Full Length Research Paper

Multi-level postal network for improved efficiency: A case study of Slovenian post

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The purpose of this paper is to analyse the possible improvement in logistics solution of the Post of Slovenia through reorganisation of the hierarchy of the postal system with the introduction of regional postal centres and parcel post, based on the improvement of the transportation between the postal units. The hypothesis is that by changing the spatial hierarchy and allowing retention and transhipment of parcels among hubs at different levels, economies of distribution costs can be achieved. With the introduction of regional parcel centres and parcel posts, the current two-level parcel distribution (postal centres and posts) is reorganised into four-levels, with the objective to overcome problems that arise at the postal logistics centres and to reduce transport costs. The function of the postal logistics centre remains the same. The postal logistics centre continually collect, process and dispatch parcels. The only difference is that the trucks collect and deliver parcels to a greater extent from and to the regional parcel centres. Up to now, they have only collected and delivered parcels from and to smaller post offices. The improvement aims to reduce transport costs at parcel distribution that represent more than 10% of the share of distribution costs (between the initial and final post office). The remainder of the costs includes the collection, redirection and delivery of parcels to the addressee. We will prove that despite the relatively small percentage of transport costs, the savings could indeed be great due to parcel separation in the area covered by the Postal Logistics Centre, Ljubljana. The solution to the system at four levels indicates lower transport costs where additional fixed costs for introducing regional parcel centres are included.

Key words: Postal system, distribution hierarchy, postal logistics centre, regional parcel centre, logistics.

INTRODUCTION

This paper deals with the optimization of parcel logistics. The distribution of parcels is based on a hierarchical postal network. The paper presents process of decision making related to the hierarchical structure inside postal network and to the determination of the optimal routes between postal units at different levels. For the most effective operation of companies that deal with parcel transportation, a decision on the following issues needs to be made (Ting et al., 2008):

i. Deter-mination of types of postal units and the hierarchical relationship between them;
ii. The location of postal units;
iii. The allocation of routes connecting postal units.

New technologies in postal traffic are enabling the modernization of postal systems and logistics in such systems, and dictating the use of mathematical optimization models in a strategic sense (for example, taking into account the location and capacity of objects in a postal network) as well as in an operative sense (for example, taking into account the management of 'time windows' as temporal intervals during which a service is completed) (Mason et al., 2007). Businesses strive to reorganize their operations in order to cut their costs and hence, maintain or even improve the level of their services (Boronico, 1999).

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When solving optimization problems at the strategic level, the question of the location and capacities of its facilities in postal logistics systems as well as the routes of these spatial networks arise (Chopra and Roberts, 2001; Simchi-Levi et al., 2003). The same goes for parcel services. In all Posts we need to achieve:

i. An effective collection and sorting of parcels;
ii. A reliable delivery;
iii. An effective and efficient transport.

The criterion functions require that the total sum of logistic costs in this service of parcels should be minimal, often under certain capacity constraints. In Switzerland, as well as in other Central European countries, the problem of postal hub location has been studied and presented as vital for efficient postal logistics in quite a few papers. Hierarchical hub location problems are well discussed and reviewed in the theory and practical applications of O'Kelly (1987), Campbell (1994), Bruns et al. (2000), Marin (2004), Ernst and Krishnamoorthy (1996), Skorin – Kapov et al. (1996).

Successful parcel service application of postal services model is to be found at Swiss post, described in Bruns et al. (2004), which deals with restructuring the parcel service network, and with choosing transhipment points among the nodes in the network. They used a discrete facility location model. Hub transportation network for parcel delivery service in Austria is described in the paper of Wasner and Zapfel (2004), where an integrated three level multi-depot hub-location vehicle routing model for network planning of parcel service in Austria is mentioned. Wasner and Zapfel (2004) described in their paper why the optimal design of depot and hub transportation networks for parcel service providers makes it necessary to develop a generalized hub location and vehicle routing model. Using a hierarchical model, they searched for an optimal number of depots among potential locations for the Austrian parcel service (searching the shortest sum of lines of all cycles in hierarchical structures of the Austrian postal system). Ernst and Krishnamoorthy (1996) provided a numerical example of Skorin – Kapov et al.'s (1996) model on the Australian Post data set for the incapacitated single allocation p–hub median problem for only 25 nodes (reduction from 200 nodes). They consider uncapacitated multiple and single allocation p-hub median problem.

Ebery et al. (2000) described the capacitated multiple allocation as the hub location problem and developed a new mixed integer linear programming formulation for the problem. They constructed an efficient heuristic algorithm, using shortest paths. This paper is based on a revised version of the Ebery et al.'s (2000) model that deals with the flow of shipments from the initial phase through the centre/or between centres to the end consumer. The original model has been expanded for the needs of optimal parcel logistics with parcel distribution at various levels. Here, the separation of dispatches at various levels with the aim of retaining parcels for one's own area is considered, although this was not the case in the model on which this study is based. Therefore, our research question is, what is the impact of the number of hierarchical levels, which determines the possibilities for separation of dispatches and transhipment at various levels, on the efficiency of the transport network? Our hypothesis is that by changing the spatial hierarchy and allowing retention and transhipment of parcels among hubs at different levels, economies of transport cost can be achieved.

To give answer to this research question, the basic concept of Ebery et al.'s (2000) model is used to evaluate a four-level distribution of parcel delivery. Our paper aims to upgrade their approach to evaluate the flows between Postal Logistics Centres - PLC and Regional Parcel Centres - RPC patronizing the given set of Parcel Posts - PP. In our approach, the number of chosen PPs and RPCs has its upper limit and is chosen among the existing posts as the potential central places in spatial hierarchy. It depends on the volume of parcel flow coming from or going to a certain RPC per day and can increase by increasing volume of parcel flow.

The purpose of this paper is to analyze the possible improvement in logistics solution of Post of Slovenia through reorganization of the hierarchy of the postal system with the introduction of regional postal centres and parcel post and based on that through improvement of the transportation between the post units. The economy of scale achieved by the 4-level structuring of hubs in central places of different levels as nodes is analyzed for the case of Post of Slovenia delivery service with the expansion of the results of Ebery et al. (2000). With the introduction of regional parcel centres and parcel posts, the current two-level parcel distribution (postal logistics centres and posts) is reorganized into a four-level one, with the objective to overcome problems that arise at the postal logistics centres and to reduce transport costs.

The function of the postal logistics centre remains the same. The postal logistics centre continues collecting, processing and dispatching parcels. The only difference is that the trucks collect and deliver parcels to a greater extent from and to the regional parcel centres. Up to now, they have only collected and delivered parcels from and to smaller post offices.

The improvement aims to reduce transport costs at parcel distribution that represent more than 10% of the share of distribution costs (between the initial and final post office). The remainder of the costs includes the collection, redirection, and delivery of parcels to the addressee. We will prove that, despite the relatively small percentage of transport costs, the savings could indeed be great due to parcel separation in the area covered by the Postal Logistics Centre Ljubljana. The solution to the 4-level system indicates lower transport costs where additional fixed costs for introducing regional parcel centres are included.

RESEARCH DESIGN AND METHOD USED

The article critically examines the idea of introducing regional parcel centres and parcel posts along with the optimal organization of parcel distribution. A postal logistics centre is a collection centre collecting parcels from regional parcel centres and parcel posts so the economic efficiency of the entire transportation system can be achieved. The postal logistics centre encompasses the volume of parcels from specific points of demand. All points of demand form part of the regional parcel centre as well as the postal logistics centre. The key to the quality and rational distribution of parcels includes an optimal location of postal logistics centres, regional parcel centres and parcel posts. The hierarchical transport network has to be built, connecting Posts, Parcel Posts, Regional Parcel Centres and Postal Logistics Centres, where the total costs of daily transhipment of all parcels would be minimal. The number of vehicles used for transportation of parcels has to be determined; the same goes for the timetable for the collection and delivery of mail.

The highlighted problems are those that are emerging during the processes of improving parcel distribution at the Post of Slovenia. Such problems are solved with the help of various models adopted by contemporary authors (Ebery et al., 2000; Bruns et al., 2000).

We use the results of Ebery et al. (2000), adding the additional function named "sorting and retention" for the local area on all levels of hubs. We describe the 4–level hub location problems with Posts, Parcel Posts, Regional Parcel Centres and Postal Logistics Centres. The developed 4-level model is not directly tested, because of its complexity; however, the solution with the 4-level hierarchy has been tested for the case of Post of Slovenia. With this, we tested the impact of the change in the number of hierarchical levels on the efficiency of the transport network.

As an example of the application of developed 4-level model, a solution to the problem of optimal flows of parcel distribution at the Post of Slovenia is given. Regional parcel centres and parcel posts are chosen based on limitations – set in advance – of the number of collected and delivered parcels. Posts on the level of local communities, patronizing a certain area, have to be assigned to the proper Parcel Post. The optimal routing problem is separately determined for each Parcel Post, giving services to the local area. As the spatial area of local communities is determined by legislation, the routing problems of each local area are of small size even in cases when two or three areas are compound.

The paper provides an optimization procedure for the area covering the Postal Logistics Centre, Ljubljana. Taking into account the existing postal logistics centres (Ljubljana and Maribor) and the combinatorial programming of optimization, the optimization problem of locating regional parcel centres in the area covered by PLC Ljubljana is examined and solved in a similar way to what was suggested by the authors of the article, Restructuring of Swiss Parcel Delivery Services (Bruns et al., 2000). Parcel post offices are determined on the basis of pre-set limitations for the number of collected and delivered parcels (based on statistical data for ten years and on the analysis of shipment flows). Individual post offices are assigned to the parcel offices based on the shortest route length (Lisec et al., 2005). Then, through application of the algorithm, the postal timetable is optimized (Zmazek et al., 2005).

DESCRIPTION OF THE CURRENT LOGISTICS OF THE POST OF SLOVENIA

Post offices accept mail throughout the day. Mail is taken from there to one of the two postal logistics centres in Slovenia, using designated trucks at least once a day. Today, there are two postal logistics centres in Slovenia,

one in Ljubljana and the other in Maribor. The two logistics centres in Ljubljana and Maribor process and redirect the mail. An exchange of mail between the two centres also takes place at night. In the morning, mail is dispatched from both logistics centres to individual post offices. Trucks from bigger post offices deliver mail to some smaller ones. Postmen then deliver the mail to their correct addressees.

Each shipment is transported by a vehicle at least two times: from the collection post to the PLC and from the PLC to the addressee. Hence, mail is transported on various routes:

i. From the sender to the post office;
ii. From the post office to the PLC (sending mail from the post office to the PLC);
iii. From the PLC (Ljubljana or Maribor) to another PLC (Maribor or Ljubljana);
iv. From the PLC to a post office (arrival of mail from the PLC to the post office);
v. From the post office to another post office (for smaller post offices a small delivery vehicle delivers mail to the bigger ones, smaller remote posts collect mail in the early hours or deliver it to the bigger post offices in the afternoons or evenings);
vi. From the post office to the addressee; and
vii. From abroad to the PLC and vice versa.

The existing logistics concept is based on the concentration of all collected parcels at both postal logistics centres, in Ljubljana and Maribor, where they are directed and sent to the relevant post offices along with the rest of the mail. These means that all of the parcels collected in Slovenia are directed either to Ljubljana or/and Maribor. Parcels that are collected at postal units in Maribor, Celje and Murska Sobota are brought to the PLC in Maribor, parcels that are collected at the postal units in Ljubljana, Kranj, Nova Gorica, Koper and Novo mesto are brought to the PLC Ljubljana. The latter case will be introduced and studied in more detail. The highest number of shipments (some 70%) is collected and transported from the Postal Logistics Centre in Ljubljana on a daily basis. Data were only collected for this area covering two-thirds of Slovenia.

Previous case studies by Lisec (2004) and Lisec et al. (2005a) have proven that dividing Slovenia into two PLC areas is still adequate, considering the volume of mail and parcel deliveries, however, the increased volume of services already calls for certain changes due to predictions of greater mail flows in the next few years.

The current logistics concept suggests that the two postal logistics centres are facing the following problems:

i. An insufficient number of available vehicles at peak times;
ii. An insufficient number of available drivers at peak times;
iii. The consistency in assurance of delivery deadlines D+

Table 1. Costs of vehicles used at the Post of Slovenia.

Costs in €/vehicle type	TV	SDV	LDV
Maintenance	8720.08	2049.62	1480.96
Depreciation	3192.86	1237.87	767.84
Insurance	2071.04	806.74	556.57
Registration	397.82	141.94	144.63
Other costs	5016.70	219.26	72.22
Total per vehicle per year	19 398.50	4455.41	3022.23
Total per vehicle per day	64.66	14.85	10.07

Source: Internal materials of the Post of Slovenia.

1 (if it is collected today that means it is delivered tomorrow), especially for big-sized parcels;
iv. inadequate space (for manipulations and inter-phase warehousing) in a PLC; and
v. the inadequate spatial capacity of vehicles at the first and the second transport level.

In 2004, problems in providing the 'just-in-time' transportation of parcels to post offices started piling up. Due to the low capacities on scheduled routes, the postal logistics centres frequently provide special transportation for the rest of the mail. This has led to an increased number of damaged and/or lost parcels. Due to growth trends, it has become increasingly difficult to provide a good delivery service for parcels within the D + 1 deadline, based solely on improvements accepted within the current logistics system. Due to the increased volume of parcels, both postal logistics centres struggle to direct and deliver all parcels in time. Problems already exist and will continue, especially with regard to the carrying out of services to meet particular deadlines. That is why it is necessary to reorganize parcel distribution.

CALCULATION OF TRANSPORT COSTS FOR THE POSTAL LOGISTICS CENTRE LJUBLJANA WITHIN THE CURRENT LOGISTICS FRAMEWORK

At the Post of Slovenia, trucks, middle-sized delivery vans and smaller delivery vehicles are used to distribute parcels. When calculating transport costs, trucks of various capacities, ranging from the biggest to the smallest, are taken into account in accordance with the existing timetable.

The timetable schedule consists of 68 routes operated by 35 trucks. The number of kilometres covered by them every day according to the timetable is 11 231. In addition, on average, an extra 1998 km are added every day due to emergency journeys. Therefore, the total distance covered by the trucks is 13 229 km a day. In the model, four additional trucks were also considered for emergency journeys. Altogether, 39 trucks of various capacities need to be taken into consideration.

29 middle-sized delivery vans cover 3514 km daily, whereas 57 light delivery vans cover 2274 km during the collection and delivery of parcels between individual post offices at the lowest level (delivery to and collection from individual post offices). The total distance covered is 19 017 km a day. The distribution of mail between individual post offices within Ljubljana, Kranj, Nova Gorica, Koper and Novo mesto was excluded from the calculation. The same will also be considered later on when transport costs in the new improved transfer mode are calculated.

Fixed and variable costs of transport were considered separately in the cost analysis. Maintenance costs, depreciation, insurance, registration and other miscellaneous costs of a vehicle and driver fall under fixed costs. The average cost of a worker includes: net salary, tax, food, transport costs, reimbursements, pension insurance, income tax, the '13th month's payment' and Christmas bonus. Fuel is recorded under variable costs. Altogether, a worker costs € 23 126.07 per year. On average, a worker costs € 77.09 per day (for 12 months and 25 working days a month, leave included). Fuel costs depend on the amount used: for truck vehicles (TV) – the use of diesel is 21.8 L per 100 km, for middle-sized delivery vans (SDV) 8.17 L and for light delivery vans (LDV), where the Euro super 95 motor fuel is used, the fuel consumption is 8.05 L per 100 km. Fuel consumption is proportional to the length of the journey.

Information about the vehicle maintenance costs is taken from an analysis of the fleet of trucks of the Post of Slovenia for one year. The results are shown in Table 1. The cost analysis of the existing transport mode can be seen in Table 2. Fewer workers are needed for middle-sized and light delivery vans as they also work on other tasks such as delivering parcels to addressees. This will also be taken into account when analyzing the number of drivers in the new system. Total transportation costs are calculated as follows:

$$c = FC_{TV} \cdot N_{TV} + FC_{SDV} \cdot N_{SDV} + FC_{LDV} \cdot N_{LDV} + FC_{voz} \cdot N_{voz} + VC_{TV} \cdot KM_{TV} + VC_{SDV} \cdot KM_{SDV} + VC_{LDV} \cdot KM_{LDV}$$

where: FC: fixed costs of individual vehicles (TV, SDV,

Table 2. Cost analysis of the current transportation mode.

Vehicle	Fixed costs of a vehicle per day (€)	Fixed costs of a driver per day (€)	Variable costs (€/km)	No. of vehicles	No. of drivers	No. of km per day
TV	64.66	77.09	0.20	39	72	13 229
SDV	14.85	77.09	0.08	29	22	3514
LDV	10.07	77.09	0.08	57	15	2274
Total number of km per day						19 017

Source: Internal materials of the Post of Slovenia.

LDV) per day; N: number of vehicles; FC_{voz}: fixed costs of drivers per day; N_{voz}: total number of drivers; VC: variable costs of individual vehicles per day; and KM: number of driven kilometres per day.

Total costs of all shipment deliveries (parcels and letters) of the existing transportation mode are:

$$c = 64.66 \cdot 39 + 14.85 \cdot 29 + 10.07 \cdot 57 + 77.09 \cdot 109 + 0.20 \cdot 13229 + 0.08 \cdot 3514 + 0.08 \cdot 2274 =$$
$$= 15651.09 \quad € \quad per \quad day.$$

We took the transport costs related to vehicles and drivers into account. However, the costs for collecting, delivering, and directing parcels to both postal logistics centres as well as the administrative costs of employees were not included. With the same technology, these are constant as long as the number of operational postal units stays the same, and where the reallocation of workers can be assumed.

AN ALTERATION OF THE HIERARCHICAL CONCEPT OF THE POSTAL LOGISTICS SYSTEM DUE TO FOUR LEVEL APPROACHES

In the present mode of postal logistic system, all the connections between individual postal units are made through PLC Ljubljana and/or Maribor. However, data on the number of parcels collected in a study, done in December 2007, of the Nova Gorica and Koper postal units have shown that it is reasonable to connect the two locations directly. This is especially effective when the daily volume of collected or dispatched parcels between both regional centres increases (Lisec et al., 2005). It may be assumed that direct connections might also be reasonable between other bigger towns in Slovenia (Lisec et al., 2005).

Therefore, the current concept of logistics system of the Post of Slovenia is suggested to be altered on the basis of the revised and expanded model introduced by Ebery et al. (2000), with the introduction of a four-level transport of parcels (Lisec, 2006), based on the current postal logistics centres and introduction of new regional parcel centres and parcel posts. The short presentation of mathematical formalization for the four level distributions is the following:

$$\min \sum_i \sum_j \sum_l \sum_m \sum_k w_{ij} c_{ijlmk} x_{ijlmk} + \sum_l f_l z_l + \sum_m f_m u_m + \sum_k f_k y_k \qquad (1)$$

Subject to:

1. There being only one-way from v_i to v_j:

$$\sum_l \sum_m \sum_k x_{ijlmk} = 1 \qquad (2)$$

2. The intensity of the flow from v_i to v_j through the node does not exceed the capacity of nodes:

$$\sum_i \sum_j w_{ij} \sum_l x_{ijl} \leq \gamma_l y_l \qquad (3)$$

$$\sum_i \sum_j w_{ij} \sum_m x_{ijm} \leq \gamma_m y_m \qquad (4)$$

$$\sum_i \sum_j w_{ij} \sum_k x_{ijk} \leq \gamma_k y_k \qquad (5)$$

When the value of the variable x_{ijlmk} is between 0 in 1. x_{ijlmk} denotes the fraction of the daily flow of parcels that travel from Post v_i to Post v_j. c_{ijlmk} is the cost of sending one unit of traffic flow. Decisions variables are as follows:

w_{ij} : The volume of the associated traffic stream of parcels;

f_k : Is the daily fixed cost associated with the operation of Postal Logistics Centre at node v_k;

f_m: Is the daily fixed cost associated with the operation of Regional Parcel Centre at node v_m;

f_l: Is the daily fixed cost associated with the operation of Parcel Post at node v_l;

γ_k : Capacity of Postal Logistics Centre at node v_k;

γ_m : Capacity of Regional Parcel Centre at node v_m;

γ_l : Capacity of Parcel Post at node v_l.

Variable z_l is defined by:

$$z_l = \begin{cases} 1, & \text{if node l is a Parcel Post} \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

Variable u_m is defined by:

$$u_m = \begin{cases} 1, & \text{if node m is a Regional Parcel Centre} \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

Variable y_k is defined by:

$$y_k = \begin{cases} 1, & \text{if node k is a Postal Logistics Centre} \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

The Posts on the level of local communities, patronizing a certain area, have to be assigned to the proper Parcel Post.

Regional parcel centres process mail locally and for the areas of other regional parcel centres in the future. Regional parcel centres as such deal with the collection and delivery of mail. Their task is to collect and deliver mail to clients in the wide area of the city and direct it to the parcel posts (in addition to delivery and dispatch from the postal logistics centre). At the same time, the regional parcel centres collect, dispatch and deliver parcels of bigger dimensions in the area of regional parcel centres. In the future, the increased volume of parcels will enable the regional parcel centres to direct parcels between them as the transporting of all parcels to the existing postal logistics centres will become questionable due to the huge volume and dimensions and will represent an extremely complicated logistics process. In the event of continuing growth in the volume of parcels the regional parcel centres will need transport conveyor belts or smaller appliances for the separation process, which at this point will not be taken into account.

The justification of introducing regional parcel centres with the aim of separating and excluding parcels for the local area will be studied due to the increased volume of parcels and especially due to rationalization of the system, for the two logistics centres have problems ensuring the direction of all parcels in one night. Problems that occur in the existing mode of transporting shipments relate to the organization of transportation, while the result of these problems is that parcels are retained in PLCs for up to two days. This does not comply with the prescribed time window D+1 mentioned earlier.

At the same time, with the allocation of the regional parcel centres, the allocation of parcel posts that cover smaller areas within the wider areas of the regional parcel centres has to be taken into account. Geographically, parcel posts usually belong to the area of the regional parcel centre. The role of parcel post is the collection and delivery of parcels in the local area and associated post offices as well as collection and delivery on the spot. Parcel posts redirect mail and parcels to smaller post offices (some bigger post offices already practice this).

ALLOCATION OF REGIONAL PARCEL CENTRES AND OF PARCEL POST SERVICES IN THE AREA OF THE POSTAL LOGISTICS CENTRE, LJUBLJANA

Using the basic concept of four level hierarchy of postal system and applying it to the case of the Post of Slovenia, the usefulness of allocating regional parcel centres at different locations (in addition to the two existing postal logistics centres in Ljubljana and in Maribor) is analyzed. We analyze their economic legitimacy and the appropriateness of their location for covering the Ljubljana area. The hierarchy of the area covered by the PLC Ljubljana shall therefore be as follows:

i. one postal logistics centre; and
ii. at most five regional parcel centres (for at least thirty post offices). Each centre would cater for 3-12 parcel posts depending on the number of collected and delivered parcels. In their local area, parcel post offices cater for 3 to 20 post offices.

These requirements are only fulfilled by the following post offices: the Postal Logistics Centre Ljubljana that also

has the function of the regional parcel centre, the parcel post and the post office, post 4101 Kranj, 6104 Koper, 8101 Novo mesto, and 5102 Nova Gorica which also operate as both parcel post and regular post offices.

Next, the cost limits for the introduction of all four regional parcel centres are calculated. To this end, the logistics cost structure has to be addressed. Logistics costs may be divided into fixed and variable ones. Fixed costs are made up of investment costs and operational costs. The former are calculated on the day of operation, while the latter do not depend on the parcel quantity processed at a particular post office. Variable costs are costs that are proportional to the quantity of mail shipments. In order to justify the allocation of regional parcel centres, the model of Bruns et al. (2000) was used. This problem can be solved using a simple location model SPLP (simple plant location problem) that looks for: the sum of the minimum total daily fixed costs in the area of delivery to transhipment points j and the sum of daily fixed costs of operating the transhipment points:

$$\min\left(\sum_{i \in I}\sum_{j \in J} c_{ij}x_{ij} + \sum_{j \in J} f_j y_j\right) \tag{9}$$

Under the following conditions:

1. Each post office must be allocated to exactly one delivery base (a regional parcel centre):

$$\sum_{j \in J} x_{ij} = 1, \qquad \forall i \in I \tag{10}$$

2. No post can be served by a "closed" delivery base (regional parcel centre):

$$x_{ij} - y_j \le 0 \qquad \forall i \in I, \ j \in J \tag{11}$$

$$x_{ij,} \ y_j \in \{0,1\} \qquad i \in I, \ j \in J \tag{12}$$

In order to find optimal solutions for the allocation of regional parcel centres in the transport network, software called Solver was used that enables the solution of a combinatorial programme of small dimensions and which is an integral part of Microsoft Excel. The problem of analyzing the optimality of the allocation of regional parcel centres needs to be solved and therefore minimal differences of additional daily fixed costs and transportation costs per day need to be calculated. These are described by objective function (9) subject to (10) to (12).

Regional parcel centres are excluded sequentially when altering additional fixed costs in steps of the size of one monetary unit (€ 1.13). Additional fixed costs are expressed as the equivalent of the travel costs per kilometre with a truck in both directions. The costs also include the appropriate salary part of the driver. € 35.03 worth of fixed costs was calculated (31 monetary units of fixed costs) as a cut-off point in justification of the transformation of a regular post office into a Regional Parcel Centre Kranj. On the contrary, additional fixed costs of € 36.16 per day, (32 monetary units of fixed costs) make the allocation of the RPC Kranj unjustified.

We also calculated the maximum amount of additional fixed costs incurred as criteria for the justification of regional parcel centres for other ordinary post offices (Koper, Novo mesto, Nova Gorica). The results are the following: up to € 76.84 (68 monetary units) of additional fixed costs per day justifies the allocation of the RPC Koper, € 77.97 (69 monetary units) of additional fixed costs per day justifies the allocation of the RPC Novo mesto and € 178.53 (158 monetary units) of additional fixed costs justifies the RPC Nova Gorica. If higher additional fixed costs are identified for the regional parcel centres, then a four-level service is not justified (when calculating the actual additional fixed costs only those costs should be taken into account that are incurred through additional building construction and equipment, reduced by the reducibility of such costs at the higher level). We calculated the marginal cost acceptable to introduce the specific RPC in order to take these cost into account as additional cost later, when we calculate transportation cost under the new four level hierarchical postal systems.

OPTIMIZATION OF PARCEL SHIPMENT FLOWS TO PLC LJUBLJANA, WITH THE NEW HIERARCHICAL STRUCTURE OF THE POSTAL NETWORK

The studied area encompasses 327 post offices, of which there is one postal logistics centre and 4 regional parcel centres, and 28 parcel posts covered by the Postal Logistics Centre Ljubljana (allocated on the grounds of limitations). The optimality of the new parcel post (PP) logistics design was checked based on data collected during the three-day observation period in March. 20% of letters were added to the total number of parcels, for such a mixture is expected between parcels and letters in the mail transfer at the Post of Slovenia. A three-day average was calculated as no extreme variability among days during the week could be observed based on the analysis (excluding Saturdays and Sundays).

Along with the two existing postal logistics centres and with the help of the algorithm, morning and afternoon transport was optimized within the parcel post office. The connection to the regional parcel centre and then to the postal logistics centre as well as between the two logistics centres were added (Zmazek and Žerovnik, 2005):

i. pick a vehicle from the fleet of trucks (normally with the

biggest capacity) and look for the postal order (an order from the most remote post office to the parcel office, from the parcel office to the regional parcel centre and between the postal logistics centres and hence at multiple levels);

ii. add post offices that are closer to the current group of post offices until the sum of the orders from the chosen post offices does not exceed the capacity of the chosen vehicle. However, do not let the value of the function rise too much and take all restrictions and demands of the problem into account (separating parcels for the local area); and

iii. repeat the process until all post offices have been chosen.

In addition, the algorithm also took the following factors into account:

i. separating parcels at post offices for local areas; and
ii. dispatch at four different levels.

The algorithm is tailored to the collection and delivery calculation. Calculated distances were taken into account and additional, existing fixed connections were assigned to them (contractual transport operators like the providers of bus and train services). The structure of vehicles of various capacities that the Post of Slovenia has at its disposal was also taken into account in the algorithm. First, routes at the highest level (PLC–PLC) were determined, followed by RPC–PLC, the PP–RPC level and last but not least, the post office–PP level. In the calculation, the time windows were also considered.

Employees at post offices only separate parcels for the local area, for the other two logistics centres and perhaps in the future for the regional parcel centres and hence do not incur any additional costs or create any extra work and, at the same time, reduce the workload at both postal logistics services. The unlimited capacity of the regional parcel centres and parcel posts was also taken into account.

The timetable is optimized by employing the algorithm. The opening times of the post offices vary. The calculation of optimal routes, which is performed, based on the application of the algorithm and the Solver programme software (used for calculating the shortest connections) also takes into account time windows before a post office opens and time windows after it closes. Post offices open at 8 am and close between 10 to 12 pm. Most post offices close between 2 to 7 pm. Only one post office closes at 10 am already and two close at midnight (in Ljubljana and Maribor). Time windows (2 h for morning deliveries and 1 h and 45 min for afternoon deliveries) are taken into account. At the same time, it is assumed that the vehicle capacity does not exceed the limit at the lowest level (between parcel post offices and post offices). That is why more vehicles can be used at the lowest level.

CALCULATION OF TRANSPORTATION COSTS FOR PLC LJUBLJANA WITH THE NEW TIMETABLE

Total costs include the transportation of parcels (vehicle and driver costs), but not the costs of the collection, delivery and redirection of parcels at both logistics centres or the administrative costs of employees which are constant regardless of the way the flows are located in the network.

The new organization of transporting shipments requires 26 trucks (excluding broken down vehicles). The total number of kilometres covered by trucks in the new system is 6263. Some drivers of middle-sized vehicles or light delivery vans can operate on several routes per day. Two additional trucks are taken into account as a backup due to potential breakdowns (they were also taken into account in the current mode of transport). For this reason, the total number of trucks is 28.

The routes between individual post offices, parcel posts, regional parcel centres and postal logistics centres ought to be operated by 29 middle-sized delivery vans and 57 light delivery vans. Middle-sized delivery vans should cover 424 km in the PLC, RPC and PP areas, and 2298 km within the parcel post office area. The total number of kilometres covered by middle-sized delivery vans is thus 2722 km.

Light delivery vans would cover 130 km in the PLC, RPC and PP area and 3652 km within the parcel post area (3413 km by light delivery vans and 239 km by busses and trains). The number of vehicles would remain the same, that is, 57 light delivery vehicles from the existing mode of transport. The total number of kilometres covered is thus 3782 km. Within the parcel post area, several vehicles may be used in order to comply with the particular time window either in the morning or in the afternoon. At the lowest level, there is no danger of exceeding the capacity limit of certain vehicles. If there are several routes within the parcel post, the routes are designed according to the principle of rounds with the routes not overlapping each other. This, however, does not affect the routes operated in the afternoons as post offices close at different hours.

The total number of kilometres covered per day between postal logistics centres, regional parcel centres, parcel posts and post offices is 12 767. This reduces the total length by 6250 km. The number of vehicles assigned to the regional parcel centres (so far they were located at the PLC Ljubljana) is determined in relation to the optimal solution. By rearranging trucks for RPC for the collection and delivery of parcels, we expand the existing system of parcel logistics so that the Post of Slovenia can cope with the increased volume of parcels both at present and in the future. If this is the case, the PLC Ljubljana would not need any additional trucks for parcel dispatch. Table 4 shows the costs analysis of the new transport mode. The costs of the new transport mode are:

Table 3. Limitation of fixed costs of allocating regional parcel centres.

Regional parcel centre	Limitation of fixed costs of allocating RPC (€)
RPC Kranj	35.03
RPC Koper	76.84
RPC Novo mesto	77.97
RPC Nova Gorica	178.53
Total	368.37

Table 4. Cost analysis of the new transportation mode.

Vehicle	Fixed costs of a vehicle per day (€)	Fixed costs of a driver per day(€)	Variable costs(€/km)	No. of vehicles	No. of drivers	No. of km per day
TV	64.66	77.09	0.20	28	52	6263
SDV	14.85	77.09	0.08	29	22	2722
LDV	10.07	77.09	0.08	57	15	3782
Total number of km per day						12 767

$$c^* = 64.66 \cdot 28 + 14.85 \cdot 29 + 10.07 \cdot 57 + 77.09 \cdot 89 + 0.20 \cdot 6263 + 0.08 \cdot 2722 + 0.08 \cdot 3782 =$$
$$= 12138.64 \quad € \quad per \quad day.$$

If additional costs of the allocation of the regional parcel centres totalling € 368.37 (Table 3) are added to the costs of the optimal mode of transport created through the introduction of the retention and separation of parcels, we obtain:

$$c_{RPC} = c^* + FC_{RPC} = 12138.64 + 368.37 = 12507.01 \quad € \quad per \quad day.$$

In comparing the costs of the present and new modes of transport (separation of parcels at post offices and parcel posts), an expansion of the workforce is not taken into account as our assumption is that the workers are reallocated to regional parcel centres from the postal logistics centre, whereby the additional fixed costs of regional parcel allocation per day are taken into account:

$c - c_{RPC} = 15651.09 - 12507.01 = 3144.08 \quad € \quad per \quad day$,

It is clear that by introducing the new mode of parcel distribution, and by introducing the regional parcel centres, the costs of the parcel distribution would fall by € 3144.08 per day (€ 943 224 per year). Distribution costs are, as a result, reduced by more than 20% compared to the current mode of transport.

Conclusion

The paper analyzed the impact of the number of hierarchical levels, which determines the possibilities for separation of dispatches and transhipment at various levels, on the efficiency of the transport network. Literature suggests that solving hierarchical hub location problems has an important effect on the efficiency of the transportation network. Based on the developed 4-level hierarchical model we tested the result of the introduction of regional parcel centres and parcel posts in the area covering Postal Logistics Centre, Ljubljana. Introduction of RPC and PP allows the separation of dispatches at various levels with the aim of retaining parcels for one's own area and transhipments among various levels.

Having studied the four-level model, we may conclude that it would be sensible to introduce a new way of distributing parcels by creating regional parcel centres and parcel posts involving the separation process of parcels for the local area and directing mail shipments to freight parcels on scheduled routes. In this way, the transport costs (logistics) would be reduced daily by 20%. In the proposed four-level model, the supply level remains the same as it is now within the network of the Post of Slovenia in terms of the locations and capacities. Further, the model also considers the actual postal and

vehicular capacities that the Post of Slovenia has available. The time windows only limit the use of vehicles. This result confirms our hypothesis that by changing the spatial hierarchy and allowing retention and transhipment of parcels among hubs at different levels economies of distribution costs can be achieved.

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