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The actual structure of the postal transportation network in the chosen postal circuit and the location of the main mail processing and distribution centre in this circuit

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Key words: local mail processing centre, main mail processing and distribution centre, matrix of minimal distances, node, postal transportation network, regional mail processing centre

Abstract

This article discusses the possibility of optimizing a particular postal transportation network within the scope of the main mail processing and distribution centres in Žilina, one of four main mail processing and distribution centres of the national postal operator in Slovakia – Slovenská pošta (referred to here, in English, as the Slovak Post). The authors compare the 3-level model of postal transportation network with the 4-level model of postal transportation network that is currently used in areas other than Žilina. When comparing both models, the authors also takes into account the processing operations of postal items required before the mail is delivered to its addressee – both models accept the technological procedures of processing and handling postal items. In addition, the authors of the presented article solves the allocated task through the construction of the distance matrix to find out if the actual location of the main mail processing and distribution centre and its facilities in the city of Žilina is optimal, from the point of view of transportation distance from this centre and the other supporting processing centres located at the second and third levels respectively within the analysed postal transportation network models.

Introduction

The Slovak Post is a postal provider of the universal (mandatory) and other postal services in Slovakia. It delivers a large number of postal items, carries out a number of cash payment operations and provides other supplementary services on a daily basis. Its main aim is to provide the postal and other services in such a way that the Post is able to satisfy its customers and gain a competitive advantage over its main competitors.

The main business activity and core business of the Slovak Post is, logically, the delivery of postal items. The structure of these core business activities is depicted in the following graph (Figure 1).

Thus, the transportation of these items in a timely and cost-efficient way may be considered as the key issue for the Post, in order to meet the requirements of its customers and its own financial goals. It therefore requires the building of an optimal transportation network including postal lines (postal routes) and a schedule for these lines (while

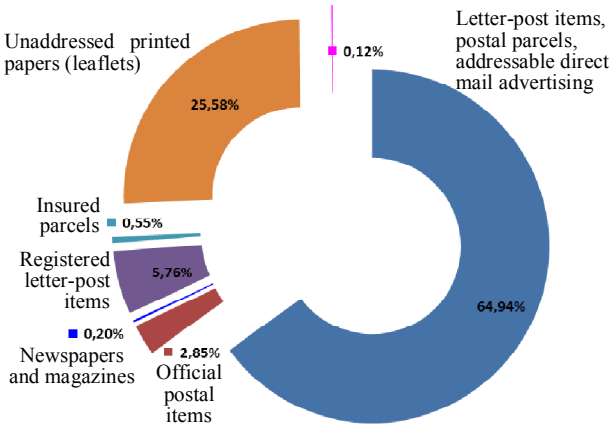

Figure 1. Structure of core business activities of the Slovak Post, a. s. in 2012 (%) [Slovak Post: Internal materials]

accepting the specifics of different types of mail, which entail their own processing requirements e.g. letters, parcels, printed papers etc. in different sizes, weights and different shapes; and that the Slovak Post offers different mail classes (1st Class Letters, 2nd Class Letters etc.) with different standards of delivery (D+1, D+2, etc.)).

Theoretical basis

The postal transportation network (PTN) in general may be characterized as the sum of the postal transportation routes which are connected to each post. It includes all postal routes and transport paths used by postal routes for the purpose of transporting different types of mail (accepting their different characteristics). An appropriate design for the configuration of any PTN model may be affected by several factors, such as the density of the transport network, the organizational arrangement of the PTN (horizontal and vertical organizational structure), geographical segmentation and the size of a given country (Kajánek, Rostašová & Bazík, 1999), as well as the different characteristics of transported postal items and technological processing procedures, as mentioned previously.

Current state

At present, the Slovak Post operates one of the most complex transportation networks in Slovakia. The *postal transportation network* (PTN) of the Slovak Post is currently divided into four main areas or postal transportation circuits, as shown in Figure 2. It is clear that every area is under the control of one of the four *main mail processing and distribution centres* (MMPDC): *Bratislava*, *Žilina*, *Zvolen*, and *Košice*. Each area has its own PTN organization and all PTNs are then interconnected via MMPDCs. The transport of postal items is performed purely via automotive transportation. The only exception is the direct railway connection between the MMPDC Bratislava and MMPDC Košice.

Currently, all the postal circuits except the MMPDC Žilina use the 4-level PTN model. The MMPDC Žilina is the only centre that has been using the 3-level PTM model, for which a testing operation was launched in 2013. As the results of the testing operation were acceptable, this model has been in full operation since January 2014.

On the basis of the above, the main objective of this paper is to determine the effectiveness of the changes to the model and to use the graph theory to verify the proper geographic location of the MMPDC Žilina.

Characteristics of the 4-level model of PTN

The structural model of the 4-level PTN is currently the most widely used variant of mail transportation in Slovakia, which is determined by the current valid methods of postal items processing. As depicted in Figure 3, the first level of this model is built up by *nodes* represented by units, which are

Figure 2. Main mail processing and distribution centres (MMPDCs) and the areas covered within their scope [authors' adaption of the existing centre framework]

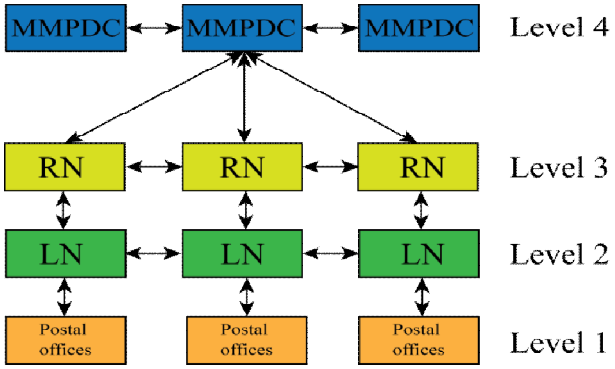

Figure 3. Postal item transportation (direction of mail flows intended for processing) in the case of the 4-level PTN model [authors' adaptation of the existing transportation framework]

similar to posting and delivery post offices. These nodes (posting and delivery post offices) then have direct transport connections with second levels nodes – the so called *local nodes* (LN) or *local mail processing centres* and represent local supporting mail processing nodes. These nodes are then connected with the *regional mail processing centres* (RPC) by postal lines, in other words with the nodes of the third level – *regional nodes* of the described model. All nodes of the second and third level represent post offices mandated with specific functions in the mail processing and handling, but the range of their tasks and responsibility differ from one another (the regional processing centres perform mail processing activities, which do not belong within the scope of the local processing centres).

The top of the 4-level PTN is represented by a MMPDC. In Slovakia, as previously mentioned these centres are: MMPDC Bratislava, MMPDC Zvolen and MMPDC Košice, which are directly linked with regional processing centres by postal lines and are responsible for the other levels of mail processing (processing of postal items from the regional processing centres that belong within their territorial scope). All these MMPDCs including MMPDC Žilina (the top of the 3-level PTN) are then linked to each other by the PTN and the existing postal lines (the connection has a complete polygonal connection), thereby the transportation of all postal items is ensured between all four postal circuits, as well with foreign countries.

The postal nodes at all levels are equipped with the appropriate facilities and resources (personal, financial), competences, responsibility and duties. The fact also remains that the nodes situated at the same level area of an equal position and in the top to bottom (and vice versa) hierarchy they have a subordinate and superior relationship. It is also the case that any postal node located at a higher level can perform the tasks of the node located at a lower level, but only if the node is located in the same area of the MMPDC. This multiple level radial network with additional cross-linking is characterized by manual or automatic processing of mail items (Čorejová et al., 1995).

Characteristics of the 3-level PTN

The following variant of the 3-level PTN model is currently used only in the area which falls within the scope of the activities of the MMPDC Žilina. It officially began operation in January 2014 after a successful test operation. In the case of this model, the PTN and postal item processing consists of three levels (Figure 4). The first level of this model is equal to the first level of the 4-level PTN model. A significant difference occurs in the second level, which is represented by the *local supporting nodes*. In the case of this model, these local nodes were merged with 8 *regional nodes* (the first column of Table 1) – regional processing centres located at the third level of the PTN – and took over their function in mail processing. In this way the 3-level PTN was created but with 17 local second level processing nodes (centres), which fell within the responsibility of the MMPDC Žilina, as shown in the table below.

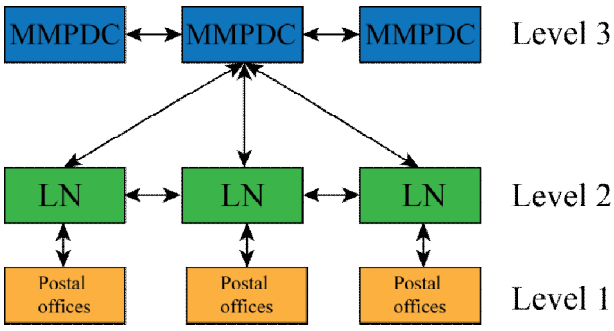

Figure 4. Postal item transportation (direction of mail flows intended for processing) in the case of the 3-level PTN model [authors' adaptation of the existing transportation framework]

Consequently, it was necessary to make the appropriate changes to the regional PTN, specifically to the postal lines and their schedules. The main task, resulting from the merger of the second and third level of the PTN in the Žilina circuit, was to reconsider the existing, or to create new, direct transport connections between the processing centres of the second level and the MMPDC Žilina, and also between the single post offices at the first level and the processing centres. In addition, the other (no less significant) aim was to simplify the separation process of postal items which would be

Table 1. Merger of local nodes and regional processing centres in the Žilina region [Slovak Post: Internal materials]

Ex-regional processing centres (RPC)	Actual local processing centres (LPC)
Trenčín (TN)	Trenčín (TN)
Ružomberok (RK)	Ružomberok (RK)
Púchov (PU)	Púchov (PU)
Liptovský Mikuláš (LM)	Liptovský Mikuláš (LM)
	Liptovský Hrádok (LH)
MMPDC Žilina (ZA)	MMPDC Žilina (ZA)
	Bytča (BY)
Čadca (CA)	Čadca (CA)
	Kysucké NovéMesto (KNM)
Martin (MT)	Martin (MT)
	Turčianske Teplice (TR)
Považská Bystrica (PB)	Považská Bystrica (PB)
	Nová Dubnica (ND)
	Ilava (IL)
Dolný Kubín (DK)	Dolný Kubín (DK)
	Tvrdošín (TS)
	Námestovo (NO)

Note: In the case of postal item processing within the city of Žilina, all mail is transported directly to the facilities of the MMPDC Žilina.

needed to support an increase in the capacity utilization of vehicles, by reducing the amount of different positions in the regional PTN and reducing the number of transport containers needed for open positions in connection with the postal item processing and sorting process. It was therefore necessary to implement the appropriate changes in the regional PTN and postal lines, which would be able to support and optimize transport infrastructure – the MMPDC Žilina must ensure a connection between the nodes at all levels (to ensure the postal routes) for all types of postal items in such a way that the postal lines will be directly linked to the technological operation of postal item processing. For this reason, the introduction of the 3-level PTN model should be perceived as a complex problem which needs to be resolved.

Objectives of the research

Due to the transition of the 4-level PTN to the new 3-level PTN in the Žilina circuit, large changes in the structure of the existing PTN and postal item processing were carried out. Therefore it is necessary to determine whether these changes were beneficial.

This paper tries to assess the transformation of the 4-level PTN to the 3-level PTN, primarily from the point of view of the following aspects:

1. *Whether the allocation of the MMPDC in the city of Žilina was the correct decision*. This means testing whether the actual construction of the 3-level PTN with regard to the transport distance of the MMPDC Žilina and the existing processing centres (nodes of the second level) is optimal, where the term "optimal" is understood to mean the minimal transport distance between this main centre and the supporting processing centres. As a complementary task, the authors also set out to discover whether the centralization of the MMPDC in Žilina was also optimal in the case of the previous 4-level PTN (the fifth part of the research paper).
2. *Determining the main positive and negative effects of the introduction of the 3-level PTN* in practice, in the operational area of the MMPDC Žilina, from the perspective of the PTN operation and mail processing operation (based on the data provided directly by the Slovak Post; the sixth part of research the paper).

The first aspect represents a problem of location, which the authors try to solve using the graph theory. The nature of this theory is not discussed in great detail, but the authors point to the appropriate literature which should sufficiently clarify the applied theory to readers.

Results and discussion

Applied methods, the design of the matrix of minimum distances

The authors chose the *sub-optimal method* based on (Plašil & Volek, 1988; Čorejová et al., 1995; Gross & Yellen, 2005) to address the first challenge, which represents the allocation problem. This method involves graphics task solving, and the design of the appropriate graph is among the most important tasks for the solution of the problem of location.

The following graph (Figure 5) points to situations in the case of both models. In the case of the model for the 4-level PTN, the different status between the regional processing centres and local processing centres are highlighted by different colours. With regards to the 3-level PTN, the different colours do not point out the different statuses, because of the merger of functions of the regional and local mail processing centres.

The vertices of the following graph represent the existing 17 individual mail processing centres in the Žilina circuit, including the MMPDC Žilina. In solving the task, the authors do not use weighting criteria for each illustrated node, since the purpose of the location task is to find an ideal position solely on the basis of the distances between the nodes at the graph's vertices. The edges of the graph represent the distance between the vertices.

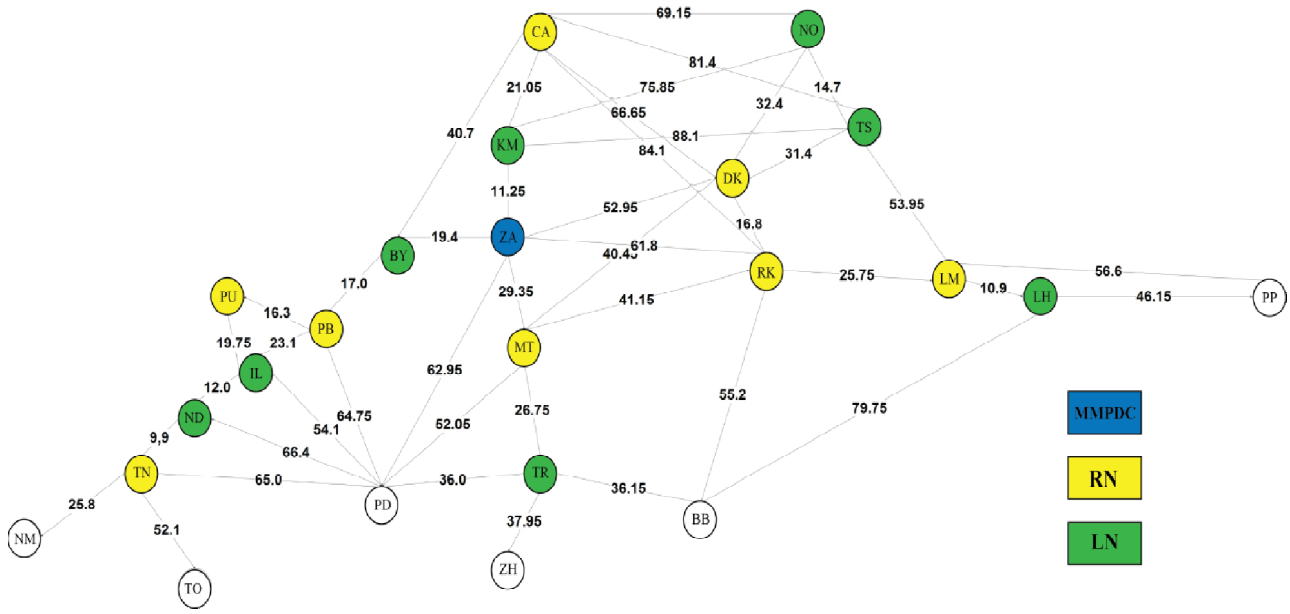

Figure 5. Graph of the PTN falling within the scope of the MMPDC Žilina [authors' adaptation of the PTN]

The exact distances between the nodes are indicated in the graph and they were acquired through the application *Google maps* (variant: the shortest route).

After finding the real distances, *a matrix of direct distances* c^0 (of direct distances between the nodes = direct connection of graph vertexes) was created. To create a complete matrix of minimum distances, *Floyd's Algorithm* was used. This algorithm is based on the initialization matrix of direct distances $c^0 = \{c_{ij}^{\ 0}\}$, where:

a) $c_{ii} = 0$;
b) $c_{ij} = \infty$ if the edge $v_i - v_j$ does not exist;
c) $c_{ij} = l\,(v_i v_j)$ valuation of the edge, if it exists.

Consequently, Floyd's algorithm sequentially generates new matrices $c^k = \{c_{ij}^{\ k}\}$, for $k = 1,2,3,...n$, where $c_{ij}^{\ k} = \min(c_{ij}^{\ k-1}, c_{ij}^{\ k-1} + c_{ij}^{\ k-1})$. Then the matrix created as the last one – matrix $c^n = \{c_{ij}^{\ n}\}$ represents a *complete matrix of minimum distances of local processing centres (in case of the 3-level PTN), respectively regional processing centres (if we consider the 4-level PTN) in the area of the MMPDC Žilina*.

Allocation of the optimal location of the MMPDC in the area of the MMPDC Žilina

Based on the graph that was designed following the determination of the exact distances between the nodes considered and the methods described in the previous part of this research paper, the authors obtained *symmetric matrices of minimum distances* of PTN for both the considered models. The necessary calculations of the matrices were made using the software *MATLAB* and the last iteration of Floyd's Algorithm represent the complete requested matrices of the minimum distances. Following this, it was necessary to calculate the sums of all columns (or rows – the final value must be equal, because of the symmetry of the matrix), where each column (or row) represents one processing facility and the distance to others. The sum of these distances is the total distance to each node of the graph, and the column (or row) with the minimal value represents the optimal position for the MMPDC in Žilina's postal circuit. It is evident therefore, based on these results, that the allocation of the main centre for mail processing in the city of Žilina can be considered optimal.

Table 2. The resulting sums of the minimum distances in the case of the 4-level PTN in the postal circuit of Žilina in kilometres

RPC	DK	RK	LM	MMPDC ZA
∑	552.0	588.1	768.35	**436.0**

RPC	CA	MT	PB	TN	PU
∑	598.5	499.6	531.0	896.0	612.5

Table 3. The resulting sums of the minimum distances in the case of the 3-level PTN in the postal circuit of Žilina in kilometres

RPC	LH	DK	TS	NO	RK	LM
∑	1668.0	1106.7	1464.4	1480.0	1195.7	1504.0

RPC	MMPDC ZA	BY	**CA**	KM	MT
∑	**920.4**	1006.4	1182.1	1038.0	1026.4

RPC	TR	PB	ND	IL	TN	PU
∑	1427.6	1125.0	1515.8	1360.0	1664.0	1310.9

Table 4. List of advantages and disadvantages of the 3-level PTN [compiled and added to by the authors, based on the internal material of the Slovak Post and personal consultations]

Advantages	Disadvantages
in the area of transportation of postal items	
Overall simplification and clarification of PTN Increase the usability of postal road line vehicles (rationalization of postal road routes)	Costs associated with drafting and testing operation
Conditions for the elimination of delays of postal road lines have been created	Changes necessary to postal road lines in the regional postal transport network to ensure the direct transport link between the local processing centres and MMPDC Žilina
in the area of processing of postal items	
Simplification of the process of handling and sorting of postal parcels	Increasing demand for new labour
Unification of routing of bags and freights in postal trucks that helps to simplify the process of dispatching	Increasing requirement for labour skills of existing employees due to shift of certain processes related to the processing and handling of postal items from regional mail processing centres to local ones
Reducing the probability of errors during the process of handling, sorting and dispatching of postal parcels	Increasing of cost of staff training
Creating conditions to increase the volume of processed and dispatched postal items Reducing the workload relating to billing of postal items and freights and achieving efficient distribution of operational loads within the PTN Reducing the workload relating to billing of postal items and freights and achieving efficient distribution of operational loads within the PTN	Problems with the ability to substitute employees at selected local nodes may occur, because handling of postal items and their sorting and dispatching are specific operations

Conclusions

Based on the close cooperation of the Slovak Post and the collected and evaluated data provided by the Post, it may be concluded that the advantages of running the 3-level PTN in the MMPDC Žilina outweigh its disadvantages and, in general, it is considered as more appropriate than the 4-level PTN. For this reason, the testing operation was also transformed. In order to also create a transparent PTN and achieve high quality in any postal item processing, it was approved that the 4-level PTN would be applied in other main mail processing centres – in the MMPDC Bratislava, MMPDC Košice and MMPDC Zvolen.

Although the testing operation of the 3-level PTN in the MMPCD Žilina was not supposed to achieve costs savings as a priority, but to improve existing processes and increase the quality of processes, the financial test evaluation also reveals costs savings as a result of the introduction of the 3-level PTN. Therefore, it seems likely that similar economic advantages can also be expected in the remaining three main mail processing areas. The main advantages and disadvantages of the 3-level PTN are listed in the Table 4.

The subject of the research was also to assess the suitability of the location of the main mail processing centre. Currently, the main centre for mail processing is located in the city of Žilina – the MMPDC Žilina. This was also the case when the 4-level PTN was in operation. The fact that Žilina is the optimal place for the location of the main mail processing centre was also confirmed by the authors' mathematical calculations. This is true for both the PTN models – in the case of the 4-level PTN, the total value of the shortest distances was 436 km, in the case of 3-level PTN, which is characterized by the feature that local processing centres took over the functions of regional processing centres, the value was 920 km.

Based on these results it can be concluded that the launching of the 3-level PTN into the area which falls within the scope of the MMPDC Žilina was successful. In addition to the anticipated improvements in postal item transportation and processing, cost savings were also achieved in comparison to the 4-level PTN. In addition, it was proved that the regional PTN, with the existing postal transport lines, is actually convenient and the location of the main mail processing centre in Žilina is optimal.

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