THE USING OF SOLVER SOFTWARE AND VEHICLE ROUTING FOR THE TRAVELING SALESMAN PROBLEM

M.Sc. Krstev D. PhD.[1], M.Sc. Pop – Andonov G.PhD.[2], Prof. Krstev A.PhD[3], Prof. Djidrov M.PhD[2],Prof. Krstev B.PhD[1], M.Sc Sashe Pavlov[1]
Faculty of Mechanical Engineering, University "Cyril and Methodius"-Skopje, the Republic of Macedonia[1]
Faculty of Mechanical Engineering, University "Goce Delcev"-Stip, the Republic of Macedonia[2]
Faculty of Computer Science, University "Goce Delcev"-Stip, the Republic of Macedonia[3]
Faculty of Natural and Technical Science, University "Goce Delcev"-Stip, the Republic of Macedonia[1]
E-mail: krstev.deni@gmail.com E-mail: goran.pop-andonov@ugd.edu.mk E-mail: misko.djidrov@ugd.edu.mk E-mail: boris.krstev@ugd.edu.mk E-mail: aleksandar.krstev@ugd.edu.mk

Abstract:*The traveling salesman problem (TSP) is one of the most studied problems in management science. Optimal approaches to solving traveling salesman problems are based on mathematical programming. But in reality, most TSP problems are not solved optimally. When the problem is so large that an optimal solution is impossible to obtain, or when approximate solutions are good enough, heuristics are applied. Two commonly used heuristics for the traveling salesman problem are the* ***nearest neighbor procedure*** *and the* ***Clark and Wright savings heuristic.***

In this paper will be present using of the solver software and principles of TSP for optimal solution of vehicle routing for domestic bottled water and different juices in the different parts of the Republic of Macedonia.

Key Words: TSP, NNP, CWSH, routing

1. Introduction

Logistic system of a company contains a fixed number of places where raw materials, materials, semi-finished and finished products remain appropriate time, whether they are in undergoing treatment or in the warehouse. The link between fixed locations is provided by the transportation system. Transport provides goods to move between various fixed points which bridges the space between buyer and supplier .For efficient and economical operation of the logistic system it is necessary to have knowledge of the transport system . The role of transport is especially important today in terms of globalization , when companies are geographically dispersed or are distant from the sources of supply , causing dependence of transport whose task is to connect companies with sources of supply on the one hand and consumption on the other.

The goal of most transportation problems is to minimize the total cost of providing the service. It includes capital expenses for the vehicle, mileage and distance or personal expenses. But other goals may also come into play. In [6], [7] and [8] vehicle routing problem is solved using different optimization methods as dynamic optimization, linear optimization, graph theory, game theory. For optimization criterion is chosen transport costs [6, 8] or fuel consumption [7].

Problems of Routing and Scheduling are commonly displayed in graphical networks. Using networks to describe these problems take precedence over allowing decision makers to visualize the problem under study. The given picture below, which consists of five circles called nodes from which four nodes (2-5) represent the locations of delivery, and the fifth node (1) represents a node of the store or warehouse, where the tour begins or ends of vehicles.

Whit bonding of these nodes is obtained line segments called arcs. They can mark time, cost or distance required to pass from one node to another. Arches can be direct or indirect. Indirect arcs are represented by simple line segments.

Direct arcs are displayed in brackets. These brackets represent the direction of the drive in case of problems in routing (e.g., one-way streets) or preferential treatment in case of problems in the schedule (where a pick-up or delivered quantity must prevail over the other).

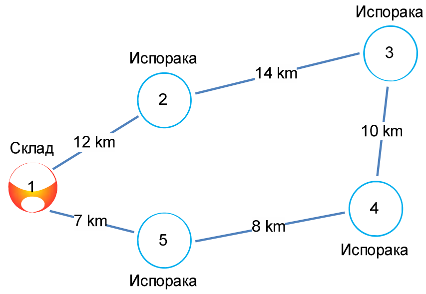

Figure1. *Routing Network Example*

From the image can be seen the simple routing of the single vehicle. Road that the vehicle passes is called the tour, and that is the direction 1 → 2 → 3 → 4 → 5 → 1 or when arches are indirect, 1 → 5 → 4 → 3 → 2 → 1. The total length of either of the two tours is 51 km. The feasibility depends on the type of problem, but in general, it implicates: The tour must include all nodes; node must be visited only once, tour must start and end in the store or warehouse. In the simplest case, you should start with a network of nodes that must be visited by a vehicle. Nodes can be visited in any order, no priority, travel expenses between two nodes is also irrelevant to the driving direction. In addition, the bearing capacity of the vehicle is not taken into account. The performance for the problem of single-vehicle road or tour where each node is visited only once and routing begins and ends at the warehouse. The tour is being created in order to minimize the total cost of the overall tour. The simplest case is known as the Traveling Salesman Problem (TSP). Traveling Salesman Problem (TSP) is one of the most studied problems in management science. Optimal achievements to solve traveling salesman problems are based on mathematical programming. But in reality, most of TSP problems cannot be solved optimally. When the problem is real big and complex, then an optimal solution is impossible to obtain, in these cases programming techniques and principles are applying. Two techniques are generally used for TSP problems including: Nearest neighbor procedure and Clark and Wright savings heuristic.

Nearest neighbor procedure (NNP) builds a tour only in accordance with the cost or driving distance from the last visited node to the nearest node in the network. In this case, the technique is simple, but it has the disadvantage of having nearsightedness or inaccuracy, which is evident from the following example. The procedure is outlined in the following: Start with the top node of the tour (warehouse or storage node), finding the closest node to the last node added to the tour, a return to step 2. Whilst all nodes are added, connecting the first and last nodes to create a complete tour.

The table below provides the complete distance matrix for symmetric six-node network shown in the figure below.

Table1. *Distance matrix for symmetric six-node network*

Од јазол	До јазол (дистинацијата во километри)					
	1	2	3	4	5	6
1	-	5.4	2.8	10.5	8.2	4.1
2	5.4	-	5.0	9.5	5.0	8.5
3	2.8	5.0	-	7.8	6.0	3.6
4	10.5	9.5	7.8	-	5.0	9.5
5	8.2	5.0	6.0	5.0	-	9.2
6	4.1	8.5	3.6	9.5	9.2	-

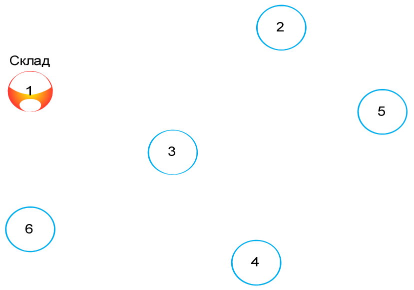

Figure2. *Traveling Salesman Problem*

According to the picture, the solution is determined as follows: Beginning at the initial node (node 1) and it is examined and considered the distances between one node and every other node. The created complete tour is 1 → 3 → 6 → 2 → 5 → 4 →1. The length of the tour amounted is 35,4 km.

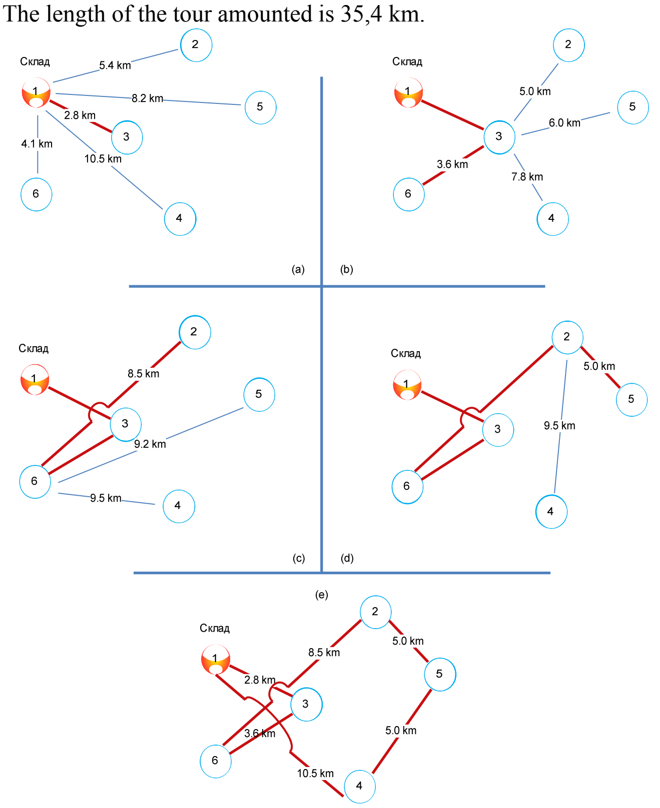

Figure 3. *Nearest neighbor Procedure*

However, the question is whether this represents the best tour or driving route? Consider again the network and try to find a better tour. Such as 1 → 2 → 5 → 4 → 3 → 6 → 1? The total length of this tour is 30.9 vs. 35,4 km to Nearest neighbor-constructed tour. This results in limitations of the technique and the principle or the application of this technique does not guarantee optimality. In this small network, it would be possible to re-label all possible tours. However, a number of problems with 100 to 200 nodes, re-labeling or renumbering every possible combination would be impossible. Before leaving this technique (NNP), it is necessary to note that, in practice, the techniques are applied to denote repetition by every possible initial node to node, resolving the problem, and then selects the lowest cost tour as a final solution . For example, if you repeat the procedure using the node 6 as the starting node, the tour will result in another length or 6 → 3 → 1 → 2 → 4 → 5 → 6 and a length of 31,3 km.

Clark and Wright savings heuristic procedure is one of the best known techniques and methods to solve TSP problems. It begins with the selection of a node as the starting node and marking the node first then it is assumed, for the moment, there are available n-1 cars, where n is the number of nodes. In other words, if we have 6 nodes in the network, then there are 5 available vehicles. Each vehicle travels from the warehouse or from the starting node to another node and returns to the starting node. But this is not practically possible solution because the purpose of TSP-problem is to find a tour in which all the nodes will be visited by a vehicle, rather than two separate vehicles, as shown in the picture. To reduce the number of vehicles required, it is necessary to combine n-1 tours originally specified.

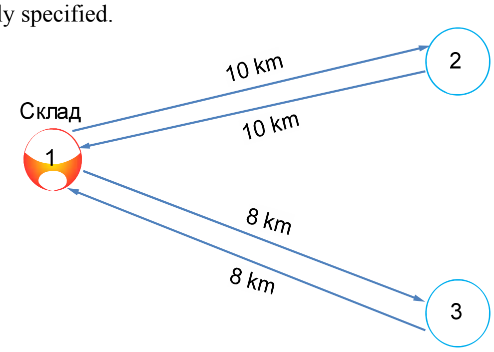

Figure4. *Initial C&W Network Configuration: Three-Node Problem*

The key to Clark and Wright savings heuristic procedure is to calculate savings. "Savings" is a measure of how much the driving range or cost can be reduced with "hooking up" - hanging a pair of nodes (in the case of the picture above nodes 2 and 3) and to create a tour 1 → 2 → 3 → 1, which can be marked for one vehicle. "Saving" is calculated as follows: By connecting nodes 2 and 3, add 5 km (distance from node 2 to node 3), but save 10 km of road from node 2 to node 1 and 8 km route from node 3 to node 1, total distance or length of tour 1 → 2 → 3 → 1 is 23 km. "Saving" which is obtained with the new configuration is 13 km. For a network with n nodes, calculate savings for each possible pair of nodes, and the amount of savings reaches Descending savings, so tours are constructed by linking the different possible pairs of nodes until a complete routing is obtained. The exhibit S & W savings heuristic procedure is as follows: Select any node as the starting node (node 1) Calculation of savings, Sij for linking the nodes i, j, and Sij = c1i + c1j-cij for i, j, = nodes 2, 3, ..., n, where cij = cost of driving from nodes i → j, Order of the savings from the biggest to the smallest, Starting at the top of the list of most sub-tour by connecting the appropriate node s and j. Stop when full tour is formed. As a demonstration of this procedure a TSP-problem is used, the network shown in the image below. It is assumed that there is one vehicle for each node (excluding the starting node) in the network. Full drawn lines show arches in use when starting with S & W savings heuristic procedure. Dashed lines show the arches that can be used, but are not currently used.

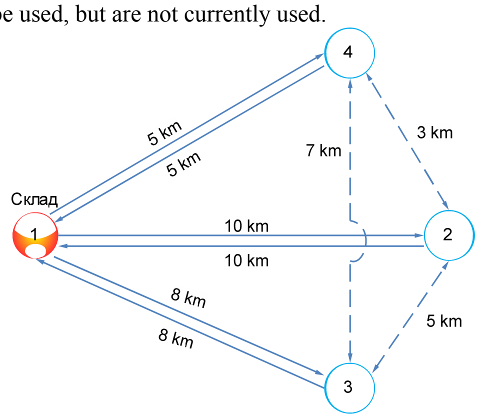

Figure 5. S & W savings heuristic procedure.

The next row of the savings for each pair of nodes is still connected. In order to save, the couples [2,3], [2, 4] and [3, 4]. The first step in the specification of a tour is to connect nodes with the highest savings, which are nodes 2 and 3. The resulting path is shown in Figure (a) below. Processing the future top savings, nodes 2 and 4 are connected according to Figure (b) below. The tour is now complete, as the last pair of nodes, 3 and 4 cannot be merged without disruption of the tour. The complete tour is 1 → 4 → 2 → 3 → 1, which has a total length of tour of 21 km. The total savings obtained for the configuration "one vehicle per node" which is shown in the picture is 25 km.

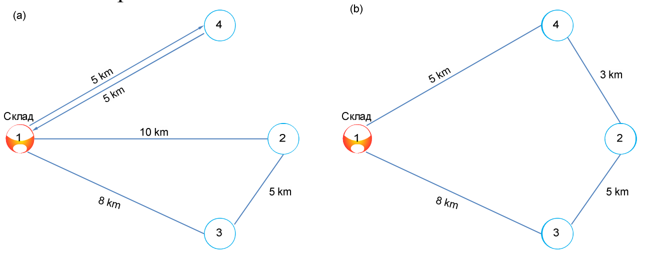

Figure 6. (a) *2-3 node connection, (b)2-4 node connection*

In general, because S & W savings heuristic procedure takes into account the cost when construct the tour; achieve better quality solutions compared to the nearest neighbor procedure (NNP). However, both procedures can easily be adjusted to suit the problems with direct arcs.

2. Traveling Salesman Problem (TSP)

When the problem is real big and complex, and it is a transportation of juices or carbonated mineral water, energy drinks Gorska - Koding - Skopje, then an optimal solution is impossible to obtain or when sufficient or sufficiently accurate approximate solutions are apply, than programming principles and techniques are used. Generally are used for solving TSP problems and the technique is: Nearest neighbor procedure.

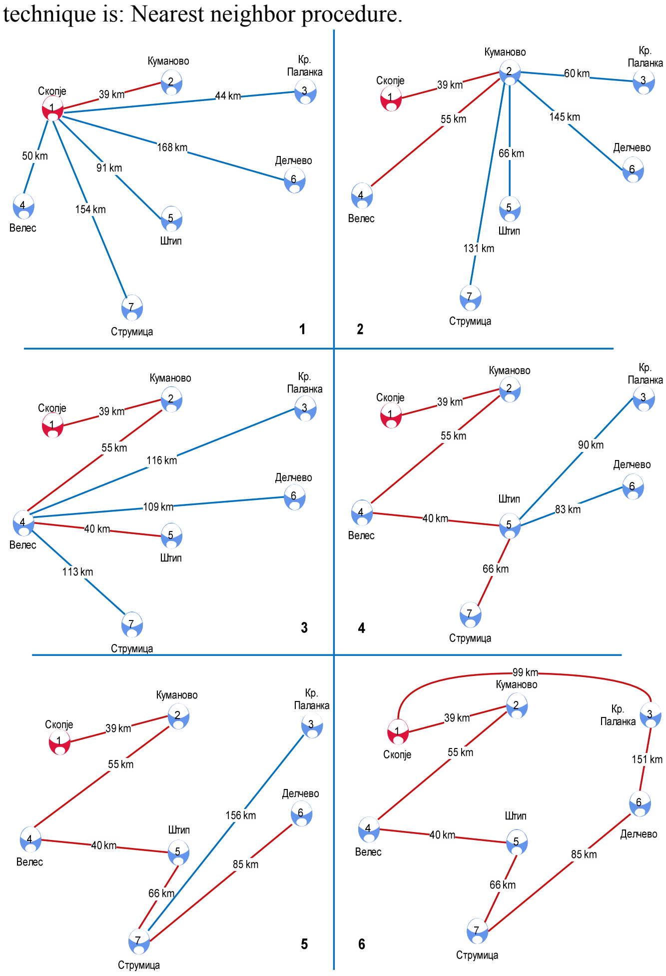

Figure 7. *Regional distribution network in Eastern part of Macedonia using the TSP*

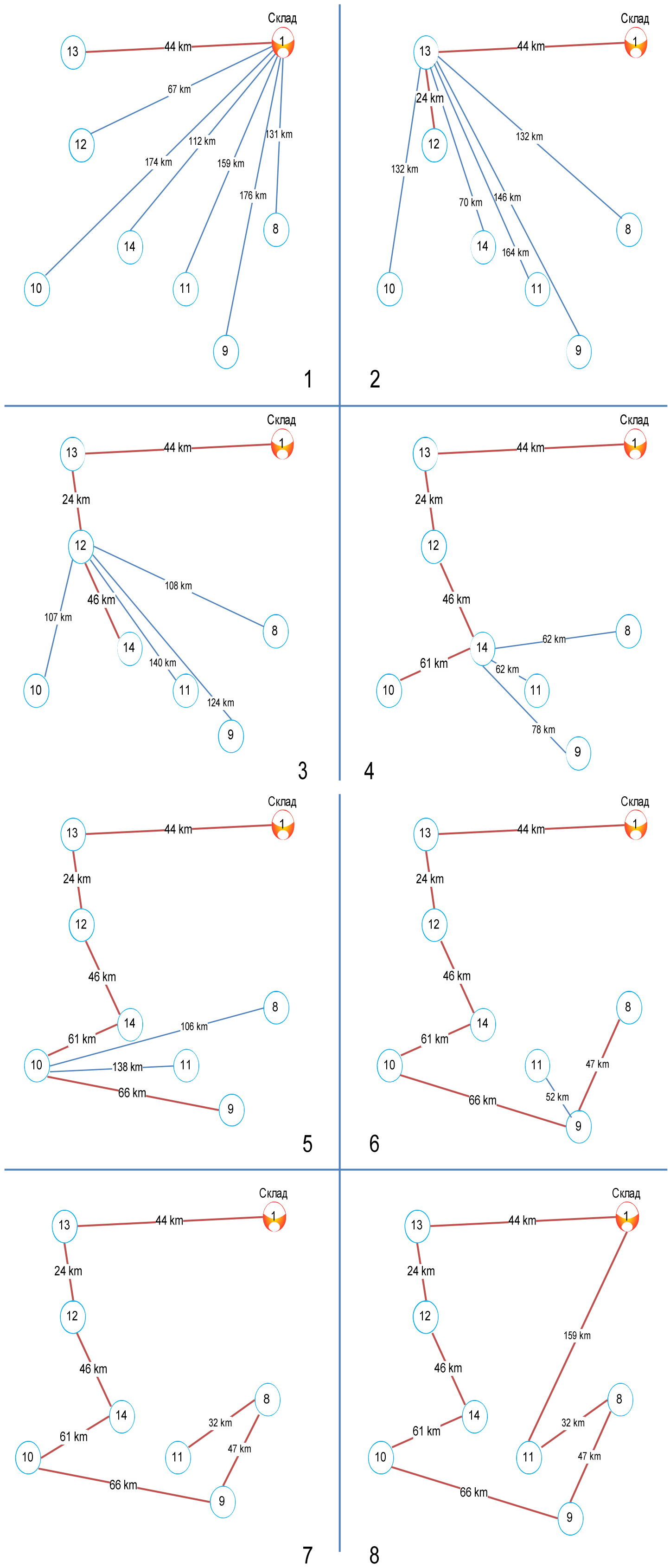

Figure 8. *Regional distribution network of Western part of Macedonia with TSP*

Conclusion

Reviewing the solutions of vehicle routing above picture you can create a complete tour 1 → 2 → 4 → 5 → 7 → 6 → 3 → 1 whose length is 535 km. Because this method does not always give the optimal value of the tour, we will again consider the network and try to find a better tour, such as 1 → 4 → 6 → 7 → 5 → 3 → 2 → 1. Total length of this tour is 461 km, versus the previous 535 km, or 48 km difference. Reviewing the solutions of vehicle routing as in picture 45, we can create a complete tour 1 → 13 → 12 → 14 → 10 → 8 → 9 → 11 → 1 whose length is 479 km. Because this method does not always give the optimal value of the tour, we will again consider the network and try to find a better tour, such as 1 → 13 → 12 → 14 → 10 → 9 → 11 → 8 → 1. The total length of this tour is 456 km, versus the previous 479 km, or difference 23 km.

Literature

[1] Котлер Ф., Армстронг Г., (2008), Принципи на маркетинг, 13то издание, Дата Понс (2009), 130-370.
[2] Котлер Ф., Келер К. Л., (2009), Маркетинг менаџмент, 13то издание, Дата Понс (2009), 2-70.
[3] Котлер Ф., Ли Н., (2010), Маркетинг во јавниот сектор, 3то издание, Дата Понс (2009), 30-90.
[4] Голомеова М., (2012), Маркетинг логистика, Скрипта УГД-ФПТН-Штип.
[5] Беј М. Р., (2009), Економија на менаџментот и бизнис страстегијата, Влада на РМ.
[6] Stoilova S. Investigation and optimization the allocation of empty wagons on the rail network. Proceedings of the Fifteenth International Scientific and Technical Conference "Transport, Environment - Sustainable Development" ECO Varna'10, pp.145-152, May, 2010, http://www.tu-varna.bg/tu-varnattt/images/eko_2010.pdf
[7] Stoilova S. Network models for traffic management of vehicles. Virtual journal for science, techniques and innovations for the industry “Machines, Technologies, Materials”,vol.1, pp.47-56, 2012, http://mech-ing.com/journal/1-2012.html
[8]Stoilova, S., Method for optimization of the interaction between the transport vehicles in the transport centers. Scientific papers: Horizons of railway transport, Zilina, Czech Republic– Vol.2, 2011, pp.134 – 141.