TRANSPORT PROBLEMS 2017 Volume 12 Issue 3
PROBLEMY TRANSPORTU DOI: 10.20858/tp.2017.12.3.4

Keywords: vehicle routing problem; optimization of postal network; p-median problem

Paweł DROŹDZIEL*, Monika WIŃSKA
Lublin University of Technology, Nadbystrzycka 38 D, 20 – 618 Lublin, Poland
Radovan MADLEŇÁK
University of Zilina, Univerzitná 1, 01026 Žilina, Slovakia
Paweł SZUMSKI
Polish Post, Wacława Moritza 2, 20 – 900 Lublin, Poland
**Corresponding author*. E-mail: p.drozdziel@pollub.pl

OPTIMIZATION OF THE POSITION OF THE LOCAL DISTRIBUTION CENTRE OF THE REGIONAL POST LOGISTICS NETWORK

Summary. The phenomenon of the present postal services is the fact that, customers expect the lowest price while maintaining the availability, security and on time delivery of mail items. We can find that, the costs associated with transport of the postal substrate is one of the most important factors affecting the total cost of the postal services. These transport costs depend on various factors such as the investment in vehicles purchase, operational costs of the postal vehicles (costs of maintenance, repairs, fuel costs of the vehicle, etc.) labour costs of the drivers and so on. For this reason, it is important to find such an operational - organizational solutions that can reduce the costs associated with the transportation of postal shipments, resulting in reducing the total cost of postal services. One option to do this is to minimize the length of postal transportation routes. This article presents the approach based on the application of graph theory to optimize existing connections of postal logistics network. Published results is oriented to revaluate existing position of local centre and find a location for the new local distribution centre potentially. New location of local distribution centre can to optimize (minimize) the total transport costs of the local postal transportation network in area of the Lublin Province.

1. INTRODUCTION

Existing postal transportation system (PTS) represents a group of organizational units (various level) connected to each other. The main objective of PTS system is to deliver postal substrate from the place of sending by sender to the place of receipt by addressee [10]. Every organizational units of PTS have to plan, manage and to control the flow of postal items, while satisfying the customers' demands. Actual demands of postal services customers are associated with the high level of reliability, care and availability of these services, but on the other hand, at a low price.

The most important factor, influencing the total cost associated with providing of mail and parcel services, represents the costs connected with transportation of postal substrate [2]. Total transportation costs depend on many factors, such as purchase price of means of transport, driver's salary, costs of maintenance and repairs, fuel costs etc. [8]. Costs of fuel consumed during the transport of mail consignments depend on the price of the fuel, the intensity of fuel consumption by vehicle engine and length of the carriage route [4]. Therefore, vital from commercial point of view, is finding new ways how to reduce costs related to transportation of postal substrate. One opportunity is minimizing the length of transport routes. As an example how to do it is to optimize of connections in postal logistics network (PLN). This solution is focused to reevaluate old and find a new position of local distribution centre within selected area. This kind of solution would reduce costs of postal transport between post offices within selected area of Lublin region [10].

2. ANALYSIS OF MAIL LOGISTICS SYSTEM OF POLISH POST

National postal operator in Poland is Polish Post (Poczta Polska) and its history has begun in 1558. It is the largest operator at the Polish post services market and it has 8490 facilities (postal offices, sorting centres, PO boxes, etc) within its network. Postal operator (Poczta Polska) is entrepreneur authorized to carry out postal activities on the basis of entry into the register of postal operators, according to Polish Postal Law [11]. Postal facility is an organizational unit of postal operator or a postal agent, where it is possible to conclude a contract for the postal services provision. It is also the place (isolated and marked by the postal operator) where clients can send or receive postal consignment or money from postal order [11].

PTS of Polish Post includes network of facilities, 14 postal distribution nodes (PDN) and auxiliary nodes. This system is providing transport between PDN and inside covering regions of nodes. The nodes and their covering regions represent the organizational units of Polish Post, that consist of sorting plant, which is the central point, and its surrounding. Sorting centre has a central position for all postal facilities in the covering area and they are connected with sorting centre by transportation network. PDNs are the most important facilities in MLS (Post Logistics System) of Polish Post and they fulfil a range of functions, e.g. consolidation and distribution of postal substrate from its subsidiary area, sorting and forwarding or reception of the consignments to/from other areas [4].

Postal distribution node in Lublin is supported by two auxiliary nodes in Radzyń Podlaski and Zamość. PDN located in Lublin covers whole Lublin region and the city itself. Lublin region has 25 122,49 km^2 of area and around 2 115 000 inhabitants. We will focus our analysis on operations in one of the auxiliary nodes areas - local distribution centre located in Radzyń Podlaski. This auxiliary node operates in area of 4 districts: Bialski, Radzyński, Łukowski and Parczewski. Local distribution centre in Radzyń Podlaski covers 6065,44 km^2 wide area with 375 000 inhabitants approximately. These citizens use the services of 46 facilities and their subsidiaries.

Table 1

A list of postal facilities with their assigned number of inhabitants

No	Location	Amount of inhabitants	No	Location	Amount of inhabitants	No	Location	Amount of inhabitants
1.	Biała Podlaska	71 319	17.	Łuków	48 308	33.	Terespol	12 633
2.	Czemierniki	4 497	18.	Międzyrzec Podlaski	27 641	34.	Małaszewicze	1 706
3.	Dębowa Kłoda	3 968	19.	Parczew	14 812	35.	Trzebieszów	7 478
4.	Drelów	5 499	20.	Milanów	4 016	36.	Tuchowicz	482
5.	Jabłoń	3 928	21.	Piszczac	7 381	37.	Stanin	9 833
6.	Janów Podlaski	5 468	22.	Podedwórze	1 706	38.	Tuczna	3 246
7.	Kąkolewnica Wschodnia	8 297	23.	Radzyń Podlaski	24 190	39.	Ulan- Majorat	6 125
8.	Kodeń	3 742	24.	Borki	6 081	40.	Wisznice	5 060
9.	Komarówka Podlaska	4 446	25.	Rokitno	3 097	41.	Sosnówka	2 532
10.	Konstantynów	4 138	26.	Serokomla	4 094	42.	Wohyń	6 970
11.	Leśna Podlaska	4 334	27.	Siemień	4 712	43.	Wojcieszków	7 050
12.	Krzywda	10 710	28.	Sławatycze	2 415	44.	Adamów	4 831
13.	Huta- Dąbrowa	1 426	29.	Jabłeczna	320	45.	Wola Mysłowska	4 880
14.	Okrzeja	1 592	30.	Sosnowica	2 668	46.	Zalesie	4 427
15.	Łomazy	5 109	31.	Stoczek Łukowski	10 761			
16.	Rossosz	2 331	32.	Jedlanka	705			

Table 1 presents the list of facilities in the particular locations of analysed area and amount of inhabitants [10, 12]. Figure 1 presents the area of Poland (Lublin region) where local centre is located in Radzyń Podlaski. The figure shows structure of road infrastructure in this region.

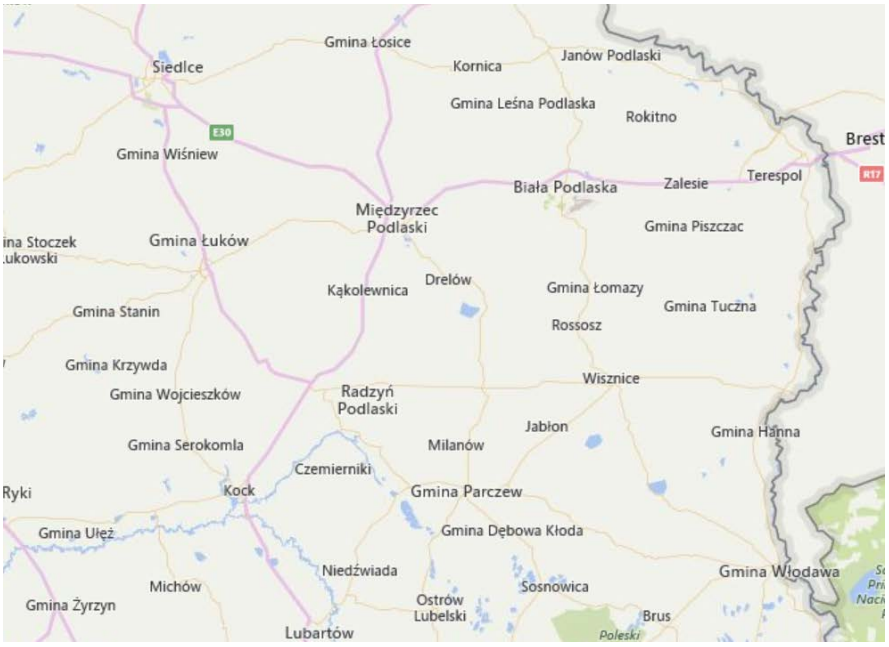

Fig. 1. Road infrastructure of region near Radzyń Podlaski

Many international land transport routes is located at the area of local distribution centre in Radzyń Podlaski (European road route E30 or Expressway S19, and railway line E-20).

The postal routes provided by Poczta Polska in area of Lublin region have the beginning and the end in local distribution centre and goes through every facility, described in Table 1. Figure 2 shows the graph of postal facilities with edges based on existing road infrastructure.

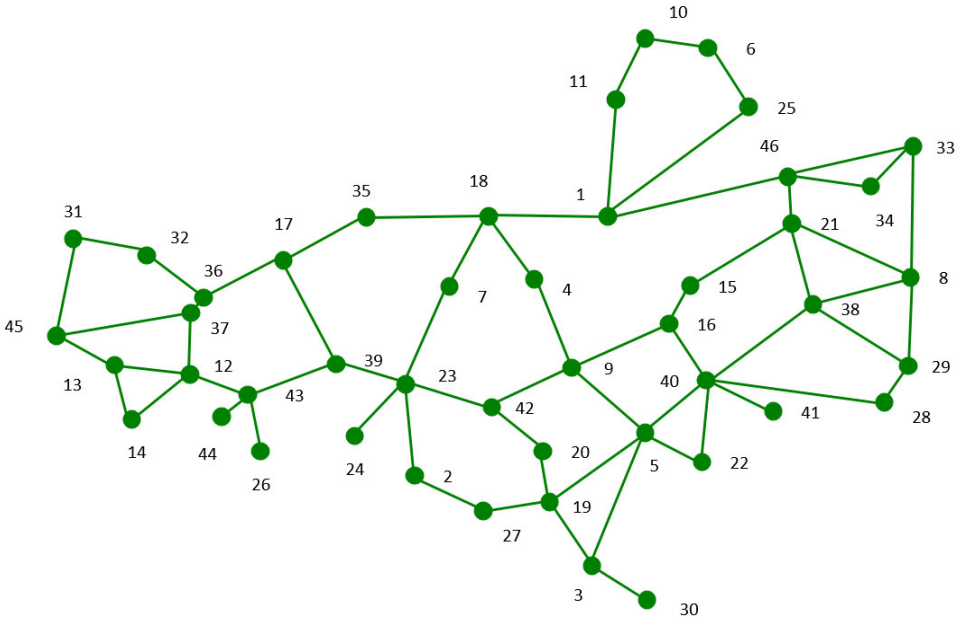

Fig. 2. Graph of postal logistics network for auxiliary node in Radzyń Podlaski (node 23); the numbers of facilities are in compliance with Table 1

On the basis of real situation where we discovered that some of these transportations are repeated, it can be stated that the postal logistics network of Polish Post in the area of local distribution centre Radzyń Podlaski forms Hamiltonian cycle, known from graph theory [3].

3. OBJECTIVES AND RESULTS

In order to check, if the local distribution centre in Radzyń Podlaski has proper location within analysed PTS area of Polish Post, we decided to solve "p-median" location problem [9], known from graph theory. Considering postal logistic network there were used definitions from graph theory to describe particular elements. Thus whole network is presented as a graph, where postal facilities are the nodes of this graph, route from one node to another node are edges and the distances between these nodes are weights of edges in created graph.

The p-median model locates p facilities to minimize the demand-weighted average distance resulting in minimizing of total costs. The cost of serving demands at specific node is given by the demand at node and the distance between demand node and the nearest facility to that node. This problem may be formulated as follows [3]:

Set of inputs:

h_j - demand at node i,

d_{ij} - distance between demand node i and candidate site j,

P - number of facilities to locate,

Decision Variables

$X_j = 1$ if we locate at candidate site j $X_j = 0$ if not

$Y_{ij} = 1$ if demands at node i are served by a facility at node j $Y_{ij} = 0$ if not

Minimize

$$\sum_{i=1}^{n} \sum_{j=1}^{n} h_i d_{ij} Y_{ij} \quad (1)$$

Subject to:

$$\sum_{j=1}^{n} Y_{ij} = 1 \quad \forall i \quad (2)$$

$$\sum_{j=1}^{n} X_j = P \quad (3)$$

The objective function (1) minimizes the total demand-weighted distance between each demand node and the nearest facility. Constraint (2) requires each demand node *i* to be assigned to exactly one facility *j*. Constraint (3) states that exactly *P* facilities are to be located [3]. The "p-median" formulation given above assumes that facilities will be located on the nodes of the network. [3].

Since we are searching for location of single centre, its suboptimal location within analysed area can be obtained by solving 1-median problem, taking into account the following conditions:

- Graph based on road connection between local postal centre and the others postal facilities in the selected area (nodes of graph);
- Value of edge in graph represent distances between nodes of graph, based on network on Fig. 2;
- Weights of nodes are given by amount of citizens (Table 1) assigned to each postal facility (node) [7].

The calculation results have shown that new location of local distribution centre should be in Międzyrzec Podlaski (Fig. 3).

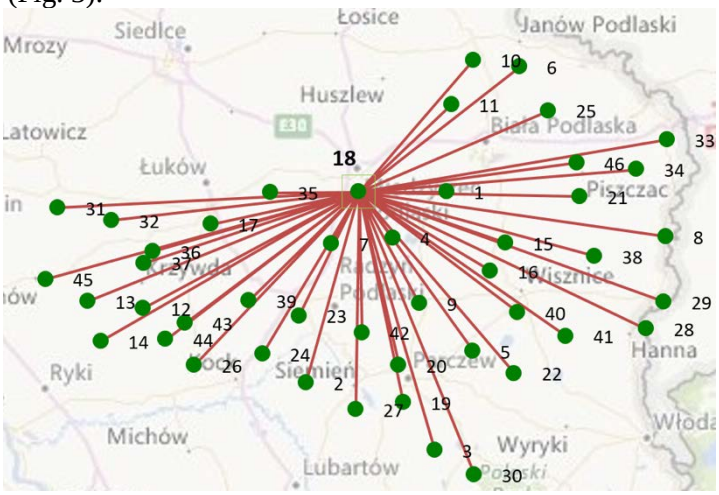

Fig. 3. Location of new local distribution centre in Międzyrzec Podlaski (node number 18)

To extend the achieved solution for p-median problem, we decided to check if the new location would reduce the transportation costs related to transport of postal consignments between the postal facilities. The optimization of transportation routes by solving vehicle routing problems are based on Clarke-Wright algorithm [3]. The actual data of currently operated 20 postal courses within addressed region were taken into account. Data obtained from tables of postal courses include time schedule of postal vehicles departures and arrivals in the main point of postal logistics network (in this case the local distribution centre), the length of travelled distance by vehicles, time of stoppages or other activities in nodes of network, and the average technical speed of vehicles. These data have been used to calculate the solution [10]. Fig. 4 presents the vehicle routing for current centre in Radzyń Podlaski.

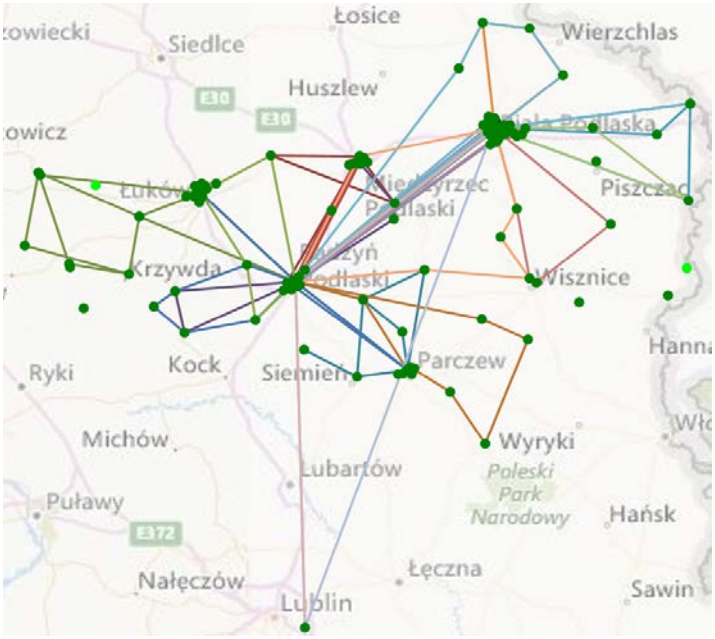

Fig. 4. Visualisation of current postal courses with local distribution centre located in Radzyń Podlaski

To be able to observe the potential optimization, at first is necessary to solve vehicle routing problem for current location of local distribution centre [8]. Then it is compared with vehicle routing problem solution for new proposed location of the centre. Following figures 5 and 6 present calculated routes of individual vehicles crossing all considered facilities of Polish Post within analysed area of

auxiliary dispatch and distribution centre (currently covered by auxiliary node in Radzyń Podlaski), obtained while minimizing the total travelled distance. Fig. 5 displays the optimized vehicle routing results for centre in Radzyń Podlaski. Fig. 6 shows the vehicle routing results when relocating the centre into Międzyrzec Podlaski [10].

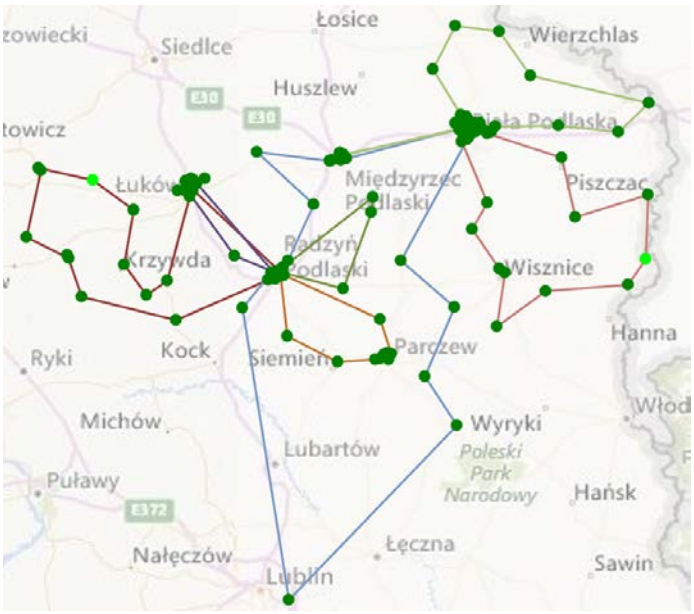

Fig. 5. Visualisation of optimized postal courses with local distribution centre located in Radzyń Podlaski

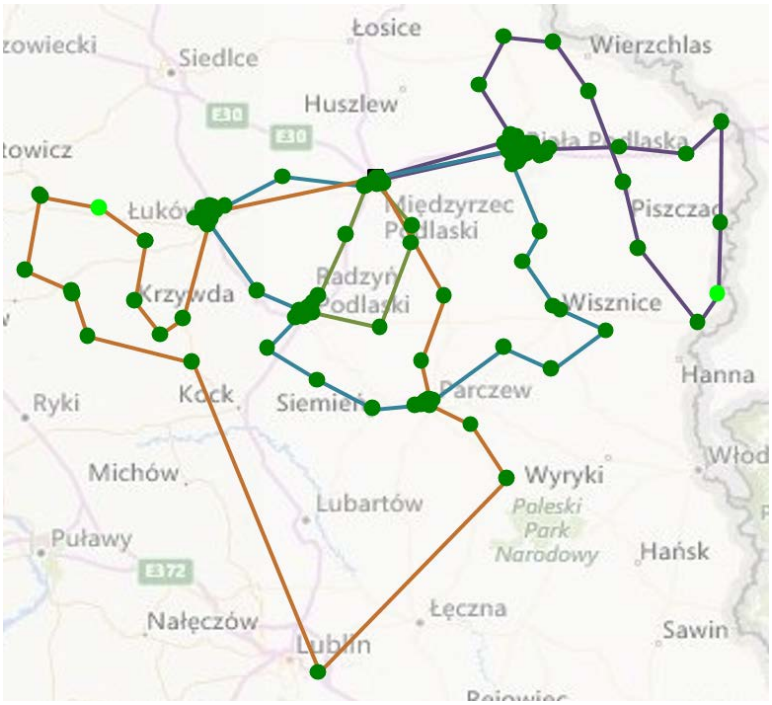

Fig. 6. Visualisation of optimized postal courses with local distribution centre located in Międzyrzec Podlaski

After analysis of results the obtained by optimization, it could be claimed that for operation of 20 courses from current distribution centre of described postal logistics network in Radzyń Podlaski currently they are using 20 vehicles which have to drive about 3935km. After optimization, the same

20 courses from distribution centre in Radzyń Podlaski are operated by 6 vehicles, while for new location of centre (in Międzyrzec Podlaski) only 4. It was also observed that the summarized number of kilometres travelled by all vehicles was reduced thanks to changing the location of auxiliary distribution centre. Such data are presented in Table 2.

Table 2

A list of postal facilities with their assigned number of inhabitants

	Postal route 1	Postal route 2	Postal route 3	Postal route 4	Postal route 5	Postal route 6	Summary
Local distribution centre located in Radzyń Podlaski	64 km	174 km	123 km	300 km	245 km	124 km	1030 km
Local distribution centre located in Międzyrzec Podlaski	87 km	243 km	250 km	366 km	-	-	946 km

4. CONCLUSIONS

The realized research, which was carried out using computer tools based on graph theory, connected with optimization of connections in postal logistics network and aimed to minimizing costs of transporting postal consignments between facilities of Polish Post in Lublin region area. The optimization was realised in two steps. In first step, we revaluated and tried to find new optimized location of local distribution centre in selected region. In second step, we optimized postal transportation routes in that region.

The results of optimization process based on p-median location problem show that it is needed to move the local distribution centre from Radzyń Podlaski to other location - Międzyrzec Podlaski.

Moreover, the new location of the distribution centre results in reduction of needed number of postal routes (represented by postal vehicles used for transportation of postal substrate) and at the same time reducing the amount of kilometres travelled by vehicles during transportations between postal facilities. Such reduction contributes to lowering the costs connected with transport of consignments in the analysed area.

In conclusion, we can state that solution proposed in this article do not take into account additional costs, which would be appeared due to movement of current local distribution centre to proposed location. These additional costs can have a crucial impact on final decision of Polish Post to move local centre to another location.

References

1. Cetiner, S. & Sepil, C. & Sural, H. Hubbing and routing in postal delivery systems. *Annals of Operations Research.* Vol. 181. No. 1. P. 109-124.
2. Corejova, T. & Imriskova, E. Convergence at the postal market. *Eksploatacja i Niezawodność - Maintenance and Reliability*. 2008. Vol. 3. P. 74-76.
3. Daskin, M. *Network and Discrete Location. Models, Algorithms and Applications*. New York: Wiley. 2013.
4. Droździel, P. & Wińska, M. & Madleňák, R. & Szumski, P. Optimization of the post logistics network and location of the local distribution center in selected area of the Lublin province. *Procedia Engineering*. 2017. Vol. 192. P. 130-135.
5. Lisec, A. & Bogataj, M. Optimal allocation of postal logistics centres. *Proceedings of the 10th International Conference on Operational Research*. Trogir. 2004. P. 35-40.
6. Liu, Y.C. & Cheng, G.Q. & Wang, Z. The design and optimization of postal distribution center using a network model. *Proceedings of 10th IEEE Conference on Industrial Electronics and Applications*. Auckland, 2015. P. 575-579.

7. Madlenak, R. & Madlenakova, L. Comparison of regional postal transportation networks in Zilina region. *Transport Means - Proceedings of the International Conference, University of Technology.* Kaunas, 2015. P. 277-280.
8. Sun, L. & Zhao, L.D. & Hou, J. Optimization of postal express line network under mixed driving pattern of trucks. *Transportation Research Part E-Logistics and Transportation Review.* 2015. Vol. 77. P. 147-169.
9. Wasiak, M. O optymalności lokalizacji obiektów metodą sieciową. *Prace Naukowe Politechniki Warszawskiej*. Warszawa. 2011 [In Polish: Wasiak, M. On the optimization of object location by network method. *Scientific works of Warsaw University of Technology*. Warsaw]
10. Wińska, M. *Optymalizacja sieci połączeń wewnątrzwęzłowych na obszarze Województwa Lubelskiego. Diploma thesis.* Wydział Mechaniczny, Politechnika Lubelska. Lublin. 2016. [In Polish: Wińska, M. *Optimization of the intra-lane network in Lubelskie Voivodship. Diploma thesis*. Faculty of Mechanical Engineering, Lublin University of Technology]
11. Ustawa z dnia 12 czerwca 2003 r. - *Prawo pocztowe* (Dz. U. nr 130, poz. 1188). [In Polish: Law of 12 June 2003 - *Postal Law* (Journal of Laws. No. 130, pos. 1188]
12. *Mapa kodów pocztowych*. Available at: www.mapa-kodow-pocztowych.pl [In Polish: *Map of postal codes*]

Received 04.01.2017; accepted in revised form 09.09.2017