14}	"medium"	road-river	hub	C
TS_{15}	"medium"	road-rail-river	corridor	C
TS_{16}	"medium"	road-rail-river	hub	D
TS_{17}	"medium"	road-rail-maritime	peripheral	D
TS_{18}	"large"	road-rail	line	C
TS_{19}	"large"	road-rail	corridor	C
TS_{20}	"large"	road-rail	hub	D
TS_{21}	"large"	road-rail-river	corridor	C
TS_{22}	"large"	road-rail-river	hub	D
TS_{23}	"large"	road-rail-maritime	ordinary	D
TS_{24}	"large"	road-rail-maritime	superior	D
TS_{25}	"very large"	road-rail-river	hub	D
TS_{26}	"very large"	road-maritime	indirect	C
TS_{27}	"very large"	road-rail-maritime	versatile	D
TS_{28}	"very large"	road-rail-maritime	superior	D
TS_{29}	"very large"	road-rail-maritime	dominant	D
TS_{30}	"very large"	road-rail-river-maritime	dominant	D
TS_{31}	"mega"	road-rail-maritime	versatile	D
TS_{32}	"mega"	road-rail-maritime	indirect	D
TS_{33}	"mega"	road-rail-maritime	superior	D
TS_{34}	"mega"	road-rail-maritime	dominant	D
TS_{35}	"mega"	road-rail-river-maritime	versatile	D
TS_{36}	"mega"	road-rail-river-maritime	dominant	D

5. CONCLUSION

The paper proposes a new methodology for defining typical IT structures that involves identifying a wide set of structural elements, the factors that influence them, as well as the strength of these influences. The methodology included the development of an MCDM model that combines the fuzzy Delphi method, by which the importance of the factors and the strength of their influence on the structural elements is determined, and the fuzzy VIKOR method, by which the ranking and selection of the key structural elements is performed. It has been found that elements that are crucial for the formation of typical IT structures are: transport modes, place and role of the terminal in the network/chain, terminal size and structure of functions and services. By combining various characteristics and modalities of the defined key elements and research of the real-life ITs in Europe, 36 typical IT structures have been defined.

By defining the typical IT structures, preconditions for their detailed analysis, comparison, performance research, efficiency, etc. have been created with the aim of finding typical structures that can serve as benchmarks for other terminals with mutually comparable characteristics. The defined methodology could be used with certain adjustments to define the structures of other types of logistics centers, which could be the subject of some future research. Besides that, significant future research direction would be more detailed research and analysis of the identified TSs and their efficiency estimation, as well as modeling the IT structures, that were not defined as the typical ones since they have not been identified in practice, but which could be competitive with the defined TSs. The proposed MCDM model could also be used for solving the problems from various fields.

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