THE ARCHIVES OF TRANSPORT

VOL. XXIV NO 2 2012

10.2478/v10174-012-0011-7

The Concept of a Logistics Centre Model as a Nodal Point of a Transport and Logistics Network[1]

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Received November 2011

Abstract

The paper presents a concept of a logistics centre model. The model is based on defined output/input flows of goods. Therefore it is possible to determine and estimate the load of elements of the centre infrastructure being at the disposal of individual service providers operating within the centre. Input and output flows are defined on the basis of the balance of flows directed to the centre from the whole logistics and transport network and are considered split into: product groups, types of transport, various transport forms of cargo. The seasonal nature of these flows has been taken into consideration. The calculations of infrastructure load assume that every service provider operating within the centre can also use elements of infrastructure owned by other centre users. The proposed model can serve various purposes. An emphasis is put herein on the possibility of estimating the degree of the transport and logistics infrastructure load of the centre on the basis of historical data as well as on the basis of forecasts. As a result, the needs related to the access to the infrastructure can be specified and used to determine and verify investment plans.

[1] The paper is the result of research conducted within the development project: "The model logistics system of Poland as a way to comodality of transport in the European Union" (Project Nr N R10 0027 06/2009, coordinated by prof. Marianna Jacyna – Warsaw University of Technology)

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1. Introduction

Efficient use of various transport modes operating separately or integrated in a multimodal fashion necessitates that there is a possibility to use the advantages of the means of transport and their transport capacities. Hence, the nodes of a logistics network should be the main points among which the means of transport and freight and forwarding solutions can fully show their possibilities and advantages. Logistics centres in addition to sea ports meet this requirement to the greatest possible extent among other points of the logistics infrastructure.

Planning of the location of logistics centres, both on the macro (as part of the national transport and logistics system) and micro scale (specific location) and determining the nature of infrastructure and technical equipment of the centre, necessitate that a series of details be indentified pertaining to: product streams incoming and outgoing from the centre, engagement and load of the infrastructure elements which are at the disposal of the centre as such, and the operators active on its premises. This, in turn, requires that the structure of product streams in the system of product groups, types of transport, transport forms of cargo be estimated [2]. A comprehensive model of a logistics centre can significantly support the solving of such issues.

The proposed model may serve various purposes. An emphasis is put on the possibility of estimating the degree of the transport and logistics infrastructure load of the centre on the basis of historical data as well as on the basis of forecasts. As a result, the needs related to the access to the infrastructure can be determined and used to specify and verify investment plans.

2. Reproducing the Logistics Centre in the Formal Description of the Distribution Subsystem

With the network description being preserved in the form of a chart, the logistics centre is presented here as one of the possible network nodes. A decision was made, however, to replace hierarchical classification (international, regional, local) with classification based on the node characteristics in accordance with the division presented in the paper [2].

As a result, it is proposed to consider the logistics centre as one of the possible types of nodal points (NP_k) of the logistics (distribution) network, which include:

- NP_1 – Sea ports
- NP_2 – Logistics centres
- NP_3 – Warehousing centres
- NP_4 – Large format warehouses
- NP_5 – Intermodal transport terminals
- NP_6 – Traditional road – rail handling terminals

- NP_7 – Inland water ports
- NP_8 – Airports

The list is supplemented by adding a set of customers NP_9 comprising both customers – RECIPIENTS of goods sent from a given nodal point, as well as entities that deliver their goods directly to the centre, skipping other nodal points (customers – SENDERS). Such an approach enables the logistics network to be "completed" and seems significant from the point of view of the full reproduction of the logistics centre in it.

In the proposed approach the set of nodal points NP of the network is the sum of sets: NP_1, NP_2, NP_3, NP_4, NP_5, NP_6, NP_7, NP_8 and NP_9:

$NP = NP_1 \cup NP_2 \cup NP_3 \cup NP_4 \cup NP_5 \cup NP_6 \cup NP_7 \cup NP_8 \cup NP_9$.

These sets are mutually disjoint.

2.1. Identification of a surrounding of a logistics centre and types of product streams

The surroundings of (any) logistics centre LC under consideration comprise subsets of sets of specific nodal point types which maintain input and output relations with the centre under consideration (Table 1).

Having defined sets of external nodal points one has then to identify all possible subsets of the above given nodal points types, that stay in a relationship with the logistics centre LC under consideration:

$(NP_k)_i$-IN – means an element of a subset of nodal points type "k" comprising those among all nodal points of this type from which streams of goods are sent to the logistics centre under consideration;

$(NP_k)_i$-OUT – means an element of a subset of nodal points type "k" comprising those among all nodal points of this type to which streams of goods are sent from the logistics centre under consideration;

Table 1

Relations of a logistics centre with its surroundings

Sets of nodal points	Subsets of nodal points staying in relationship with the LC under consideration	
Sea ports (NP1)	$(NP_1)_i$-IN	$(NP_1)_i$-OUT
Logistics centres (NP2)	$(NP_2)_i$-IN	$(NP_2)_i$-OUT
Warehousing centres (NP3)	$(NP_3)_i$-IN	$(NP_3)_i$-OUT
Large format warehouses (NP4)	$(NP_4)_i$-IN	$(NP_4)_i$-OUT
Intermodal transport terminals (NP5)	$(NP_5)_i$-IN	$(NP_5)_i$-OUT
Traditional road – rail handling terminals (NP6)	$(NP_6)_i$-IN	$(NP_6)_i$-OUT
Inland water ports (NP7)	$(NP_7)_i$-IN	$(NP_7)_i$-OUT
Airports (NP8)	$(NP_8)_i$-IN	$(NP_8)_i$-OUT
Individual customers (NP9)	$(NP_9)_i$-IN	$(NP_9)_i$-OUT

For example:

$(NP_1)_1$-IN – means a sea ports (1) belonging to a subset comprising those among all sea ports from which streams of goods are sent to the logistics centre under consideration;

$(NP_2)_1$-OUT – means a logistics centre (2) belonging to a subset comprising those among all other logistics centres to which streams of goods are sent from the logistics centre under consideration;

A further step must involve describing all pairs:

$\{(NP_m)_i; (NP_n)_j\text{-OUT}\}$ and $\{(NP_n)_i\text{-IN}; (NP_m)_i\}$

where:

m, n – indices of a network node type;

i, j – indices identifying specific nodes of a given type

$NP_m, NP_n \in \{NP_1, NP_2, NP_3, NP_4, NP_5, NP_6, NP_7, NP_8, NP_9\}$,

whereby, if m = n then i ≠ j (a given node may not send streams to itself).

Using vectors specifying all possible means of input/output (transport mode and form of cargo) as well as stream volume (e.g. yearly or mean daily) and their structure split into individual types of transport and forms of cargo.

Since the basic objective of the paper is to reproduce the logistics centre in the logistics and transport network, it is assumed further down the paper that NP_m =LC (logistics centre).

There are different definitions of a logistics centre in the logistics terminology which stem from the attempts at classifying their functionalities (e.g. logistics and distribution centre, logistics centre of distribution) or are the result of a marketing strategy of enterprises using the name "logistics centre" to describe a finished goods warehouse or a central warehouse [1]. It is assumed herein that a logistics centre is a spatial facility with the relevant organization and infrastructure making it possible for independent enterprises to perform operations on goods in relation to their warehousing and transfer between the sender and the recipient, including support of intermodal transport and performing operations on the resources used for this purpose [2].

In order to describe the input and output streams it is necessary to define various transport modes and transport forms of cargo which makes up these streams. It is important both for further evaluation of the co-modality in the whole network and for the balancing of input steams against capacity of the logistics centre infrastructure.

Five basic transport modes and 11 transport forms of cargo are assumed in the presented version of the model. They are considered jointly in a matrix system. It is proposed that the model presented in Table 2 be adopted.

The structure proposed in the table above will be used to structure the input and output streams. Obviously, some of the associations: "transport mode – form of cargo" may never occur in practice (e.g. air freight of bulk dry goods) but the proposed model is universal and suitable for further modelling.

Table 2

The structure identifying product streams adopted in the model on account of the transport mode and the transport form of cargo

Transport mode	Road	Rail (train)	Inland water	Sea	Air	**Transport form of cargo**
	$\mathbf{TM_{1.R}}$	$\mathbf{TM_{1.T}}$	$\mathbf{TM_{1.W}}$	$\mathbf{TM_{1.S}}$	$\mathbf{TM_{1.A}}$	bulk gas
	$\mathbf{TM_{2.R}}$	$\mathbf{TM_{2.T}}$	$\mathbf{TM_{2.W}}$	$\mathbf{TM_{2.S}}$	$\mathbf{TM_{2.A}}$	bulk liquid
	$\mathbf{TM_{3.R}}$	$\mathbf{TM_{3.T}}$	$\mathbf{TM_{3.W}}$	$\mathbf{TM_{3.S}}$	$\mathbf{TM_{3.A}}$	bulk dry
	$\mathbf{TM_{4.R}}$	$\mathbf{TM_{4.T}}$	$\mathbf{TM_{4.W}}$	$\mathbf{TM_{4.S}}$	$\mathbf{TM_{4.A}}$	bulk unit unpacked
	$\mathbf{TM_{5.R}}$	$\mathbf{TM_{5.T}}$	$\mathbf{TM_{5.W}}$	$\mathbf{TM_{5.S}}$	$\mathbf{TM_{5.A}}$	bulk unit packed
	$\mathbf{TM_{6.R}}$	$\mathbf{TM_{6.T}}$	$\mathbf{TM_{6.W}}$	$\mathbf{TM_{6.S}}$	$\mathbf{TM_{6.A}}$	on pallets
	$\mathbf{TM_{7.R}}$	$\mathbf{TM_{7.T}}$	$\mathbf{TM_{7.W}}$	$\mathbf{TM_{7.S}}$	$\mathbf{TM_{7.A}}$	in packages
	$\mathbf{TM_{8.R}}$	$\mathbf{TM_{8.T}}$	$\mathbf{TM_{8.W}}$	$\mathbf{TM_{8.S}}$	$\mathbf{TM_{8.A}}$	in containers
	$\mathbf{TM_{9.R}}$	$\mathbf{TM_{9.T}}$	$\mathbf{TM_{9.W}}$	$\mathbf{TM_{9.S}}$	$\mathbf{TM_{9.A}}$	in swap bodies
	$\mathbf{TM_{10.R}}$	$\mathbf{TM_{10.T}}$	$\mathbf{TM_{10.W}}$	$\mathbf{TM_{10.S}}$	$\mathbf{TM_{10.A}}$	in trailers (including bimodal transport)
	$\mathbf{TM_{11.R}}$	$\mathbf{TM_{11.T}}$	$\mathbf{TM_{11.W}}$	$\mathbf{TM_{11.S}}$	$\mathbf{TM_{11.A}}$	other

E.g. $TM_{6.R}$ means transport of cargo on pallets using road transport whereas $TM_{8.S}$ means transport of cargo in containers using sea freight.

2.2. Tables describing the input streams into a logistics centre

Input streams into a logistics centre LC (LC_i) will be described using three tables determining: the general total volume of input from different sources, the structure of these streams split into transport modes and transport forms of cargo and their sizes expressed in units of weight, in the same division.

In the general case, the input table must isolate streams of individual product groups. The table of yearly volumes of input streams as per product groups can be described as in Table 3.

Table 3

Volumes of yearly input streams as per product groups

$[(NP_j)_m$-IN; $LC_i] =$	Volume IN_PG1
	Volume IN_PG2
	Volume IN_PG3
	Volume IN_PG4
	....
	Volume IN_PGN

(j – index of the network node type;
m – index identifying a specific node of a given type)

where:

PG1 = Agriculture;
PG2 = Coal;
PG3 = Metal ores;
PG4 = Food;
PG5 = Textiles;
PG6 = Wood;
PG7 = Coke, briquettes;
PG8 = Chemicals;
PG9 = Other non-metallic;
PG10 = Metals;
PG11 = Machines and equipment;
PG12 = Transport equipment;
PG13 = Furniture;
PG14 = Recyclable materials;
PG15 = Other;

The input table must also take into consideration the transport modes supporting input streams and transport equipment (units) in accordance with Table 2. For this purpose one must first specify the distribution of types of transport as per product categories and determine the table of the structure of transport types and transport units. Table $[(NP_j)_m$-IN.%; $LC_i]$ has three dimensions: the transport form of cargo, the transport mode, the product group, as presented in Figure 1.

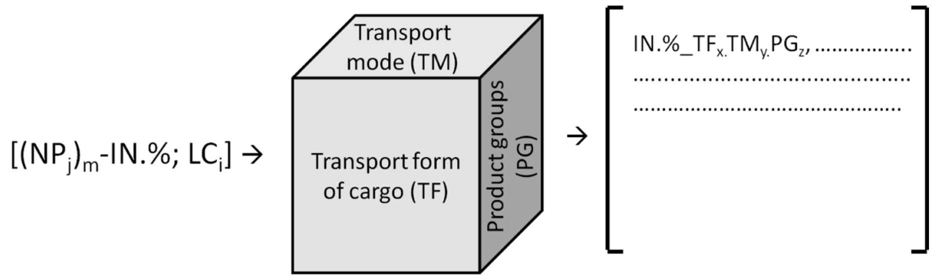

Fig. 1. Graphic illustration of the table $[(NP_j)_m$-IN.%; $LC_i]$
(j – index of the network node type; m – index identifying a specific node of a given type)

For example:
$IN.\%\_6.R_{PGi}$ – is an element of the table $[(NP_j)_m$-IN.%; $LC_i]$ indicating a percent share of input (from the $(NP_j)_m$ node) for the transport of cargo on pallets effected using road transport (as defined in table 2) in the complete input stream for the PG_i product group specified in tonnes.
The following relation must exist for every PG_i product group:

$$\sum_{j=1}^{j=11} IN\%\_j.R_{PGi} + \sum_{j=1}^{j=11} IN\%\_j.T_{PGi} + \sum_{j=1}^{j=11} IN\%\_j.W_{PGi} + \sum_{j=1}^{j=11} IN\%\_j.S_{PGi} + \sum_{j=1}^{j=11} IN\%\_j.A_{PGi} = 100\% \quad (1)$$

where: j – index of the transport mode form of cargo, i – index of the product group.

Merger of both tables: $[(NP_j)_m$-IN;LC] and $[(NP_j)_m$-IN.%;LC] (even though we are not speaking of a formal matrix calculus here) leads to determining yearly volumes of input streams of goods split into product groups and modes of delivery (transport modes and transport units), presented in Table 4.

Table 4

Yearly input streams split into product groups and transport modes and transport and cargo units used

	Transport modes						
$[(NP_m)_j$-IN.M; $LC_i]$ =	IN.M_1.R_{PG1}	IN.M_1.T_{PG1}	IN.M_1.W_{PG1}	IN.M_1.S_{PG1}	IN.M_1.A_{PG1}	Form of cargo	Product groups
	IN.M_2.R_{PG1}	IN.M_2.T_{PG1}	IN.M_2.W_{PG1}	IN.M_2.S_{PG1}	IN.M_2.A_{PG1}		
	....						
	IN.M_11.R_{PG1}	IN.M_11.T_{PG1}	IN.M_11.W_{PG1}	IN.M_11.S_{PG1}	IN.M_11.A_{PG1}		
	IN.M_1.R_{PG2}	IN.M_1.T_{PG2}	IN.M_1.W_{PG2}	IN.M_1.S_{PG2}	IN.M_1.A_{PG2}	Form of cargo	
	IN.M_2.R_{PG2}	IN.M_2.T_{PG2}	IN.M_2.W_{PG2}	IN.M_2.S_{PG2}	IN.M_2.A_{PG2}		
	....						
	IN.M_11.R_{PG2}	IN.M_11.T_{PG2}	IN.M_11.W_{PG2}	IN.M_11.S_{PG2}	IN.M_11.A_{PG2}		
	....						
	IN.M_1.R_{PG15}	IN.M_1.T_{PG15}	IN.M_1.W_{PG15}	IN.M_1.S_{PG15}	IN.M_1.A_{PG15}	Form of cargo	
	IN.M_2.R_{PG15}	IN.M_2.T_{PG15}	IN.M_2.W_{PG15}	IN.M_2.S_{PG15}	IN.M_2.A_{PG15}		
	....						
	IN.M_11.R_{PG15}	IN.M_11.T_{PG15}	IN.M_11.W_{PG15}	IN.M_11.S_{PG15}	IN.M_11.A_{PG15}		

(m – index of the network node type; j – index identifying a specific node of a given type)

For example, for NP_1 (sea port):

IN.M_5.R_{PG13} – is an element of the table $[(NP_1)_j$-IN.M; $LC_i]$ indicating a summary yearly volume of bulk packed furniture using road transport (as defined in Table 2) delivered to the LC_i logistics centre under consideration from the *j*th sea port.

Tables describing output streams will be described analogously to the input stream tables:

- Output volume table: $[LC_i$; $(NP_m)_j$-OUT;],
- Output structure table: $[(NP_m)_j$-OUT.%; $LC_i]$,
- Table of output streams split into product groups and transport types and transport and cargo units used: $[(NP_m)_j$-OUT.M; $LC_i]$.

For example, for NP_2 (logistics centre):

OUT.M_6.T_{PG4} – is an element of the table $[(NP_m)_j$-OUT.M; $LC_i]$ indicating a summary yearly volume of food (product group PG4) sent on pallets using rail transport (train), as defined in table 2, from the LC_i logistics centre under consideration to the *j*th logistics centre.

One must bear in mind that in the general case, for every pair of nodal points $\{(NP_m)_j; (NP_n)_i\}$, the following conditions must be fulfilled:

$$[(NP_n)_i; (NP_m)_j - IN] = [(NP_n)_i - OUT; (NP_m)_j]$$

and

$$[(NP_m)_j; (NP_n)_i - IN] = [(NP_m)_j - OUT; (NP_n)_i]$$

where:
m, n – indices of a network node type;
i, j – indices identifying specific nodes of a given type.

This is represented by the condition of "reciprocity" of relations between any two nodal points of a logistics network.

The formal description presented above broadens the description of the relation between nodes of a network with the size of product streams. Such an approach may be further developed to obtain more details (e.g. tables of monthly, quarterly flows taking into consideration the seasonal nature of intensity of goods streams in individual product groups). At the same time such an approach makes it possible to balance streams in the whole network and in its selected segments, taking into consideration the structures of types of transport used. Such an approach, finally, allows the basic, general model of a logistics centre to be determined.

3. The General Model of a Logistics Centre Taking into Consideration Input and Output Product Flows and the Characteristics of the Centre Infrastructure

Even though the proposed model enables any nodal point of a logistics network to be represented, in accordance with the classification presented above, the main aim of the task is to develop a general model of a logistics centre.

On the basis of the model presented earlier, any LC logistics centre can be described in a general manner, which characterizes input and output streams in accordance with the tables $[(NP_m)_i - IN;LC]$ and $[LC; (NP_n)_j - OUT]$.

The proposed model of a logistics centre reflects both the structure of input and output streams for considered transport modes and transport forms of cargo and the internal structure of the LC comprising service providers and the services they offer as well as the infrastructure at the disposal of the centre and individual service providers along with its characteristics. Such an approach ensures compliance with the tables described earlier

$$[(NP_m)_i - IN.\%;LC] \text{ and } [LC; (NP_n)_j - OUT.\%]$$

$$\text{and } [(NP_m)_i - IN.M; LC] \text{ and } [LC; (NP_n)_j - OUT.M],$$

where:

$m, n-$ indices of a network node type;

i, j – indices identifying specific nodes of a given type

Figures 2 and 3 present aspects of organization and operation of the logistics centre and services providers located on its premises: the profiles and characteristics of services, supported product groups, transport modes supporting input and output streams and the infrastructure possessed.

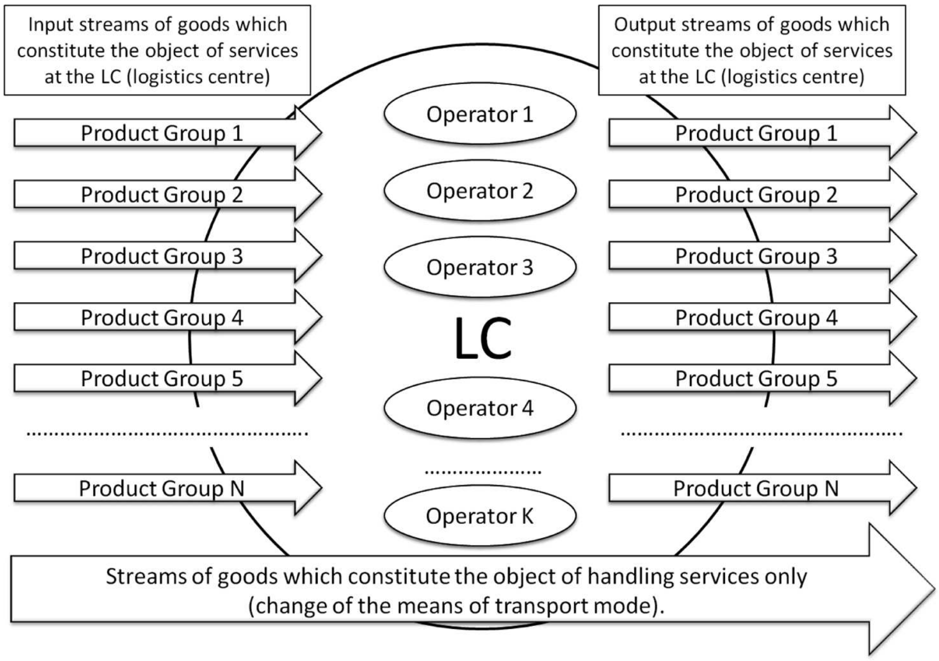

Fig. 2. General model of product flow through the logistics centre from the following perspective: product groups – service providers [3]

The proposed model of a logistics centre should allow:

- description of input and output streams at the level of the whole LC logistics centre and every service provider active on its premises, split into product groups, types of transport and cargo units supporting these streams and taking into consideration the seasonal nature of loads (i.e. with reference to a defined period),
- identification and description of the load of individual infrastructure elements at the disposal of service providers active on the premises of the centre with the possibility to evaluate the extent to which they are used.

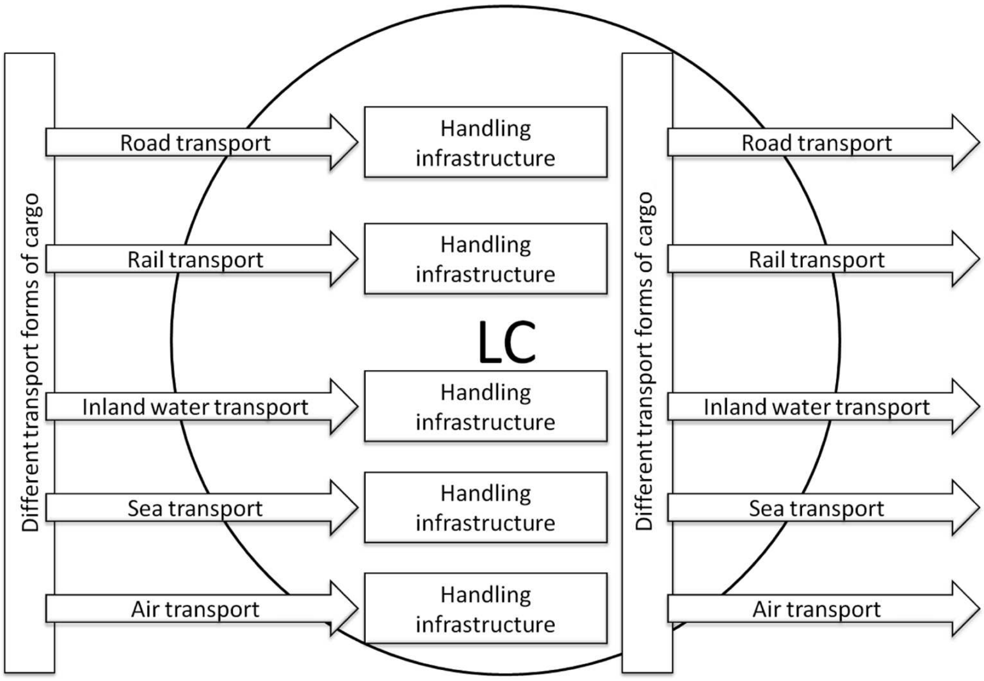

Fig. 3. Model of product flow through the logistics centre taking into consideration diversification of types of transport and cargo units [3]

3.1. Formal description of the internal structure of a logistics centre

It is assumed that on the premises of the logistics centre, ***nsp*** service providers are active and in order to make the formal description more consistent it is assumed that a service provider may be occupied with any activity (e.g. running a hotel).

Service providers P_0, P_1, P_2, ...P_{nsp} are described in the Table of Service Providers of the Centre (TPC) and the centre as such, which can also act as the service provider, is being considered as U_0.

It is necessary to specify the following for every service provider:

- a general model of possible activities of the service provider (Activity Profile Vector APV), comprising all possible activities and thus exhausting all possible profiles of the service providers' activities,
- a model of the supported product groups (Supported Product Groups Vector PGV) in accordance with the list presented earlier,
- a model of the infrastructure possessed (Infrastructure Possessed Vector IPV).

Sample models of the service provider activity and the infrastructure at their disposal are shown in Table 5.

Unlike the vectors $[APV]_j$ and $[PGV]_j$, (for the "*j*" service provider), for which values of individual rows can assume values from the set {0; 1}, values of the

Table 5

Models of the service provider activity and the infrastructure at their disposal

[APV] =	A1 = Warehousing		[IPV]=	I1 = Intermodal transport terminal [daily capacity – units]
	A2 = Forwarding			I2 = Unloading gates [daily capacity – units]
	A3 = Transport			I3 = Handling platforms
	A4 = Customs services			I4 = Warehousing space [capacity – number of pallet places]
	A5 = Distribution			I5 = Car park [number of parking spaces]
	A6 = Value adding services			I6 = Handling equipment [daily capacity – units]
	A7 = Servicing means of transport			I7 = Internal transport means and equipment
	A8 = Fuel services			I8 = Quay
	A9 = Banking and finance services			I9 = Vehicle service stations
	A10 = Information and marketing services			I10 = Fuel station [daily capacity – number of vehicles]
	A11 = Coordination of common services			I11 = Office area
	A12 = Hotel services			I12 = Hotel [number of beds]
	A13 = Catering services			I13 = Bar-restaurant [daily capacity – number of customers]

rows of vector $[\mathrm{IPV}]_j$ are indicative of characteristics of the capacity of a given infrastructure element (in agreed units) and the value “0” in a given row means a given infrastructure element is missing.

Any service provider active on the premises of the logistics centre under consideration may thus be described using three vectors indicating types of its activity, the scope of supported product groups and the infrastructure at its disposal along with its characteristics.

The above description makes it possible to present – in the three dimensions indicated – the characteristics of the whole centre:

$$\begin{cases} [\mathrm{APV}]_{\mathrm{LC}} = \sum_{j=1}^{nsp} [\mathrm{APV}]_{\mathrm{j}} \\ [\mathrm{PGV}]_{\mathrm{LC}} = \sum_{j=1}^{nsp} [\mathrm{PGV}]_{\mathrm{j}} \\ [\mathrm{IPV}]_{\mathrm{LC}} = \sum_{j=1}^{nsp} [\mathrm{IPV}]_{\mathrm{j}} \end{cases} \tag{2}$$

whereby vectors $[\mathrm{APV}]_{LC}$ and $[\mathrm{PGV}]_{LC}$ are calculated as logical disjunctions of the vectors $[\mathrm{APV}]_j$, and $[\mathrm{PGV}]_j$, and the vector $[\mathrm{IPV}]_{LC}$ as the algebraic sum of the vectors $[\mathrm{IPV}]_j$. Hence the vectors $[\mathrm{APV}]_{LC}$, $[\mathrm{PGV}]_{LC}$ and $[\mathrm{IPV}]_{LC}$ have an identical structure as the vectors describing individual service providers ($[APV]_j$, $[PGV]_j$ and $[IPV]_j$) and form the characteristics of the whole centre.

3.2. Description of input streams

Irrespective of vectors characterizing service providers and the whole centre, it is necessary to define vectors (tables) determining goods flows (input and output).

It is assumed that basic vectors determine summary input and output streams for every service provider split into isolated product groups (Table 6).

Table 6

Summary yearly input stream to the "j" service provider

$[IN]_j$ =	Summary yearly input stream for the service provider P_j in PG1 – Agriculture
	Summary yearly input stream for the service provider P_j in PG2 – Coal
	....
	Summary yearly input stream for the service provider P_j in PG15 – Other

(*j*– *service provider index)*

From a more detailed perspective the same relations for input and output must be specified taking into consideration the structure of types of transport and the cargo units used (Table 7).

Table 7

Structure of types of transport for input streams for the service provider "j"

	Transport modes						
$[IN.\% - TM]_j$	IN.%_1 $_j$.R$_{PG1}$	IN.%_1 $_j$.T$_{PG1}$	IN.%_1 $_j$.W$_{PG1}$	IN.%_1 $_j$.S$_{PG1}$	IN.%_1 $_j$.A$_{PG1}$	Form of cargo	Product groups
	IN.%_2 $_j$.R$_{PG1}$	IN.%_2 $_j$.T$_{PG1}$	IN.%_2 $_j$.W$_{PG1}$	IN.%_2 $_j$.S$_{PG1}$	IN.%_2 $_j$.A$_{PG1}$		
	....						
	IN.%_11 $_j$.R$_{PG1}$	IN.%_11 $_j$.T$_{PG1}$	IN.%_11 $_j$.W$_{PG1}$	IN.%_11 $_j$.S$_{PG1}$	IN.%_11 $_j$.A$_{PG1}$		
	IN.%_1 $_j$.R$_{PG2}$	IN.%_1 $_j$.T$_{PG2}$	IN.%_1 $_j$.W$_{PG2}$	IN.%_1 $_j$.S$_{PG2}$	IN.%_1 $_j$.A$_{PG2}$	Form of cargo	
	IN.%_2 $_j$.R$_{PG2}$	IN.%_2 $_j$.T$_{PG2}$	IN.%_2 $_j$.W$_{PG2}$	IN.%_2 $_j$.S$_{PG2}$	IN.%_2 $_j$.A$_{PG2}$		
	....						
	IN.%_11 $_j$.R$_{PG2}$	IN.%_11 $_j$.T$_{PG2}$	IN.%_11 $_j$.W$_{PG2}$	IN.%_11 $_j$.S$_{PG2}$	IN.%_11 $_j$.A$_{PG2}$		
	....						
	IN.%_1 $_j$.R$_{PG15}$	IN.%_1 $_j$.T$_{PG15}$	IN.%_1 $_j$.W$_{PG15}$	IN.%_1 $_j$.S$_{PG15}$	IN.%_1 $_j$.A$_{PG15}$	Form of cargo	
	IN.%_2 $_j$.R$_{PG15}$	IN.%_2 $_j$.T$_{PG15}$	IN.%_2 $_j$.W$_{PG15}$	IN.%_2 $_j$.S$_{PG15}$	IN.%_2 $_j$.A$_{PG15}$		
	....						
	IN.%_11 $_j$.R$_{PG15}$	IN.%_11 $_j$.T$_{PG15}$	IN.%_11 $_j$.W$_{PG15}$	IN.%_11 $_j$.S$_{PG15}$	IN.%_11 $_j$.A$_{PG15}$		

(j – service provider index)

Merger of the tables $[IN]_j$ and $[IN.\% - RT]_j$ leads to determining volumes of input streams of goods split into product groups and modes of delivery (Table 8).

Table 8

Summary yearly input streams to the service provider "j"

	Transport modes						
[IN.M - TM]$_j$	IN.M_1$_j$.R$_{PG1}$	IN.M_1$_j$.T$_{PG1}$	IN.M_1$_j$.W$_{PG1}$	IN.M_1$_j$.S$_{PG1}$	IN.M_1$_j$.A$_{PG1}$	Form of cargo	Product groups
	IN.M_2$_j$.R$_{PG1}$	IN.M_2$_j$.T$_{PG1}$	IN.M_2$_j$.W$_{PG1}$	IN.M_2$_j$.S$_{PG1}$	IN.M_2$_j$.A$_{PG1}$		
	....						
	IN.M_11$_j$.R$_{PG1}$	IN.M_11$_j$.T$_{PG1}$	IN.M_11$_j$.W$_{PG1}$	IN.M_11$_j$.S$_{PG1}$	IN.M_11$_j$.A$_{PG1}$		
	IN.M_1$_j$.R$_{PG2}$	IN.M_1$_j$.T$_{PG2}$	IN.M_1$_j$.W$_{PG2}$	IN.M_1$_j$.S$_{PG2}$	IN.M_1$_j$.A$_{PG2}$	Form of cargo	
	IN.M_2$_j$.R$_{PG2}$	IN.M_2$_j$.T$_{PG2}$	IN.M_2$_j$.W$_{PG2}$	IN.M_2$_j$.S$_{PG2}$	IN.M_2$_j$.A$_{PG2}$		
	....						
	IN.M_11$_j$.R$_{PG2}$	IN.M_11$_j$.T$_{PG2}$	IN.M_11$_j$.W$_{PG2}$	IN.M_11$_j$.S$_{PG2}$	IN.M_11$_j$.A$_{PG2}$		
	....						
	IN.M_1$_j$.R$_{PG15}$	IN.M_1$_j$.T$_{PG15}$	IN.M_1$_j$.W$_{PG15}$	IN.M_1$_j$.S$_{PG15}$	IN.M_1$_j$.A$_{PG15}$	Form of cargo	
	IN.M_2$_j$.R$_{PG15}$	IN.M_2$_j$.T$_{PG15}$	IN.M_2$_j$.W$_{PG15}$	IN.M_2$_j$.S$_{PG15}$	IN.M_2$_j$.A$_{PG15}$		
	....						
	IN.M_11$_j$.R$_{PG15}$	IN.M_11$_j$.T$_{PG15}$	IN.M_11$_j$.W$_{PG15}$	IN.M_11$_j$.S$_{PG15}$	IN.M_11$_j$.A$_{PG15}$		

(j – service provider index)

For example, for j=2

IN.M_8$_2$.T$_{PG13}$ – a summary yearly volume of furniture delivered to the P$_2$ service provider using rail transport in containers.

Vectors (tables) of output can be described in the same fashion as tables:

$$[\text{OUT}]_j,\ [\text{OUT.\% - TM}]_j,\ [\text{OUT.M - TM}]_j.$$

3.3. The principle of balancing streams

The sum of input streams as part of the *i*th product group for the *k*th transport mode to all ***nsp*** service providers of the LC centre must equal the sum of input streams from all nodal points of the network surroundings (NP) of the centre:

$$\sum_{j=0}^{nsp}[\text{IN.M - TM}] = \sum_{m=1}^{9}\sum_{i=1}^{NNP_m}\left[(NP_m)_i - \text{IN.M; LC}\right] \tag{3}$$

where:

- NP$_1$ – Sea ports (m=1)
- NP$_2$ – Logistics centres (m=2),
- NP$_3$ – Warehousing centres (m=3),
- NP$_4$ – Large format warehouses (m=4)
- NP$_5$ – Intermodal transport terminals (m=5)
- NP$_6$ – Traditional road – rail handling terminals (points) (m=6)
- NP$_7$ – Inland water ports (m=7)
- NP$_8$ – Airports (m=8)
- NP$_9$ – Customers (m=9)
- NNP$_m$ – the number of nodal points of *m*th type of a network node in the network surroundings of the LC centre

Likewise for the output streams:

$$\sum_{j=0}^{NP} [OUT.M - TM]_j = \sum_{m=1}^{9} \sum_{i=1}^{NNP_m} \left[LC; (NP_m)_i - OUT.M\right] \tag{4}$$

The following is assumed in the above equations:

m – index of the type of network node;

i – indices identifying specific nodes of a given type;

j – service provider index.

3.4. Taking into consideration the seasonal nature of input and output

In fact, input and output streams can show seasonal changes. It is proposed that it be included in the model in such a way that every row of tables $[IN]_j$ and $[OUT]_j$ is distributed over 52 weeks of the year. It should be assumed that in some situations it will suffice to distribute it over 12 periods (months) or 4 (quarters).

If the seasonal fluctuations of input and output streams are taken into consideration, it will be possible to obtain a more comprehensive evaluation of the extent to which the resources (the infrastructure possessed) are used and their potential deficits.

In justified cases, it may also be necessary to take into consideration the seasonal nature of the division of the structure of types of transport supporting individual streams at the input and output.

The consequence of such an approach is the origination of nsp x T tables $[IN]_{j,t}$ and $[OUT]_{j,t}$, and, respectively, $[IN.M\text{-}TM]_{j,t}$ and $[OUT.M\text{-}TM]_{j,t}$, determining input and output streams (expressed in units of measurement) to the service provider "j" in the period "t" – in general and split into types of transport (Table 9).

Table 9

Structure of the table [IN.M-TM]$_{j,t}$

	Types of transport						
[IN.M - TM]$_{j,t}$	IN.M_1$_{j,t}$.R$_{PG1}$	IN.M_1$_{j,t}$.T$_{PG1}$	IN.M_1$_{j,t}$.W$_{PG1}$	IN.M_1$_{j,t}$.S$_{PG1}$	IN.M_1$_{j,t}$.A$_{PG1}$	Form of cargo	Product groups
	IN.M_2$_{j,t}$.R$_{PG1}$	IN.M_2$_{j,t}$.T$_{PG1}$	IN.M_2$_{j,t}$.W$_{PG1}$	IN.M_2$_{j,t}$.S$_{PG1}$	IN.M_2$_{j,t}$.A$_{PG1}$		
	IN.M_11$_{j,t}$.R$_{PG1}$	IN.M_11$_{j,t}$.T$_{PG1}$	IN.M_11$_{j,t}$.W$_{PG1}$	IN.M_11$_{j,t}$.S$_{PG1}$	IN.M_11$_{j,t}$.A$_{PG1}$		
	IN.M_1$_{j,t}$.R$_{PG2}$	IN.M_1$_{j,t}$.T$_{PG2}$	IN.M_1$_{j,t}$.W$_{PG2}$	IN.M_1$_{j,t}$.S$_{PG2}$	IN.M_1$_{j,t}$.A$_{PG2}$	Form of cargo	
	IN.M_2$_{j,t}$.R$_{PG2}$	IN.M_2$_{j,t}$.T$_{PG2}$	IN.M_2$_{j,t}$.W$_{PG2}$	IN.M_2$_{j,t}$.S$_{PG2}$	IN.M_2$_{j,t}$.A$_{PG2}$		
	IN.M_11$_{j,t}$.R$_{PG2}$	IN.M_11$_{j,t}$.T$_{PG2}$	IN.M_11$_{j,t}$.W$_{PG2}$	IN.M_11$_{j,t}$.S$_{PG2}$	IN.M_11$_{j,t}$.A$_{PG2}$		
	IN.M_1$_{j,t}$.R$_{PG15}$	IN.M_1$_{j,t}$.T$_{PG15}$	IN.M_1$_{j,t}$.W$_{PG15}$	IN.M_1$_{j,t}$.S$_{PG15}$	IN.M_1$_{j,t}$.A$_{PG15}$	Form of cargo	
	IN.M_2$_{j,t}$.R$_{PG15}$	IN.M_2$_{j,t}$.T$_{PG15}$	IN.M_2$_{j,t}$.W$_{PG15}$	IN.M_2$_{j,t}$.S$_{PG15}$	IN.M_2$_{j,t}$.A$_{PG15}$		
	IN.M_11$_{j,t}$.R$_{PG15}$	IN.M_11$_{j,t}$.T$_{PG15}$	IN.M_11$_{j,t}$.W$_{PG15}$	IN.M_11$_{j,t}$.S$_{PG15}$	IN.M_11$_{j,t}$.A$_{PG15}$		

(j – index of the service provider; t – index of the adopted unit of time characterizing the seasonal nature)

The table $[OUT.M – TM]_{j,t}$ has a similar form.

Mutual relation between these tables is illustrated by Figure 4.

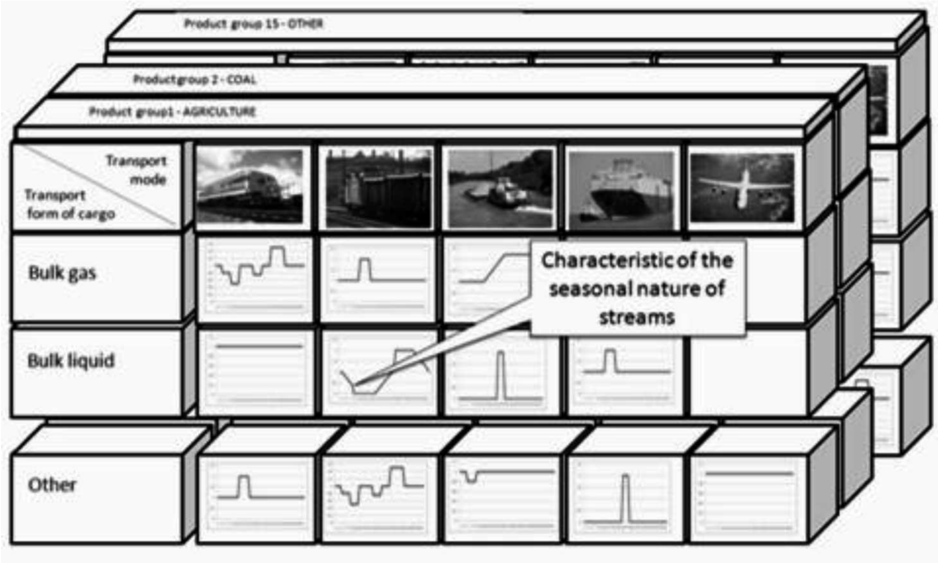

Fig. 4. Structure of input (output) tables – $[IN.M\text{-}TM]_{j,t}$ and $[OUT.M\text{-}TM]_{j,t}$ for the service provider "j" [6]

For each of the distinguished "t" periods, the sum of input streams as part of the *i*th product group for *k*th transport mode to all ***nsp*** service providers of the LC centre must equal the sum of input streams from all nodal points of the network surroundings (NP) of the centre:

$$\sum_{j=0}^{nsp} [IN.M - TM]_{j,t} = \sum_{m=1}^{9} \sum_{i=1}^{NNP_m} \left[(NP_m)_i - IN.M; LC\right] \qquad (5)$$

where:

m – index determining the type of network node, as in the equation (3),

- NNP_m – the number of nodal points of *m*th type of a network node in the network surroundings of the LC centre

Likewise, the following relation must occur for the output streams:

$$\sum_{j=0}^{nsp} [OUT.M - TM]_{j,t} = \sum_{m=1}^{9} \sum_{i=1}^{NNP_m} \left[LC; (NP_m)_i - OUT.M\right] \qquad (6)$$

3.5. Evaluation of the use of Infrastructure

Such an evaluation necessitates that the relations between the transport mode supporting input and output streams and the components of the infrastructure possessed be determined. Such relations must be specified for every service provider and every product group. Every service provider should have the possibility of using also the infrastructure at the disposal of other service providers. It is proposed that the relation be determined by determining a percentage share of a given element of the infrastructure in the service of the stream under consideration.

For every product stream sent to the service provider P_i (as per the service provider table [TPC]) and within the transport group PG_j (in accordance with [PGV]), we use the transport mode TM_k (as per the table [TM]) and the transport form of the cargo "m" to create tables $[IN\% \ Inf]_{i,j,k,m}$ determining the distribution of this stream within the centre on the infrastructure possessed in the following system: the type of infrastructure ([IPV] vector) – the entity possessing the infrastructure (service provider) – [TPC] (Table 10).

Table 10

Distribution of the input stream over the centre infrastructure

$[IN.\% \ Inf]_{i,j,k,m} =$	$IN.\%\_P_0\_1;$	$IN.\%\_P_1\_1;$	$IN.\%\_P_2\_1;$	…	$IN.\%\_P_N\_1$
	$IN.\%\_P_0\_2;$	$IN.\%\_P_1\_2;$	$IN.\%\_P_2\_2;$	…	$IN.\%\_P_N\_2$
	$IN.\%\_P_0\_3;$	$IN.\%\_P_1\_3;$	$IN.\%\_P_2\_3;$	…	$IN.\%\_P_N\_3$
	………………				
	$IN.\%\_P_0\_nI_0;$	$IN.\%\_P_1\_nI_1;$	$IN.\%\_P_2\_nI_2;$	…	$IN.\%\_P_N\_nI_N$

(Indices: i – of the service provider, recipient of cargo; j – of the product group, k – of the transport mode, m – of the transport form of cargo)

where:
nI_i – number of types of the infrastructure possessed by the *i*th service provider.

For example:

The value of the element $IN.\%\_P_2\_6$ of the table $[IN.\% \ Inf]_{3,13,2,8}$ determines part of the stream of products from the group PG13 − Furniture (j=13) sent to the service provider P_3 (i=3), using rail transport (k=2), in containers (m=8), serviced with handling equipment owned by the service provider P_2. This is illustrated in Figure 5.

A precondition is that the sum of values of all elements for every table $[IN.\% \ Inf]_{i,j,k}$ equals 100%.

On the basis of the set of tables $[IN\% \ Inf]_{i,j,k}$ one must then determine tables $[IN.M \ Inf]_{i,j,k,t}$ specifying in units of measurement (e.g. tonnes) parts of the stream sent to the service provider P_i, as part of the PG_j transport group using the TM_k transport and the transport mode and cargo unit "m" in a given period "t", and supported using the infrastructure at the disposal of various service providers active on the premises of the centre (Table 11 – $[\text{IN.\% Inf}]_{i,j,k,m,t}$).

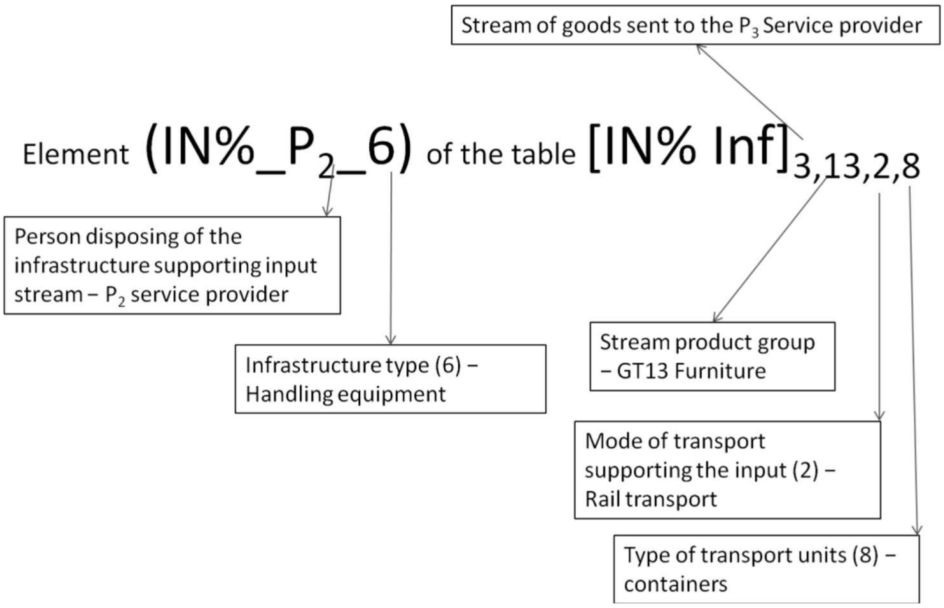

Fig. 5. Illustration of the structure of indexing the table $[\text{IN.\% Inf}]_{i,j,k,m}$ – example [3]

Table 11

Distribution of the input stream over the centre infrastructure possessed taking into consideration the seasonal nature of the streams

$[\text{IN.\% Inf}]_{i,j,k,m,t}$ =	IN.%_P_0_1 $_t$;	IN.%_P_1_1 $_t$;	IN.%_P_2_1 $_t$;	...	IN.%_P_N_1 $_t$
	IN.%_P_0_2 $_t$;	IN.%_P_1_2 $_t$;	IN.%_P_2_2 $_t$;	...	IN.%_P_N_2 $_t$
	IN.%_P_0_3 $_t$;	IN.%_P_1_3 $_t$;	IN.%_P_2_3 $_t$;	...	IN.%_P_N_3 $_t$
	....				
	IN.%_P_0_n$I_{0,t}$;	IN.%_P_1_n$I_{1,t}$;	IN.%_P_2_n$I_{2,t}$;	...	IN.%_P_N_n$I_{N,t}$

(Indices: i – of the service provider, recipient of cargo; j – of the product group, k – of the transport mode, m – of the transport form of cargo, t – of the adopted unit of time characterizing the seasonal nature)

If we assume that x signifies a service provider and y_x a specific type of infrastructure owned by him, then every element (x,y_x) of the table $[\text{IN.M Inf}]_{i,j,k,m,t}$ is calculated as the product of the respective element (n, m) of the table $[\text{IN.\% Inf}]_{i,j,k,m}$ by the respective element (j, k) of the table $[\text{IN.M – RT}]_{j,t}$.

The next step is to determine tables $[\text{IN.u Inf}]_{i,j,k,m}$ presenting individual streams expressed in transport/cargo units, e.g. in the number of containers, carriages, vehicles, pallet cargo units, etc. It is assumed that averaged quantity relations between the mass of the cargo and the number of transport/cargo units will be defined for every transport mode, separately for every product group with the possibility of it being differentiated for various service providers.

It necessitates that conversion factors: mass (in tonnes) – number of transport/cargo units be determined for every element of the centre infrastructure i.e. those at the disposal of all service providers located in the centre, hence for every element of the table [IN.% Inf]$_{i,j,k,m}$ (Table 12).

Table 12

Conversion factors: mass (in tonnes) – number of transport/cargo units

[IN.c Inf]$_{i,j,k,m}$ =	IN.c_P_0_1;	IN.c_P_1_1;	IN.c_P_2_1;	...	IN.c_P_N_1
	IN.c_P_0_2;	IN.c_P_1_2;	IN.c_P_2_2;	...	IN.c_P_N_2
	IN.c_P_0_3;	IN.c_P_1_3;	IN.c_P_2_3;	...	IN.c_P_N_3
	....				
	IN.c_P_0_nI_0;	IN.c_P_1_nI_1;	IN.c_P_2_nI_2;	...	IN.c_P_N_nI_N

(Indices: i – of the service provider, recipient of cargo; j – of the product group, k – of the transport mode, m – of the transport form of cargo, t – of the adopted unit of time characterizing the seasonal nature)

E.g. if the element (IN.c_P_0_1) of the table [IN.p Inf]$_{3,13,2,8}$ equals 2.2, it should be interpreted in the following fashion:

The average mass of a container (m=8) delivered using rail transport (k=2) to the service provider "3" (i=3), containing furniture (j=13) entering through the container terminal belonging to the service provider P_0 (IN.p_P_0_1) equals 2,2 tonnes.

If every element of each table [IN.M Inf]$_{i,j,k,m,t}$ is multiplied by the element of the corresponding table [IN.% Inf]$_{i,j,k,m}$ – the table [IN.u Inf]$_{i,j,k,m,t}$ is obtained (Table 13).

Table 13

Distribution of the input stream over the centre infrastructure possessed taking into consideration the seasonal nature of the streams and expressed in transport units

[IN.u Inf]$_{i,j,k,m,t}$ =	IN.u_P_0_1_t;	IN.u_P_1_1_t;	IN.u_P_2_1_t;	...	IN.u_P_N_1_t
	IN.u_P_0_2_t;	IN.u_P_1_2_t;	IN.u_P_2_2_t;	...	IN.u_P_N_2_t
	IN.u_P_0_3_t;	IN.u_P_1_3_t	IN.u_P_{2-t};	...	IN.u_P_N_3_t
	....				
	IN.u_P_0_nI_0;	IN.u_P_1_nI_1;	IN.u_P_2_nI_2;	...	IN.u_P_N_nI_N

(Indices: i – of the service provider, recipient of cargo; j – of the product group, k – of the transport mode, m – of the transport form of cargo, t – of the adopted unit of time characterizing the seasonal nature)

The relevant tables pertaining to the output streams are defined and calculated analogously for every "i" service provider, "j" product group, "k" transport mode and "m" transport mode and cargo unit.

[OUT.% Inf]$_{i,j,k,m}$, [OUT.% Inf]$_{i,j,k,m,t}$,

and [OUT.M Inf]$_{i,j,k,m}$, [OUT.c Inf]$_{i,j,k,m}$, [OUT.u Inf]$_{i,j,k,m}$

Table 14 shows loads of the infrastructure supporting output streams split into "t" periods in the system service provider – infrastructure possessed (in the relevant transport and cargo units):

Table 14

Loads of the infrastructure supporting output streams split into "t" periods in the system service provider – infrastructure possessed

[OUT.u Inf]$_{i,j,k,m,t}$ =	OUT.u_P$_0$_1$_t$;	OUT.u_P$_1$_1$_t$;	OUT.u_P$_2$_1$_t$;	…	OUT.u_P$_N$_1$_t$
	OUT.u_P$_0$_2$_t$;	OUT.u_P$_1$_2$_t$;	OUT.u_P$_2$_2$_t$;	…	OUT.u_P$_N$_2$_t$
	OUT.u_P$_0$_3$_t$;	OUT.u_P$_1$_3$_t$	OUT.u_P$_2$_3$_t$;	…	OUT.u_P$_N$_3$_t$
	………………………………………………………				
	OUT.u_P$_0$_nI$_{0,t}$;	OUT.u_P$_1$_nI$_{1,t}$;	OUT.u_P$_2$_nI$_{2,t}$;	…	OUT.u_P$_N$_nI$_{N,t}$

(Indices: i – of the service provider, recipient of cargo; j – of the product group, k – of the transport mode, m – of the transport form of cargo, t – of the adopted unit of time characterizing the seasonal nature)

Both sets of tables: [IN.u Inf]$_{i,j,k,t}$ and [OUT.u Inf]$_{i,j,k,t}$ will serve to calculate the total load [TL.u Inf]$_{LC,t}$ of all elements of the centre infrastructure expressed in the relevant units, split into adopted periods of the seasonal nature.

For every period "t", every element (m, n) of the table [TL.u Inf]$_{LC}$ (n – service provider index, m – infrastructure type index) the following is calculated:

$$\left([\text{TLI. u Inf}]_{\text{LC,t}}\right)_{\text{x, y}} = \sum_{i=0}^{nsp} \sum_{j=1}^{nPG} \sum_{k=1}^{nI} \sum_{m=1}^{11} \left(\left([\text{IN. u Inf}]_{\text{i,j,k,m,t}}\right)_{\text{x,y}} + \left([\text{OUT. u Inf}]_{\text{i,j,k,m}}\right)_{\text{x,y}}\right)$$

The next step is to calculate the average daily load for every "t" period and for every element of the infrastructure. Hence, the conversion factor determining the number of days per the assumed period (ndp) must be specified. For example, for a weekly period ndp = 6 (assuming Sundays are days off work). The table of daily loads of the infrastructure [DTL.u Inf]$_{LC,t}$ can be calculated from the formula:

$$[\text{DTL.u Inf}]_{\text{LC,t}} = \frac{[\text{TL.u Inf}]_{\text{LC,t}}}{\text{ndp}}$$

Tables [DTL.u Inf]$_{LC,t}$ can be used to evaluate the degree of infrastructure use. For this purpose the best solution is to build a table of available infrastructure for the whole centre [IPV]$_{LC}$ (Table 15).

The merger of tables [DTL.u Inf]$_{LC,t}$ and table [IPV]$_{LC}$ gives a set of tables of the infrastructure load factors [FTL]$_{LC,t}$ (Table 16).

Table 15

Permissible daily load volumes of individual components of the centre infrastructure

$[IPV]_{LC}$ =	$I1\_P_0$	$I1\_P_1$	$I1\_P_2$	…	$I1\_P_N$
	$I2\_P_0$	$I2\_P_1$	$I2\_P_2$	…	$I2\_P_N$
	$I3\_P_0$	$I3\_P_1$	$I3\_P_2$	…	$I3\_P_N$
	…………………………………………………………				
	$InI_0\_P_0$	$InI_1\_P_1$	$InI_2\_P_2$	…	$InI_N\_P_N$

Table 16

Load factors of individual components of the centre infrastructure

$[FTL]_{LC,t}$ =	$\frac{(DTL\_I1\_P_0)_t}{I1\_P_0}$	$\frac{(DTL\_I1\_P_1)_t}{I1\_P_1}$	$\frac{(DTL\_I1\_P_2)_t}{I1\_P_2}$		$\frac{(DTL\_I1\_P_N)_t}{I1\_P_N}$
	$\frac{(DTL\_I2\_P_0)_t}{I2\_P_0}$	$\frac{(DTL\_I2\_P)_t}{I2\_P_1}$	$\frac{(DTL\_I2\_P_2)_t}{I2\_P_2}$		$\frac{(DTL\_I2\_P_N)_t}{I2\_P_N}$
	$\frac{(DTL\_I3\_P_0)_t}{I3\_P_0}$	$\frac{(DTL\_I3\_P_1)_t}{I3\_P_1}$	$\frac{(DTL\_I3\_P_2)_t}{I3\_P_2}$		$\frac{(DTL\_I3\_P_N)_t}{I3\_P_N}$
	…………………………………………………………				
	$\frac{(DTL\_NI\_P_0)_t}{nI\_P_0}$	$\frac{(DTL\_NI\_P)_t}{NDI\_P_1}$	$\frac{(DTL\_NI\_P_2)_t}{NDI\_P_2}$		$\frac{(DTL\_NI\_P_N)_t}{NDI\_P_N}$

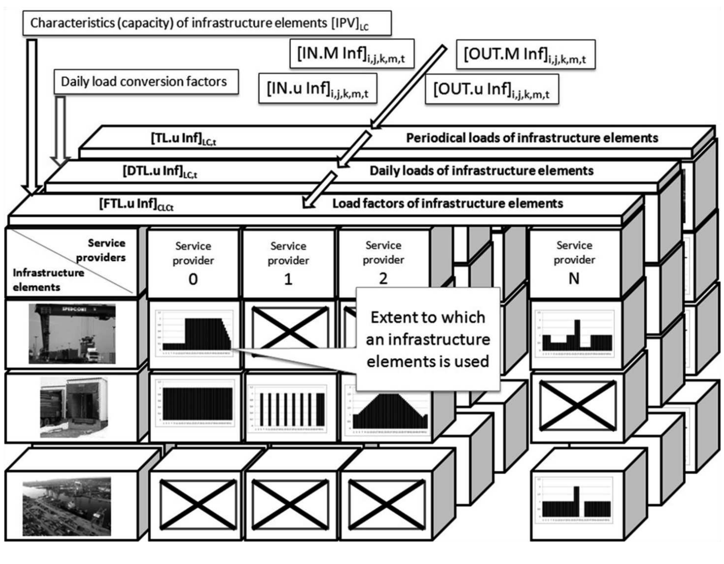

Fig. 6. The steps aimed at creating a table characterizing the extent to which the centre infrastructure is used $[FTL]_{LC,t}$ [6]

The table $[\mathrm{FTL}]_{LC,t}$ may then be presented in a graphic form in different cross-sections, providing important information pertaining to e.g. investment or de-investment needs also from the perspective of a forecast.

Figure 6 illustrates the steps presented above aimed at creating a table characterizing the extent to which the centre infrastructure is used $[\mathrm{FTL}]_{LC,t}$.

3.6. Model Synthesis

Figure 7 illustrates the sequence of defining subsequent tables making up the presented model of relations among them. It formed the basis for developing a tool (application in the EXCEL spreadsheet) allowing any logistics centre to be modelled in accordance with the adopted rules.

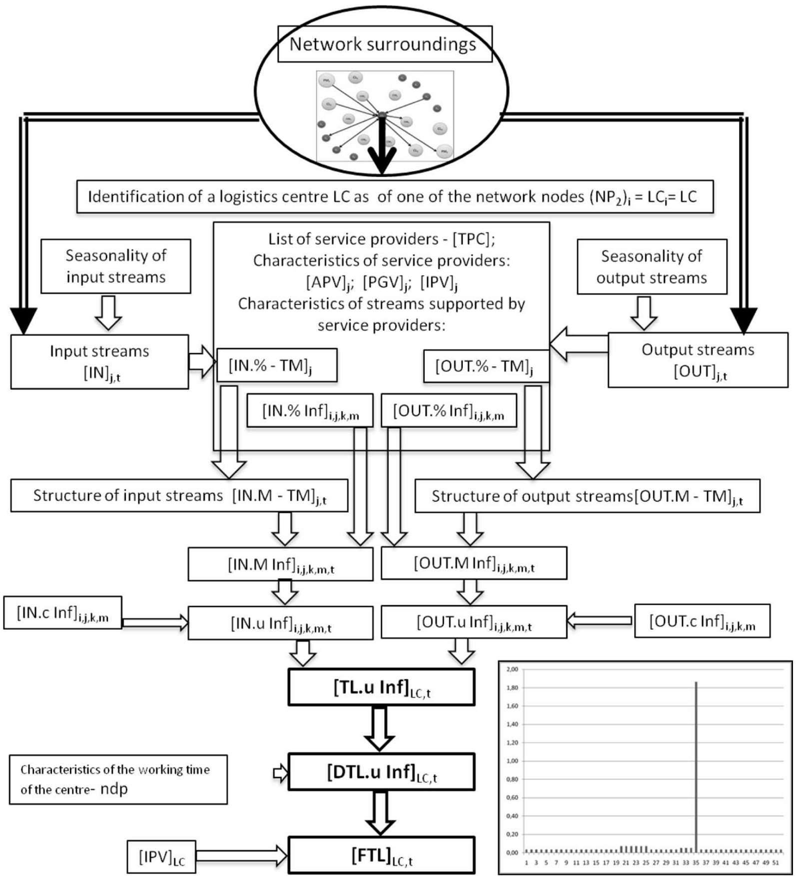

Fig. 7. Model synthesis [3, 6]

4. Summary

The proposed model of a logistics centre, taking into consideration the relations determined when describing it, as an element of the transport and logistics network, makes it possible to:

- Identify and describe the input and output streams at the level of the whole LC centre and every service provider active on its premises, split into product groups, types of transport and loading units supporting these streams and taking into consideration the seasonal nature of such loads (i.e. referenced to a defined period).
- Identify and describe the load of individual infrastructure elements which are at the disposal of service providers active on the premises of the centre with the possibility of evaluating the extent to which they are used. The table $[\mathrm{FTL}]_{LC,t}$ forming the final result of using the model can be presented graphically in different sections providing important information on e.g. investment or de-investment needs also from the perspective of a forecast.
- The proposed approach may be modified as per other information needs (e.g. operation costs, number of employees). It only necessitates that information be supplemented with additional input tables and relations among individual data and their sets be determined.

The quality and suitability of results obtained on the basis of the proposed model depends to a large extent on the quality of input data. A conclusion, however, must be drawn, that even if their limited availability and preciseness is assumed, the results of modelling may form significant support in the process of planning the creation and development of a logistics centre.

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