ALLOCATING DELIVERY VEHICLES WITHIN THE TRANSPORT NETWORK BY APPLYING MATHEMATICAL MODEL

ABSTRACT

This paper presents possibilities of applying mathematical models in daily allocation of delivery vehicles and routing operations. Two mathematical models are designed for solving vehicle allocation problem and vehicle routing problem, respectively. The models are tested on real system data, obtained from Croatian Postal Company. The vehicle allocation model reduces the number of delivery vehicles needed, while the vehicle routing model optimizes delivery routes. Advantages of mathematical modeling are quantified by comparing the results obtained by applying mathematical models against the solutions given by the Company operators.

KEY WORDS

delivery vehicle allocation; delivery vehicle routing; mathematical models

1. INTRODUCTION

Express service (pickup and delivery), also called express delivery services, and today is common service requested from more and more customers. It started in the United States in 1960’s. In its short history, express services have experienced a rapid growth and have expanded all over the world. Nowadays, there are many express service companies playing important roles in the field of express service. The modern express services are not only the rapid goods delivering, but also the financial and information exchanging. Development of information technology and computer science will benefit this industry. Express delivery services industry is still growing today and probably will keep growing in the near future.

Part of logistical problems in those companies are related to the optimization of the delivery vehicles allocation and routing. Quality operational decisions in short time period for allocation and routing is prerequisite for efficiency of operations. Since these problems are NP hard problems, generating optimal solution is very demanding and time consuming. For this reason, the problems are approximated by linear programing mathematical models, however the optimal solution is obtained by using heuristic algorithms. In the term linear programing, programming refers to mathematical programing, which refers to a planning process that allocates resources in the best possible way [1].

Large companies today (like DHL, UPS) for solving these problems use different custom-made software, which are not cheap. For small regional companies that software represent a negligible financial cost and they are not willing to invest if they do not see operational benefit.
For this reason, they prefer to rely on dispatcher experience in delivery vehicle allocation decision-making.

One of such small regional companies in express delivery service business is Croatian Post Company. Croatian Post delivers every second parcel today in Croatia. In other words, by the volume of delivered mail and the quality of its service Croatian Post is the market leader in parcel and express mail delivery. HP express is Croatian Post’s express delivery service, covering the entire territory of Croatia. It is an express package delivery and pickup service in defined time windows. They use 3PL information system for collecting customer service requests, but company dispatcher based on his experience does allocation and routing.

Completing delivery and pickup processes in the defined time windows is the primary demand that has to be fulfilled. Failing to do so, results in a negative effect on the level of customer service, which leads to loss of customers and potential earnings. Optimization of vehicle allocation in delivery systems reduces operational costs, and increases the level of customer service while allocating vehicles in a non-optimal way generates higher operational costs, and can create a negative effect on the level of customer service.

The solution of the problem is obtained by optimizing mathematical model of the real system, which is entered into Microsoft Excel spreadsheet. Additional software tools are used, Evolver Add-on, which uses genetic algorithm for finding heuristic solutions and Google Maps add-on, which is used for finding the travel time distance between locations. Compared to exact algorithms, heuristics procedures take less computation time but do not guarantee optimal solutions [2]. In order to facilitate the solution process, two separate but related mathematical models (vehicle allocation and vehicle routing) were designed.

Solving the major problems in the program tool Excel is not the best solution because there are specific software tools for solving logistics problems, but the solution obtained Excel may indicate the need for changes in the operational activities. Comparing the results obtained by solving mathematical models, and solutions given by the dispatcher, it is possible to evaluate improvements.

2. DESCRIPTION OF THE LOGISTIC PROBLEM

Costumers, either via call center or web based application, generate the demand for the package pickup and delivery process. After the demand has been created, the call center forwards the request towards to the dispatcher. The dispatcher decides to which delivery vehicle the pickup process will be allocated. All of the delivery operations are grouped by postal region (sector) and allocated to delivery vehicles.

Every vehicle/driver in the delivery network has an assigned delivery book, which consists of a list of costumers for delivery and pickup. Also, the delivery book contains information about every delivery process (package information, delivery address and the defined time window), and the order in which the operations are to be executed [3].

The order in which delivery and pickup processes are executed is defined by two influence factors. The prime influence factor is the delivery window in which the process must be completed, which means that the processes with the sooner time window-deadline (e.g. 8 am) must be completed before any processes with a latter of a time window-deadline (e.g. 10 am). The secondary influence factor is the priority right, which defines that key costumers of the delivery service provider will be serviced before the other costumers.

The decision method, which the dispatcher uses, is based on the area of the pickup process and the postal region of the delivery vehicle. Processes execution order in the delivery
book is created using computer solutions by dispatcher. Computer solution in use does not include the allocation and routing algorithms. The dispatcher according to his/her experience allocates the delivery vehicles for each demand area or postal region (sector). Delivery vehicles driver himself does vehicle routing in each given sector.

Since the allocation and routing of vehicles are based on the dispatchers experience and evaluation, they may not be optimal. Also, since the allocation of pickup processes can occur during the day, when delivery book is already created and in use, there is need for reallocation of the pickup processes to vehicles in an optimal way and also for rerouting.

3. MATHEMATICAL MODELS FOR VEHICLE ALLOCATION AND VEHICLE ROUTING

Creating and solving mathematical models for vehicle allocation and routing, can help the dispatcher in making optimal decisions, which could lead to increasing system performance and the level of customer service.

The proposed solution for described problem consists of two separate, but linked mathematical models. Those models are:

- Mathematical model for vehicle allocation
- Mathematical model for vehicle routing

First, it is necessary to allocate delivery vehicle for each demand area (sector). The mathematical model for vehicle allocation defines which sectors will be allocated towards the delivery vehicle, and therefore creates delivery routes. After the delivery vehicle has been allocated to demand sector, vehicle routing according to influence factor has to be done. The mathematical model for vehicle routing optimizes created routes for each sector. Each of mathematical models is described as follows:

Mathematical model for vehicle allocation

**Objective function – minimize the number of allocated vehicles**

\[
\min F = \sum_{k=1}^{m} y_k
\]

\[(1.1)\]

\[
y_k = 1 \iff \sum_{i=1}^{n} x_{ik} \geq 1 \ \forall \ k = 1, ..., m
\]

\[(1.2)\]

\[
y_k = 0 \iff \sum_{i=1}^{n} x_{ik} = 0 \ \forall \ k = 1, ..., m
\]

\[(1.3)\]

**Subject to the Constraints**

\[
T_{i+1} \geq T_i \ \forall \ i = 1, ..., n
\]

\[(1.4)\]

\[
T_i \geq b_{ik} + s \ \forall \ i = 1, ..., n; \ k = 1, ..., m
\]

\[(1.5)\]

\[
\sum_{k=1}^{m} x_{ik} = 1 \ \forall \ i = 1, ..., n; \ k = 1, ..., m
\]

\[(1.6)\]
A. Švehla, D. Božić, R. Stanković: Allocating Delivery Vehicles Within the Transport Network by Applying ...

\[ x_{ik} \in \{0,1\} \quad \forall \ i = 0, \ldots, n; \ j = 0, \ldots, n; \ k = 1, \ldots, m \quad (1.7) \]

\[ m_{i-1,k} + x_{ik}(P_i - R_i) \leq q \quad \forall \ i = 1, \ldots, n; \ k = 1, \ldots, m \quad (1.8) \]

\[ m_{0k} = \sum_{i=1}^{n} x_{ik} R_i \quad \forall \ k = 1, \ldots, m \quad (1.9) \]

\[ \sum_{k}^{m} \sum_{i=0}^{n} \sum_{j}^{n} x_{ik} (t_{ik} + s) \leq D \quad \forall \ i = 0, \ldots, n; \ j = 0, \ldots, n; \ k = 1, \ldots, m \quad (1.10) \]

Where:

- \( y_k \) = binary variable, if the vehicle \( k \) is allocated (at least one costumer is allocate; the variable \( K_i \) = variable gets the value of 1, otherwise the variable gets the value 0
- \( x_{ik} \) = binary variable, value 1 if the costumer is allocated towards the vehicle \( k \), value 0 if it’s not allocated
- \( m \) = total number of vehicles
- \( n \) = total number of clients
- \( b_{ik} \) = the time of beginning of the service for costumer \( i \), by the vehicle \( k \)
- \( i = 1, \ldots, n; \ k = 1, \ldots, m \)
- \( R_i \) = mass of the package for delivery on the location of the costumer \( i \)
- \( P_i \) = mass of the package for collection on the location of the costumer \( i \)
- \( t_{ij} \) = travel time distance from location \( i \) towards the location \( j \)
- \( q \) = vehicle capacity \( k \)
- \( T_i \) = time window for executing the service on location \( i \)
- \( y_k \) = decision variable: if the vehicle is allocated the variable has a value of 1, if it’s not allocated the value is 0
- \( D \) = drivers work time
- \( m_i \) = sum of the mass of packages on board delivery vehicle \( k \) after finishing the service on location \( i \)

The inequity (1.4) defines that the order for visiting costumers is defined trough subsequent time windows. The inequity (1.5) defines that the time for completing the service must be lower or equal to the time windows for that costumer. The equation (1.6) defines that every costumer is serviced only once. Equation (1.7) defines the decision variable \( x_{ik} \) as a binary variable. The equation (1.8) defines that the total mass of the packages in the vehicle \( k \), after completing the service at the location \( i \), does not exceed the vehicle carrying capacity. The equation (1.9) calculates the total mass of the packages for delivery at the distribution center. The equation (1.10) expresses that the overall time of all operations completed by the driver, does not exceed his working time.

Mathematical model for vehicle routing

The model is based upon the general VRPDP (“Vehicle Routing Problem with Deliveries and Pickups”) [4]. The original model is modified to include time based values and constraints.

Objective function:
\[
\min F = \sum_{i=0}^{n} \sum_{j=0}^{n} x_{ij} (t_{ij} + s)
\] (2.1)

Subject to the Constraints
\[
T_j \geq T_i \quad \forall \ j \geq i
\] (2.2)
\[
T_i \geq b_i + s \quad \forall \ i = 1, \ldots, n;
\] (2.3)
\[
\sum_{i=0}^{n} \sum_{j=0}^{n} x_{ij} (t_{ij} + s) \leq D \quad \forall \ i = 0, \ldots, n; \quad j = 0, \ldots, n;
\] (2.4)
\[
b_j = b_i + s + t_{ij} \quad \forall \ i = 1, \ldots, n; \quad j = 1, \ldots, n;
\] (2.5)

Where:
- \(x_{ij}\) = decision variable: value 1 if the delivery vehicle travels from customer \(i\) towards customer \(j\), otherwise the value of the variable is 0
- \(b_i\) : moment of starting the service on location \(i\); \(i = 1, \ldots, n\)
- \(t_{ij}\) : travel time distance between location from location \(i\) towards the location \(j\)
- \(T_i\) : time window for completing the service on location \(i\); \(i = 1, \ldots, n\)
- \(s\) : time needed for completing the operational processes on a location
- \(D\) : drivers work time

The inequity (2.2) defines that the customers with earlier time window-deadline (e.g. 10:00), are serviced before the customers, which have a later time window-deadline (e.g. 12:00). The inequity (2.3) defines that all of the customers are serviced before exceeding the time window value. The equation (2.4) expresses that the overall time of all operations completed by the driver, does not exceed his working time. The equation (2.5) defines the starting time of the service on the location \(j\), which consists of starting time of the service at the previous location \(i\), time needed to complete the service at the location \(i\), and the travel time between locations \(i\) and \(j\).

4. DISCUSSION OF THE RESULTS

In order to indicate possibilities and advantages of mathematical modeling in dispatcher daily operational decisions, two solutions were analyzed:
- Solutions made by dispatcher, and
- Solutions made by help of mathematical models.

The procedure for comparing the solution made by the dispatcher and the solution gained by solving the problem via mathematical models is shown in the Figure 1.
Dispatcher solution for observed demand in particular area and data is taken from HP express service department. As there are differences in amount and frequency of demand as well as traffic congestions between urban and suburban area, solutions for both areas are analyzed.

Using the same input data as the dispatcher, firstly the mathematical model for vehicle allocation is used for allocating customers to the delivery vehicle. Afterwards, the mathematical model for vehicle routing is used for creating optimal delivery routes.

The input data is based on the following information:

- Name and surname of the Customer
- Address of the Customer
- Type of process (delivery, pickup or both)
- Time window
- Mass of the package for delivery to the customer
- Mass of the package for pickup from the costumer

The two problems, the problem of delivery and pickup in an urban area and the problem of delivery and pickup in a suburban area, differentiate one from other in multiple characteristics. Most notably, the density of customers and the average travel time between two costumers.

For the purpose of presentation in this paper, only one demand sector for each area is taken, demand sector in urban area with 102 customers and one demand sector in suburban area with 50 customers.

Steps of creating solutions by the use of mathematical modeling are presented further in text. Based on the information of customer addresses, the travel time matrix is created
using the Google Maps plugin function “GetGoogleTravelTime”, which uses navigation functions of the Google Maps server for calculating the shortest route between locations. The matrix shown in the Table 1 contains travel time distances between all locations, which are street addresses of costumers and the LDC. The values of time distance are in the HH:MM format. Only one segment of the table is shown due to insufficient space.

Table 1 - Travel time matrix

<table>
<thead>
<tr>
<th>Distance between the LDC and customers</th>
<th>Distance between the customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1:00:08 00:00 00:15 00:15 00:13 00:15 00:12 00:08 00:11 00:27 00:17</td>
</tr>
<tr>
<td>1 00:09</td>
<td>2:00:15 00:00 00:06 00:08 00:09 00:10 00:11 00:09 00:06 00:23 00:05</td>
</tr>
<tr>
<td>2 00:12</td>
<td>3:00:12 00:03 00:06 00:06 00:07 00:14 00:09 00:07 00:12 00:22 00:05</td>
</tr>
<tr>
<td>3 00:14</td>
<td>4:00:13 00:08 00:04 00:16 00:04 00:16 00:07 00:10 00:18 00:10 00:10</td>
</tr>
<tr>
<td>4 00:16</td>
<td>5:00:20 00:13 00:09 00:08 00:00 00:23 00:14 00:17 00:14 00:11 00:11</td>
</tr>
<tr>
<td>5 00:17</td>
<td>6:00:11 00:02 00:10 00:07 00:08 00:11 00:06 00:17 00:18 00:21 00:12</td>
</tr>
<tr>
<td>6 00:07</td>
<td>7:00:08 00:02 00:10 00:07 00:08 00:11 00:06 00:17 00:18 00:21 00:12</td>
</tr>
<tr>
<td>7 00:05</td>
<td>8:00:08 00:07 00:06 00:10 00:10 00:11 00:09 00:05 00:09 00:24 00:20</td>
</tr>
<tr>
<td>8 00:02</td>
<td>9:00:27 00:02 00:18 00:17 00:15 00:30 00:22 00:24 00:01 00:20 00:20</td>
</tr>
<tr>
<td>9 00:12</td>
<td>10:00:17 00:04 00:06 00:09 00:10 00:12 00:13 00:08 00:25 00:00 00:00</td>
</tr>
<tr>
<td>10 00:15</td>
<td>11:00:16 00:04 00:06 00:09 00:10 00:14 00:10 00:12 00:10 00:23 00:02</td>
</tr>
<tr>
<td>11 00:05</td>
<td>12:00:09 00:08 00:11 00:13 00:15 00:05 00:10 00:04 00:26 00:11 00:11</td>
</tr>
<tr>
<td>12 00:02</td>
<td>13:00:25 00:25 00:21 00:20 00:18 00:30 00:22 00:28 00:18 00:23 00:23</td>
</tr>
<tr>
<td>13 00:08</td>
<td>14:00:08 00:14 00:12 00:10 00:12 00:11 00:09 00:10 00:22 00:16 00:16</td>
</tr>
<tr>
<td>14 00:13</td>
<td>15:00:13 00:10 00:07 00:05 00:06 00:15 00:07 00:09 00:21 00:12 00:12</td>
</tr>
<tr>
<td>15 00:11</td>
<td>16:00:12 00:08 00:07 00:07 00:09 00:13 00:06 00:07 00:22 00:10 00:10</td>
</tr>
<tr>
<td>16 00:11</td>
<td>17:00:09 00:12 00:10 00:08 00:10 00:13 00:04 00:11 00:20 00:14 00:14</td>
</tr>
<tr>
<td>17 00:07</td>
<td>18:00:09 00:08 00:07 00:09 00:11 00:11 00:05 00:04 00:23 00:10 00:10</td>
</tr>
<tr>
<td>18 00:02</td>
<td>19:00:14 00:04 00:04 00:06 00:08 00:15 00:11 00:09 00:22 00:05 00:05</td>
</tr>
<tr>
<td>19 00:13</td>
<td>20:00:10 00:18 00:14 00:15 00:15 00:18 00:14 00:04 00:16 00:26 00:20</td>
</tr>
</tbody>
</table>

Due to size of excel sheet presented results in table 1, 2 and 3 shows only 20 customers, but the calculation is done for all 102 and 50 customers.

The mathematical model for vehicle allocation, shown in chapter 3, is transferred in MS Excel, and is solved by using a mathematical software tool Evolver. The solution given by the solving tool is given in Table 2.

As shown in Table 2, vehicles 1 and 3 are allocated. Costumers allocated to vehicle 1 are the following: 3, 4, 7, 8, 9, 10, 11, 13, 18, 19 and 20. Costumers allocated to vehicle 1 are the following: 1, 2, 5, 6, 12, 14, 15, 16 and 17.
Allocating costumers to delivery vehicles creates delivery routes, which then need to be optimized. A new distance matrix is created containing only locations of costumers allocated to the respective delivery vehicle. The mathematical model for vehicle route optimization is transferred to Excel, and is solved by using the mathematical software Evolver. The proposed solution is shown in Table 3.

As shown in Table 3, the delivery schedule is 0, 1, 4, 3, 2, 11, 10, 12, 6, 8, 5, 9, 7, 13, 17, 20, 14, 16, 18, 19, 15 and 0.

Note that the location with the indicator 0 is the LDC, which is the starting and ending location in the delivery route. The higher priority costumers with a sooner time window-deadline (e.g. costumer with identification number 2), are serviced before the costumers which have a later time window-deadline (e.g. costumer with identification number 11). The total time needed for completing delivery processes, pickup processes and the return to the LDC is 4:57. Time window and vehicle capacity conditions are met.

After calculating solution via respective mathematical models, results of both solutions are compared. Table 4 shows the results of the solutions given by the dispatcher and by using mathematical models, for problems set in the urban and suburban area.
Type of delivery vehicle used in both problems is a medium size delivery van, which has a carrying capacity of 1490 kg. The urban type problem consists of 102 processes, which consist of 78 deliveries and 24 pick-ups. The suburban type problem consists of 50 processes, which are divided into 32 deliveries and 18 pick-ups. Since the density of customers is higher in the urban area, the average traveling time distance is lower in comparison to the suburban area, which means that a higher number of customers can be served in the urban area than in a suburban area for the same amount of time.

In case of the urban area, the solution gained by solving the mathematical model for vehicle allocation allocated 2 delivery vehicles, which is an improvement of 33%, in comparison to dispatcher’s solution which allocated three delivery vehicles. Customers allocated to delivery vehicle 1 are the following: 1, 4, 5, 6, 7, 9, 11, 12, 13, 15, 18, 19, 22, 24, 25, 26, 28, 30, 33, 34, 35, 37, 38, 39, 40, 41, 42, 43, 45, 48, 49, 51, 56, 59, 62, 66, 67, 68, 69, 71, 72, 81, 82, 83, 85, 89, 90, 92, 99, 100, 101 and 102. Customers allocated to delivery vehicle 2 are the following: 2, 3, 8, 10, 14, 16, 17, 20, 21, 23, 27, 29, 31, 32, 36, 46, 47, 50, 52, 53, 54, 55, 57, 58, 60, 61, 63, 64, 65, 70, 73, 74, 75, 76, 77, 78, 79, 80, 84, 86, 87, 88, 91, 93, 94, 95, 96, 97 and 98. After optimizing delivery routes of two allocated vehicles, the total time needed for serving all customers is 13:35, which in comparison to the dispatcher time of 13:52 is an improvement of 2%.

In case of the suburban area, the solution generated by solving the mathematical model for vehicle allocation allocated only one delivery vehicle, which is an improvement of 50%, in comparison to two allocated delivery vehicles by the dispatcher. After optimizing the delivery route in the vehicle routing model, the total time needed for serving all customers decreased to 5:23, which is an improvement of 32%, in comparison to dispatcher’s solution. The mass of packages did not exceed the carrying capacity of allocated vehicles in both types of problem. The highest total mass of delivery packages was allocated towards the vehicle 1 in the

**Table 4 - Comparison of generated solutions**

<table>
<thead>
<tr>
<th>Problem type</th>
<th>Urban</th>
<th>Urban</th>
<th>Suburban</th>
<th>Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution obtained by</td>
<td>Dispatcher</td>
<td>By using mathematical models</td>
<td>Dispatcher</td>
<td>By using mathematical models</td>
</tr>
<tr>
<td>Number of customers</td>
<td>102</td>
<td>102</td>
<td>102</td>
<td>50</td>
</tr>
<tr>
<td>Number of delivery processes</td>
<td>78</td>
<td>78</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Number of pickup processes</td>
<td>24</td>
<td>24</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Number of allocated vehicles</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Number of customers allocated to vehicle 1</td>
<td>26</td>
<td>51</td>
<td>27</td>
<td>50</td>
</tr>
<tr>
<td>Total time needed to complete all processes allocated to vehicle 1 [HH:MM]</td>
<td>4:09</td>
<td>5:23</td>
<td>3:57</td>
<td>5:23</td>
</tr>
<tr>
<td>Total mass of packages delivered by vehicle 1 [kg]</td>
<td>33,7</td>
<td>75,5</td>
<td>159,8</td>
<td>232,7</td>
</tr>
<tr>
<td>Total mass of packages picked up by vehicle 1 [kg]</td>
<td>46,5</td>
<td>33</td>
<td>66,1</td>
<td>78,2</td>
</tr>
<tr>
<td>Number of customers allocated to vehicle 2</td>
<td>40</td>
<td>51</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Total time needed to complete all processes allocated to vehicle 2 [HH:MM]</td>
<td>5:14</td>
<td>6:12</td>
<td>4:01</td>
<td>N/A</td>
</tr>
<tr>
<td>Total mass of packages delivered by vehicle 2 [kg]</td>
<td>63</td>
<td>54,1</td>
<td>72,9</td>
<td>N/A</td>
</tr>
<tr>
<td>Total mass of packages picked up by vehicle 2 [kg]</td>
<td>5,9</td>
<td>50,4</td>
<td>12,1</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of customers allocated to vehicle 3</td>
<td>36</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total time needed to complete all processes allocated to vehicle 3 [HH:MM]</td>
<td>4:29</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total mass of packages delivered by vehicle 3 [kg]</td>
<td>33</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total mass of packages picked up by vehicle 3 [kg]</td>
<td>31</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
suburban area with a value of 232.7, which equals to only 15 % of the vehicles maximum carrying capacity. It should be noted that the HP express did not provide the volumetric mass values for the packages, therefore their influence is neglected in the solution.

5. CONCLUSION

Operator’s solutions for assigning and routing delivery vehicles that was analyzed, didn’t fully meet the demands of efficiency and effectiveness (allocation based on operator’s assessment and experience). For this reason, logistic costs of the company are not minimized, while the highest service level isn’t achieved. The optimal solutions of the vehicle assignment problem and the vehicle routing problem were obtained by applying software tools on the mathematical models of the real system.

In order to quantify the improvements, the solutions implemented by the operator were compared to the solutions generated by software tools, in optimizing mathematical models of the problems. In almost every iteration, the optimized solution was better than the operator’s solution, only in few iterations the solutions were similar.

Methodology outlined in this paper enable reducing the number of allocated vehicle and the total distance vehicles travel at deliveries and pickups, which results in better utilization of the fleet and increase of the service level. Due to simplicity of use, flexibility and quick problem solving, this methodology is particularly suited for daily use in real-life situations, especially when subsequent modifications are required.

The software tools that were used have certain limitations which makes them insufficient for problems with high number of deliveries and pickups, however the same methodology still could be implemented for such problems, but facilitated by more advanced software tools.

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[3] Company Hpekspres