SUSTAINABLE DISTRIBUTION LOGISTICS OF RETAIL CHAINS

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Abstract: Distribution logistics of retail chains is very specific, because the network of retail chains is usually very extensive and there are many constraints for distribution of goods, for example time windows of central warehouses (depots) and stores for loading and unloading, more deliveries within the same day to stores or distribution of objects of reverse logistics from stores to central warehouses. There are many flows between stores and central warehouses, for example product flows, information flows, financial flows, reverse flows etc. Sustainable distribution logistics should respect three pillars of sustainability, there are: economic, social and environmental pillars. Sustainable distribution logistics of retail chains should investigate the possibilities of streamlining with consideration to the pillars of sustainability. The article will focus on the distribution planning tools which are being used for planning of distribution logistics for retail chains. There are some algorithms of graph theory, for example: Vehicle routing problem with pickup and delivery with time windows. The aim of the article will be to find an algorithm for this type of exercise which will respect all defined constraints and pillars of sustainability for distribution logistics of retail chains. The algorithm will be simulated on a specific network of retail chain as a case study.

Keywords: distribution logistics, retail chain, vehicle routing problem, sustainability.

1. Introduction

The popularity of retail chains has grown in recent years among customers. Many retail chains have hundreds of stores and many central warehouses (depots). Demands on transport infrastructure and transport system as a whole are increasing. The intensity of traffic grows in the surroundings of individual stores, not only thanks to customers but also through the distribution logistics. The same applies for the surroundings of the central warehouses (depots) because hundreds of suppliers supply every day central warehouses and central warehouses deliver goods every day to hundreds of stores. It is also widely known that transport and distribution have a negative impact on the environment. This makes it necessary to pay maximum attention to distribution logistics. At the same time, greater emphasis is placed on sustainability issues through three pillars of sustainability and especially on the negative impacts of transport and distribution on the environment from the perspective of the environmental pillar of sustainability.

2. Theoretical Background of the Sustainable Distribution Logistics

Sustainable logistics is a research area developed since the 1990s according to Wiederkehr et al. (2004). Davis and Barekat (2002) stressed the terms like eco-logistics because these terms were increasingly used to define a sustainable environmental logistics. Schulte (1999) described sustainable distribution or sustainable distribution logistics as any means of transportation of goods in logistic chain with lowest possible impact on the environment and society. The term distribution includes according to the author the whole distribution process from storage, order processing and picking. packaging, improved vehicle loadings, delivery to the customer and reverse logistics. Sustainable distribution is based on three pillars: environmental pillar, economic pillar and social pillar. Faccio and Gamberi (2015) perceive logistic activities as the necessary condition for the harmonious growth of every urban area, even if they are also the main cause of pollution, noise and accidents. The rapid development of the demand for urban transportation has a negative impact on urban surroundings and on the environment (Wang et al., 2014). Faccio and Gamberi (2015) defined four groups of key players in the field of distribution logistics there are: retailers (stores etc.), carriers and warehouse companies, residents (inhabitants) and administrators (at national, regional and local levels). Karakikes and Nathanail (2017) stressed the importance of the urban distribution of goods because it is the main component of sustainable transport networks and one of the main contributors on traffic congestion and environmental pollution in the cities and agglomerations. Matsumoto et al. (2017) mentioned sustainable distribution or sustainable distribution logistics which considers both facility for distribution supply chain and also the transportation. Authors further emphasized the associated negative environmental impacts of distribution logistics and the need to use quality planning tools for distribution logistics. New challenges have been observed in models of vehicle routing problems which considered basic tools for implementing sustainable distribution channels in urban areas (Carrabs, Cerulli and Sciomachen, 2014). Retail chains have usually a very extensive network which consists of depots (central warehouses) $D_1 \cdots D_n$ and customers (stores) $C_1 \cdots C_n$. The stores are supplied directly from direct suppliers $SD_1 \cdots SD_n$ or indirectly from depots. The depots are supplied from indirect suppliers $SI_1 \cdots SI_n$. Direct flows of the goods and indirect flows of the goods are depicted in the Fig. 1. Stores produce reverse flow especially transport units (pallets, crates, boxes etc.). These transport units are returned directly to the direct suppliers or indirectly to the indirect suppliers through the depots. The diagram of the distribution and reverse logistics of retail chains are depicted in the Fig. 1.

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Fig. 1.

The Diagram of the Distribution and Reverse Logistics of Retail Chains Source: authors

3. Methods and Data

Methods and data are presented in this chapter. The algorithm of heuristic method for Vehicle routing problem with pickup and delivery with time windows is presented firstly. Then VRP Spreadsheet Solver is paid attention because this Microsoft Excel Workbook is used to solve a case study which is theoretically described at the end of the chapter.

Algorithm of heuristic method for Vehicle routing problem with pickup and delivery with time windows according to Desaulniers *et al.* (2002) uses these types of variables: binary flow variables x_{ijk} , time variables T_{ik} (specifying when vehicle *k* starts the service at node $i \in V_k$) and variables L_{ik} giving the load of vehicle *k* after the service at node $i \in V_k$ has been completed. The formulation of Vehicle routing problem with pickup and delivery with time windows according to Desaulniers *et al.* (2002) is as follows formulas 1-15.

$$\min \sum_{k \in K} \sum_{(i,j) \in A_k} c_{ijk} x_{ijk} \tag{1}$$

subject to

$$\sum_{k \in K} \sum_{i \in N_k \cup \{d(k)\}} x_{iik} = 1; \forall i \in P$$
(2)

$$\sum_{i \in N_k} x_{ijk} - \sum_{i \in N_k} x_{j,n+i,k} = 0; \ \forall \ k \in K, i \in P_k$$
(3)

$$\sum_{j \in P_k \cup \{d(k)\}} x_{o(k),j,k} = 1; \forall k \in K$$

$$\tag{4}$$

$$\sum_{i \in N_k \cup \{o(k)\}} x_{ijk} - \sum_{i \in N_k \cup \{d(k)\}} x_{ijk} = 0; \forall k \in K, j \in N_k$$

$$\tag{5}$$

$$\sum_{i \in D_k \cup \{o(k)\}} x_{i,d(k),k} = 1; \forall k \in K$$
(6)

$$x_{ijk} (T_{ik} + s_i + t_{ijk} - T_{jk}) \le 0; \ \forall \ k \in K, (i,j) \in A_k$$
(7)

$$a_i \le T_{ik} \le b_i; \ \forall \ k \in K, i \in V_k \tag{8}$$

$$T_{ik} + t_{i,n+i,k} \le T_{n+i,k}; \ \forall \ k \in K, i \in P_k$$

$$\tag{9}$$

$$x_{ijk}(L_{ik} + l_j - L_{jk}) = 0; \ \forall \ k \in K, (i, j) \in A_k$$
(10)

$$l_i \le L_{ik} \le C_k; \ \forall \ k \in K, i \in P_k \tag{11}$$

 $0 \le L_{n+i,k} \le C_k - l_i; \ \forall \ k \in K, n+1 \in D_k$ $\tag{12}$

$$L_{o(k),k} = 0; \ \forall \ k \in K$$
(13)

$$x_{ijk} \ge 0; \ \forall \ k \in K, (i,j) \in A_k \tag{14}$$

 x_{iik} binary; $\forall k \in K, (i, j) \in A_k$

(15)

The linear objective function (1) minimizes the total travel cost. Constraints (2-3) impose that each request is served exactly once and by the same vehicle. Constraints (4-6) characterize a multi-commodity flow structure and ensure that each vehicle k starts from its origin depot o(k) and terminates its route at its destination depot d(k). Compatibility requirements between routes and schedules are handled by constraints (7) and (8) are the time window constraints. For each request, constraints (9) force the vehicle to visit the pickup node before the delivery node. Constraints (10) express the compatibility requirements between routes and vehicle loads, while (11-12) the vehicle dependent capacity intervals at pickup and delivery nodes. The initial vehicle load is imposed by (13), and no negativity and binary requirements are given by (14-15). Constraint sets (3) through (15), as well as the objective function, are separable for each vehicle $k \in K$ (Desaulniers *et al.*, 2002).

The algorithm for Vehicle routing problem with pickup and delivery with time windows is solved in the Microsoft Excel workbook "VRP Spreadsheet Solver" which is an open source unified platform for representing, solving and visualizing the results of Vehicle Routing Problems. VRP Spreadsheet Solver uses public Geographical Information Systems (Bing Maps) and metaheuristics. The author of the "VRP Spreadsheet Solver" is Güneş Erdoğan and its scientific area covers exact and heuristic optimization methods, ambulance location problems, traveling salesman problems, vehicle routing problems and scheduling problems (Güneş, 2018).

Güneş Erdoğan and other co-authors are the authors of the following scientific articles, for example A Note on a Polynomial Time Solvable Case of the Quadratic Assignment Problem (Güneş and Tansel, 2006), A Branch-and-Cut Algorithm for Quadratic Assignment Problems Based on Linearizations (Güneş and Tansel, 2007), Ambulance Location for Maximum Survival (Erkut, Ingolfsson and Güneş, 2008), Computational Comparison of Five Maximal Covering Models for Locating Ambulances (Erkut *et al.*, 2009), The Traveling Salesman Problem with Pickup and Delivery and First-In-First-Out Loading (Güneş, Cordeau and Laporte, 2009), Scheduling Ambulance Crews for Maximum Coverage (Güneş *et al.*, 2010), The Attractive Traveling Salesman Problem (Güneş, Cordeau and Laporte, 2010), The Traveling Salesman Problem with Pickups, Deliveries and Handling Costs (Battarra *et al.*, 2010), A Branch-and-Cut Algorithm for the Non-Preemptive Capacitated Swapping Problem (Güneş, Cordeau and Laporte, 2010), Formulations and Branch-and-Cut Algorithms for the Generalized Vehicle Routing Problem (Bektaş, Güneş and Ropke, 2011), Modelling and solving an m-location, n-courier, priority-based planning problem on a network (Güneş, Tansel and Akgün, 2012), Metaheuristics for the traveling salesman problem with pickups, deliveries and handling costs (Güneş et al., 2012), The Orienteering Problem with Variable Profits (Güneş and Laporte, 2013) and Exact Algorithms for the Clustered Vehicle Routing Problem (Bettarra, Güneş met Algorithms for the Clustered Vehicle Routing Problem (Bettarra, Güneş and Yigo, 2014).

The case study will be used for application of Vehicle routing problem with pickup and delivery with time windows in the real retail chain. The case study is the method of the qualitative research based on the study of one or a small amount of situations for application of the findings for the similar cases according to Nielsen, Mitchell and Nørreklit (2015).

The case study data represent the data of the real retail chain in the Czech Republic, but this case study is limited to just one depot (central warehouse) which is located in the Praha-východ and the case study is limited for the one round of distribution within the day. The visualization of the depot and customers (stores) is in the Fig. 2.



Fig. 2.

The Visualization of the Depot and Customers (Stores) Source: authors with use Güneş (2018)

Location of the depot, locations of all 50 customers (stores), latitudes, information about start and end of time windows which must be respected, number of pallet space for pickup and delivery (one pallet space represented one standardized euro pallet) are in the Table 1.

Table 1

Locations, Latitudes and Time Windows of the Depot and Customers 01 - 50

Location result of customer P Latifude (s) Latifude (s) start end (pape) Praha-sychod, CZ Depot 50,1274131 14,621371 00:00 23:59 Behd pol Bezdezem, CZ Customer 01 50,001222 14,8014817 05:36 05:00 9 13 Beroum, CZ Customer 03 49,0583331 14,013940 05:15 06:00 3 9 Broumoxy, CZ Customer 05 50,058511 16,3318097 03:30 07:00 8 13 Ceská Stalace, CZ Customer 06 50,346639 16,0427625 04:45 05:00 11 18 Dobruska, CZ Customer 08 50,547128 15,0418339 04:00 06:30 5 17 Fridalen, CZ Customer 10 50,0660141 15,985897 05:00 07:00 8 24 Horice v Podkrkonoši, CZ Customer 13 50,0660214 15,985897 05:00 07:00 18 24 Horice v Podkrkonoši, CZ		Type (denot			Time window		Pickup	Delivery
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Hrádek nad Nisou, CZ Customer 14 50,8527897 14,8445472 06:00 07:00 8 22 Hronov, CZ Customer 15 50,4798497 16,1819714 05:45 07:00 0 13 Chlumec nad Cidlinou, CZ Customer 17 50,8169256 14,9688361 03:30 06:15 7 23 Chrudim, CZ Customer 18 49,9510922 15,795758 04:00 07:00 4 19 Jablonec nad Nisou, CZ Customer 12 50,7243075 15,110772 04:45 07:30 9 6 Jaroměř, CZ Customer 21 50,4372261 15,3516250 03:30 05:00 10 12 Liberec, CZ Customer 23 50,5306247 15,3734103 04:45 07:00 9 9 Mitmón, CZ Customer 23 50,5306247 15,3734103 04:45 05:30 0 15 Mimón, CZ Customer 27 50,5272047 14,9713353 04:15 06:06 8 6 Minchov Hradištč, CZ <t< td=""><td>Hradec Králové, CZ</td><td>Customer 13</td><td>50,2092283</td><td>15,8327683</td><td>05:30</td><td>06:30</td><td>5</td><td>16</td></t<>	Hradec Králové, CZ	Customer 13	50,2092283	15,8327683	05:30	06:30	5	16
Hronov, CZ Customer 15 50,4798497 16,1819714 05:45 07:00 0 13 Chlumec nad Cidlinou, CZ Customer 17 50,1544031 15,4602619 05:15 06:45 8 7 Chrastava, CZ Customer 18 49,9510922 15,7955758 04:00 07:00 4 19 Jablonec nad Nisou, CZ Customer 19 50,7243075 15,1710772 04:45 07:30 9 6 Jaroměř, CZ Customer 21 50,3561958 15,92113644 04:15 08:00 8 24 Jičín, CZ Customer 21 50,739972 15,0584492 04:00 06:30 11 16 Lomnice nad Popelkou, CZ Customer 23 50,2071408 15,2975814 03:30 07:00 11 11 Mimón, CZ Customer 25 50,058686 14,7247361 04:00 06:00 8 21 Miadà Boleslav, CZ Customer 25 50,527047 14,9713353 04:15 06:15 11 22 Most, CZ	Hrádek nad Nisou, CZ	Customer 14	50,8527897	14,8445472	06:00	07:00	8	22
Chlumec nad Cidlinou, CZ Customer 16 50,1544031 15,4602619 05:15 06:45 8 7 Chrastava, CZ Customer 17 50,8169256 14,9688361 03:30 06:15 7 23 Chrudin, CZ Customer 18 49,9510922 15,7555758 04:00 07:00 4 19 Jablonee nad Nisou, CZ Customer 21 50,754758 15,9213644 04:15 08:00 8 24 Jičin, CZ Customer 21 50,470297 15,518440 04:15 08:00 9 9 Mestec Králové, CZ Customer 23 50,5306247 15,3716370 04:45 07:00 9 9 Misto Králové, CZ Customer 24 50,508486 14,7247361 04:00 06:00 8 21 Minchove Hradišté, CZ Customer 27 50,5272047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,310491 15,51147 03:45 07:00 0 19 Nová Mésto nad Metují, CZ<	Hronov, CZ	Customer 15	50,4798497	16,1819714	05:45	07:00	0	13
Chrastava, CZ Customer 17 50,8169256 14,9688361 03:30 06:15 7 23 Chrudim, CZ Customer 18 49,9510922 15,7955758 04:00 07:00 4 19 Jablonec nad Nisou, CZ Customer 19 50,735075 15,1710772 04:45 07:30 9 6 Jaromër, CZ Customer 20 50,3561958 15,9213644 04:15 08:00 8 24 Jičin, CZ Customer 21 50,5306247 15,3574103 04:45 07:00 9 9 Městec Králové, CZ Customer 22 50,5306247 15,3734103 04:45 07:00 8 21 Miada Boleslav, CZ Customer 25 50,658686 14,7247361 04:00 06:00 8 21 Miada Boleslav, CZ Customer 28 50,503069 13,6361742 03:34 07:30 0 29 Machod, CZ Customer 28 50,4167044 16,162883 04:30 07:30 9 20 Most, CZ Customer 3	Chlumec nad Cidlinou, CZ	Customer 16	50,1544031	15,4602619	05:15	06:45	8	7
Chrudim, CZ Customer 18 49,9510922 15,7955758 04:00 07:00 4 19 Jablonce nad Nisou, CZ Customer 19 50,7243075 15,1710772 04:45 07:30 9 6 Jaroměř, CZ Customer 20 50,3561958 15,9213644 04:15 08:00 8 24 Jičin, CZ Customer 21 50,7699972 15,0584492 04:00 06:30 11 16 Lomnice nad Popelkou, CZ Customer 22 50,20711808 15,2975814 03:30 07:00 9 9 Mástec Králové, CZ Customer 25 50,6586886 14,7247361 04:00 06:00 8 21 Miada Boleslav, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 15 Miada Boleslav, CZ Customer 27 50,527047 14,9713353 04:45 05:30 0 11 22 Most, CZ Customer 30 50,444939 15,5151317 06:00 8 6 Nové Maka, CZ	Chrastava, CZ	Customer 17	50,8169256	14,9688361	03:30	06:15	7	23
Jablonec nad Nisou, CZ Customer 19 50,7243075 15,1710772 04:45 07:30 9 6 Jaroměř, CZ Customer 20 50,3561958 15,9213644 04:15 08:00 8 24 Jičín, CZ Customer 21 50,4372261 15,3516250 03:30 05:00 10 12 Liberec, CZ Customer 23 50,5306247 15,3734103 04:45 07:00 9 9 Méstec Králové, CZ Customer 24 50,658686 14,7247361 04:00 06:00 8 21 Miadá Boleslav, CZ Customer 27 50,5527047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,503069 13,6361742 03:45 07:30 9 20 Nová Paka, CZ Customer 31 50,434929 15,5150317 05:00 08:00 6 17 Nové Mésto nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Paradubice, CZ <	Chrudim, CZ	Customer 18	49,9510922	15,7955758	04:00	07:00	4	19
Jaroměř, CZ Customer 20 50,3561958 15,9213644 04:15 08:00 8 24 Jičín, CZ Customer 21 50,47372261 15,3516250 03:30 05:00 10 12 Liberec, CZ Customer 22 50,7699972 15,0584492 04:00 06:30 11 16 Lomnice nad Popelkou, CZ Customer 24 50,2071808 15,2975814 03:30 07:00 9 9 Městec Králové, CZ Customer 25 50,6580886 14,7247361 04:00 06:00 8 21 Mladá Boleslav, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 15 Mnichovo Hradiště, CZ Customer 28 50,503069 13,6361742 03:45 07:30 9 20 Nová Paka, CZ Customer 30 50,4349391 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,32820 16,151464 05:30 06:00 8 6 Nový Bydzov,	Jablonec nad Nisou, CZ	Customer 19	50,7243075	15,1710772	04:45	07:30	9	6
Jičin, CZ Customer 21 50,4372261 15,3516250 03:30 05:00 10 12 Liberec, CZ Customer 22 50,769972 15,0584492 04:00 06:30 11 16 Lomnice nad Popelkou, CZ Customer 24 50,2306247 15,3734103 04:45 07:00 9 9 Méstec Králové, CZ Customer 24 50,2071080 15,2978514 03:30 07:00 11 111 Mimoň, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 15 Minchovo Hradiště, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,1628883 04:30 07:30 9 20 Nová Mesto nad Metuji, CZ Customer 31 50,343922 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 33 50,0385383 15,780266 05:45 07:00 1 11 Podebrady, CZ	Jaroměř, CZ	Customer 20	50,3561958	15,9213644	04:15	08:00	8	24
Liberec, CZ Customer 22 50,7699972 15,0584492 04:00 06:30 11 16 Lomnice nad Popelkou, CZ Customer 23 50,5306247 15,3734103 04:45 07:00 9 9 Městec Králové, CZ Customer 24 50,2071808 15,2975814 03:30 07:00 11 11 Mimoň, CZ Customer 25 50,5586868 14,7247361 04:40 06:00 8 21 Mladá Boleslav, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 15 Michovo Hradiště, CZ Customer 28 50,503069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 30 50,4944939 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 34 50,1242838 16,2748839 03:30 05:30 06:00 7 9	Jičín, CZ	Customer 21	50,4372261	15,3516250	03:30	05:00	10	12
Lomnice nad Popelkou, CZ Customer 23 50,5306247 15,3734103 04:45 07:00 9 9 Méstec Králové, CZ Customer 24 50,2071808 15,2975814 03:30 07:00 11 111 Mimoň, CZ Customer 25 50,6586886 14,7247361 04:00 06:00 8 21 Miada Boleslav, CZ Customer 27 50,5272047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,162883 04:30 07:30 9 20 Nová Paka, CZ Customer 31 50,343952 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 33 50,0385383 15,7802056 05:45 07:00 1 111 Poděbrady, CZ Customer 34 50,122841802 15,5603075 05:15 06:00 7 9 Rychnov nad Kněžnou, CZ	Liberec, CZ	Customer 22	50,7699972	15,0584492	04:00	06:30	11	16
Městec Králové, CZ Customer 24 50,2071808 15,2975814 03:30 07:00 11 11 Mimoň, CZ Customer 25 50,6586886 14,7247361 04:00 06:00 8 21 Mladá Boleslav, CZ Customer 26 50,512047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,1628883 04:30 07:30 9 20 Nová Paka, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 31 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 7 9 Rychnov nad Kněžnou, CZ Customer 35 50,0398478 15,5603075 05:15 06:00 7 9 Rychnov nad Kněžnou, CZ	Lomnice nad Popelkou, CZ	Customer 23	50,5306247	15,3734103	04:45	07:00	9	9
Mimoň, CZ Customer 25 50,6586886 14,7247361 04:00 06:00 8 21 Mladá Boleslav, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 115 Minchovo Hradiště, CZ Customer 27 50,5272047 14,9713853 04:15 06:15 11 22 Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 20 Nová Paka, CZ Customer 30 50,4944939 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 32 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 7 9 Rychnov nad Kněžnou, CZ Customer 37 50,6019053 15,3355211 04:00 06:15 4 6	Městec Králové, CZ	Customer 24	50,2071808	15,2975814	03:30	07:00	11	11
Mladá Boleslav, CZ Customer 26 50,4113514 14,9031850 04:45 05:30 0 15 Mnichovo Hradiště, CZ Customer 27 50,5272047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,162883 04:30 07:30 9 20 Nová Paka, CZ Customer 30 50,4944939 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 33 50,0385383 15,7802056 05:45 07:00 1 11 Poděbrady, CZ Customer 35 50,0398478 15,5603075 05:15 06:00 7 9 Rychnov nad Kněžnou, CZ Customer 36 50,1628389 16,2748839 03:30 05:30 10 12 Semily, CZ	Mimoň, CZ	Customer 25	50,6586886	14,7247361	04:00	06:00	8	21
Mnichovo Hradiště, CZ Customer 27 50,5272047 14,9713353 04:15 06:15 11 22 Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,1628883 04:30 07:30 9 20 Nová Paka, CZ Customer 30 50,4944939 15,515017 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 33 50,0385383 15,7802056 05:45 07:00 1 11 Poděbrady, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 4 18 Přelouč, CZ Customer 37 50,6019053 15,3355211 04:00 06:15 4 6 Stráž pod Ralskem, CZ Customer 38 50,7028011 14,8010175 04:45 07:00 8 5 Tanvald, CZ <	Mladá Boleslav, CZ	Customer 26	50,4113514	14,9031850	04:45	05:30	0	15
Most, CZ Customer 28 50,5030069 13,6361742 03:45 07:00 0 19 Náchod, CZ Customer 29 50,4167044 16,1628883 04:30 07:30 9 20 Nová Paka, CZ Customer 30 50,4944939 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 33 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 4 18 Prelouč, CZ Customer 34 50,1628389 16,2748839 03:30 05:30 10 12 Semily, CZ Customer 38 50,7028011 14,8010175 04:45 07:00 8 5 Tanvald, CZ Customer 39 50,7373536 15,3355211 04:00 06:15 4 6 Stráż pod Ralskem, CZ Custome	Mnichovo Hradiště, CZ	Customer 27	50,5272047	14,9713353	04:15	06:15	11	22
Náchod, CZCustomer 2950,416704416,162888304:3007:30920Nová Paka, CZCustomer 3050,494493915,515031705:0008:00617Nové Město nad Metují, CZCustomer 3150,343952216,151546405:3006:0086Nový Bydžov, CZCustomer 3250,241502515,490820606:0006:30106Pardubice, CZCustomer 3350,038538315,780205605:4507:00111Poděbrady, CZCustomer 3450,142418615,118812204:1506:00418Přelouč, CZCustomer 3550,039847815,560307505:1506:0079Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4349,869118615,580023905:3007:301022Tébechovice pod Orebem, CZCustomer 4349,869118615,580023905:3046Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,512374216,016675 <td>Most, CZ</td> <td>Customer 28</td> <td>50,5030069</td> <td>13,6361742</td> <td>03:45</td> <td>07:00</td> <td>0</td> <td>19</td>	Most, CZ	Customer 28	50,5030069	13,6361742	03:45	07:00	0	19
Nová Paka, CZ Customer 30 50,4944939 15,5150317 05:00 08:00 6 17 Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 32 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 33 50,0385383 15,7802056 05:45 07:00 1 11 Poděbrady, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 4 18 Přelouč, CZ Customer 35 50,0398478 15,5603075 05:15 06:00 7 9 Rychnov nad Kněžnou, CZ Customer 36 50,1628389 16,2748839 03:30 05:30 10 12 Semily, CZ Customer 38 50,7028011 14,8010175 04:45 07:00 8 5 Tanvald, CZ Customer 40 50,6403975 13,8245072 03:45 08:00 0 23 Trutnov, CZ <td< td=""><td>Náchod, CZ</td><td>Customer 29</td><td>50,4167044</td><td>16,1628883</td><td>04:30</td><td>07:30</td><td>9</td><td>20</td></td<>	Náchod, CZ	Customer 29	50,4167044	16,1628883	04:30	07:30	9	20
Nové Město nad Metují, CZ Customer 31 50,3439522 16,1515464 05:30 06:00 8 6 Nový Bydžov, CZ Customer 32 50,2415025 15,4908206 06:00 06:30 10 6 Pardubice, CZ Customer 33 50,0385383 15,7802056 05:45 07:00 1 11 Poděbrady, CZ Customer 34 50,1424186 15,1188122 04:15 06:00 4 18 Přelouč, CZ Customer 35 50,0398478 15,5603075 05:15 06:00 7 9 Rychnov nad Kněžnou, CZ Customer 36 50,1628389 16,2748839 03:30 05:30 10 12 Semily, CZ Customer 37 50,6019053 15,3355211 04:00 06:15 4 6 Stráž pod Ralskem, CZ Customer 38 50,7028011 14,8010175 04:45 07:00 8 5 Tanvald, CZ Customer 40 50,6403975 13,8245072 03:45 08:00 0 23 Trutnov, CZ	Nová Paka, CZ	Customer 30	50,4944939	15,5150317	05:00	08:00	6	17
Nový Bydžov, CZCustomer 3250,241502515,490820606:0006:30106Pardubice, CZCustomer 3350,038538315,780205605:4507:00111Poděbrady, CZCustomer 3450,142418615,118812204:1506:00418Přelouč, CZCustomer 3550,039847815,560307505:1506:0079Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Těbechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Turnov, CZCustomer 4349,869118615,58002905:3007:0096Turnov, CZCustomer 4550,151363316,07697203:4507:15214Ústí nad Orlicí, CZCustomer 4550,151363316,07697203:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,3936106	Nové Město nad Metují, CZ	Customer 31	50,3439522	16,1515464	05:30	06:00	8	6
Pardubice, CZCustomer 3350,038538315,780205605:4507:00111Poděbrady, CZCustomer 3450,142418615,118812204:1506:00418Přelouč, CZCustomer 3550,039847815,560307505:1506:0079Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Témošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4749,973874416,3936106 <t< td=""><td>Nový Bydžov, CZ</td><td>Customer 32</td><td>50,2415025</td><td>15,4908206</td><td>06:00</td><td>06:30</td><td>10</td><td>6</td></t<>	Nový Bydžov, CZ	Customer 32	50,2415025	15,4908206	06:00	06:30	10	6
Poděbrady, CZCustomer 3450,142418615,118812204:1506:00418Přelouč, CZCustomer 3550,039847815,560307505:1506:0079Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Těbechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Témošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,6182350 <td>Pardubice, CZ</td> <td>Customer 33</td> <td>50,0385383</td> <td>15,7802056</td> <td>05:45</td> <td>07:00</td> <td>1</td> <td>11</td>	Pardubice, CZ	Customer 33	50,0385383	15,7802056	05:45	07:00	1	11
Přelouč, CZCustomer 3550,039847815,560307505:1506:0079Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Témošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 4950,626968115,609374204:3007:301023	Poděbrady, CZ	Customer 34	50,1424186	15,1188122	04:15	06:00	4	18
Rychnov nad Kněžnou, CZCustomer 3650,162838916,274883903:3005:301012Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,25	Přelouč, CZ	Customer 35	50,0398478	15,5603075	05:15	06:00	7	9
Semily, CZCustomer 3750,601905315,335521104:0006:1546Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Rychnov nad Kněžnou, CZ	Customer 36	50,1628389	16,2748839	03:30	05:30	10	12
Stráž pod Ralskem, CZCustomer 3850,702801114,801017504:4507:0085Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Semily, CZ	Customer 37	50,6019053	15,3355211	04:00	06:15	4	6
Tanvald, CZCustomer 3950,737353615,305853604:1507:301022Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Stráž pod Ralskem, CZ	Customer 38	50,7028011	14,8010175	04:45	07:00	8	5
Teplice, CZCustomer 4050,640397513,824507203:4508:00023Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Tanvald, CZ	Customer 39	50,7373536	15,3058536	04:15	07:30	10	22
Trutnov, CZCustomer 4150,561006715,912703604:3005:0025Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Teplice, CZ	Customer 40	50,6403975	13,8245072	03:45	08:00	0	23
Třebechovice pod Orebem, CZCustomer 4250,200968315,992231105:0006:30015Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Trutnov, CZ	Customer 41	50,5610067	15,9127036	04:30	05:00	2	5
Třemošnice, CZCustomer 4349,869118615,580023905:3007:0096Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Třebechovice pod Orebem, CZ	Customer 42	50,2009683	15,9922311	05:00	06:30	0	15
Turnov, CZCustomer 4450,587284715,156801106:0007:30317Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Třemošnice, CZ	Customer 43	49,8691186	15,5800239	05:30	07:00	9	6
Týniště nad Orlicí, CZCustomer 4550,151363316,077697203:4505:3046Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Turnov, CZ	Customer 44	50,5872847	15,1568011	06:00	07:30	3	17
Úpice, CZCustomer 4650,512374216,016067505:4507:15214Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Týniště nad Orlicí, CZ	Customer 45	50,1513633	16,0776972	03:45	05:30	4	6
Ústí nad Orlicí, CZCustomer 4749,973874416,393610605:1506:15215Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Úpice, CZ	Customer 46	50,5123742	16,0160675	05:45	07:15	2	14
Varnsdorf, CZCustomer 4850,911543914,618235003:4507:00517Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Ústí nad Orlicí, CZ	Customer 47	49,9738744	16,3936106	05:15	06:15	2	15
Vrchlabí, CZCustomer 4950,626968115,609374204:3007:301023Železný Brod, CZCustomer 5050,642740015,254077505:0008:0087	Varnsdorf, CZ	Customer 48	50,9115439	14,6182350	03:45	07:00	5	17
Železný Brod, CZ Customer 50 50,6427400 15,2540775 05:00 08:00 8 7	Vrchlabí, CZ	Customer 49	50,6269681	15,6093742	04:30	07:30	10	23
	Železný Brod, CZ	Customer 50	50,6427400	15,2540775	05:00	08:00	8	7

Source: authors

VRP Spreadsheet Solver applied these limited conditions for this case study: one depot, fifty customers, the fastest route in Bing Maps, the average vehicle speed was set to 70 kilometers per hour, homogenous car fleet with maximum capacity thirty three pallet space, hard time windows type, service time in depot was one hour and customer service time was half an hour.

4. Results

Results of the vehicle routing problem with pickup and delivery with time windows for the case study are presented in the Table 2, there are twenty three vehicles with defined routes to the customers. Every vehicle starts and ends in the depot. The number in brackets indicates the number of pallet space for pickup and delivery in the depot and for each customer. The vehicle 17 serves only one customer (40), other vehicles serve from two to three customers. Three customers serve vehicle number 3, 4, 16, 18 and 21. This is the optimal solution according to entered inputs with the use of VRP Spreadsheet Solver.

Table 2

Vehicle	Route (pickup/delivery)								
Vehicle 01	Depot (33/0)	Customer 29 (9/20)	Customer 04 (8/13)	Depot (0/17)					
Vehicle 02	Depot (32/0)	Customer 07 (9/16)	Customer 13 (5/16)	Depot (0/14)					
Vehicle 03	Depot (33/0)	Customer 36 (10/12)	Customer 45 (4/6)	Customer 47 (2/15)	Depot (0/16)				
Vehicle 04	Depot (31/0)	Customer 34 (4/18)	Customer 16 (8/7)	Customer 32 (10/6)	Depot (0/22)				
Vehicle 05	Depot (31/0)	Customer 01 (9/22)	Customer 08 (8/9)	Depot (0/17)					
Vehicle 06	Depot (29/0)	Customer 49 (10/23)	Customer 37 (4/6)	Depot (0/14)					
Vehicle 07	Depot (33/0)	Customer 27 (11/22)	Customer 24 (11/11)	Depot (0/22)					
Vehicle 08	Depot (31/0)	Customer 10 (9/14)	Customer 48 (5/17)	Depot (0/14)					
Vehicle 09	Depot (33/0)	Customer 06 (11/18)	Customer 42 (0/15)	Depot (0/11)					
Vehicle 10	Depot (30/0)	Customer 05 (3/9)	Customer 25 (8/21)	Depot (0/11)					
Vehicle 11	Depot (28/0)	Customer 28 (0/19)	Customer 03 (3/9)	Depot (0/3)					
Vehicle 12	Depot (29/0)	Customer 39 (10/22)	Customer 50 (8/7)	Depot (0/18)					
Vehicle 13	Depot (30/0)	Customer 11 (8/24)	Customer 43 (9/6)	Depot (0/17)					
Vehicle 14	Depot (33/0)	Customer 35 (7/9)	Customer 20 (8/24)	Depot (0/15)					
Vehicle 15	Depot (29/0)	Customer 17 (7/23)	Customer 19 (9/6)	Depot (0/16)					
Vehicle 16	Depot (32/0)	Customer 41 (2/5)	Customer 46 (2/14)	Customer 09 (10/13)	Depot (0/14)				
Vehicle 17	Depot (23/0)	Customer 40 (0/23)	Depot (0/0)						
Vehicle 18	Depot (31/0)	Customer 21 (10/12)	Customer 31 (8/6)	Customer 15 (0/13)	Depot (0/18)				
Vehicle 19	Depot (33/0)	Customer 22 (11/16)	Customer 44 (3/17)	Depot (0/14)					
Vehicle 20	Depot (30/0)	Customer 18 (4/19)	Customer 33 (1/11)	Depot (0/5)					
Vehicle 21	Depot (33/0)	Customer 12 (5/7)	Customer 30 (6/17)	Customer 23 (9/9)	Depot (0/20)				
Vehicle 22	Depot (28/0)	Customer 26 (0/15)	Customer 02 (9/13)	Depot (0/9)					
Vehicle 23	Depot (27/0)	Customer 38 (8/5)	Customer 14 (8/22)	Depot (0/16)					

Solution of the Case Study With Individual Routes and Information About Pickup and Delivery

Source: authors

The visualization of the solution for twenty three vehicles and routes is presented in the Fig. 3.



Fig. 3. *The Visualization of the Solution (Twenty Three Vehicles) Source: authors with use Güneş (2018)*

5. Conclusion

In the future can be expected a further increase of traffic intensity due to population growth and population's increasing demands on mobility. The growing boom of e-commerce will lead to greater pressure on distribution logistics and the rising popularity of retail chains, rising sales and higher sales volumes increase the demand for distribution logistics of retail chains. On the other hand, it is necessary to emphasize the need to reduce the negative impacts of transport. One of the potential to reduce the negative impacts of distribution logistics is to use efficient planning tools to optimize the distribution logistics of the retail chain.

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