OPTIMIZING COLLECTION ROUTES OF COLLECTION PLACES

JANA NOVOTNA¹, STANISLAV BARTON², LUKAS RENCIN²
¹Department of Agricultural, Food and Environmental Technology
²Department of Technology and Automobile Transport
Mendel University in Brno
Zemedelska 1, 613 00 Brno
CZECH REPUBLIC
xnovot62@node.mendelu.cz

Abstract: This thesis attends to the optimization of separated waste collection routes, the waste is being collected by the company Technické služby VM s.r.o. The solution is carried out according to the salesman's methods with farthest insertion's algorithm. This algorithm provides possible solutions in an interface of two algebraic systems Maple and Bjornson's application. The routes for separated waste collection, which are compared, constitute an output.

Key Words: collection route, algorithm, waste, separated waste, optimisation

INTRODUCTION
Waste production has become part of everyday life. With the increasing number of inhabitants of our planet is increasing the amount of waste produced. Nowadays, it is therefore necessary to ensure the minimization of waste and the efficient management of waste. There are many effective methods of waste recovery or removal. In most cases, however, necessary to move the waste from the place of origin to the place of its processing. For effectively loading with waste, must also be provided efficient methods of collecting, gathering, treatment and transportation of waste. This work is primarily devoted to the issue of waste collection routes from sites, where waste is collected, to the sites, where waste is inspected, used and maintained.

To tackle the issue of efficient waste collection method is used Salesman (Cook 2012). The traveling salesman problem belongs to the category of optimization problems where the objective is to find the shortest route between points so that the optimized route passing through each point exactly once and returning back to the starting point. Using optimization methods for collection and transportation of waste, the loading of waste can significantly streamline and accelerate (Burdová 2011). Many information and logistics systems are able to streamline and automate a large portion of processes. This leads to an increase in the quality of services, centralization of data, easier administration tasks and possibilities of evaluation and planning activities.

This work focuses on optimizing the routes of collection points. Salesman methods are therefore applied to the selected collection area and an optimized path is created between the villages.

MATERIAL AND METHODS
The aim was to create optimized routes for the collection of plastic, paper, colored glass, white glass and biodegradable waste. Collecting area, which is administered by Technical Services Velké Meziříčí (TSVM), representing 54 municipalities, including local areas around the Velké Meziříčí. For each type of waste was made a list of municipalities where there is a collection of the waste (Běloch 2014). As input data were used maps that are available from the server www.mapy.cz/, and GPS position coordinates villages (www.mapy.cz).

Creating of collection routes was made in the program Bjornson’s application available online from websites and http://bjornson.inhb.de (Bjornson 2008) and in program Maple. Both of these software creates optimal a collecting route by using the algorithm farthest insertion. Editing and route optimization was performed manually and by using Maple (Bartoň 1999).
Algorithm of farthest insertion belongs to the methods of insertion algorithms. The principle of the method of inserting cities into partial paths is to start building a partial path with several points and in further steps this way adjusted to the final stage include all the points. These techniques are generally referred to as the insertion algorithms. Currently, there are several variants of these algorithms, which differ by the selection of the next point. In all variants of these algorithms have the total length of the partial route increase minimally. Variant of farthest insertion selects one next point of partial route, which is farthest from one of the points in already built partial route.

Algorithm of farthest insertion in Bjornson’s application does not allow you to insert your own data, it was necessary to all municipalities in which it is carried out of the collection of separated waste, assign coordinates \([X, Y]\) that determine their position and mutual distance on the axes. Instead villages that appear normally on the map portals, has therefore created a set of points, supplemented by one point \([0]\), which represents the starting position of each vehicle, and ending with the highest numerical value that represents the last visited site on the route (in this case, always local landfill where there is a weighing of all vehicles on vehicle weight) before the vehicle returns to the starting point \([0]\), where there is a emptying of a collection vehicle, the sanitation, maintenance and necessary administrative tasks. These two points are always part of optimized routes for each separated waste separately.

In the program Maple, to optimize data was used the Petřík’s algorithm of farthest insertion. This algorithm is fully described in the collection 11th Summer School of Applied Informatics and for his extent is described here only briefly. (Hřebíček et al. 2014). This algorithm has been after professional consulting adapted and adjusted to optimally processed input data. The first step of Petřík´s algorithm in the program Maple was retrieved the data. From the assigned GPS coordinates were calculated coordinates of the center collecting areas and take into account the curvature of the earth. The middle of the collecting area is always assigned to coordinate \([0,0]\) on the chart (Hřebíček et al. 2014). Points in the argument then was assigned serial numbers in alphabetical list of municipalities and new coordinates \([X, Y]\). Furthermore, the determined number of processed points, which varies depending on the type of separated waste. The smallest number of points includes races for collection of biodegradable waste. Most points within the route for collection and transport of plastic. It was subsequently determined the distance between any two points and then was created a matrix clearance distances of individual points. It was now possible to create an algorithm farthest insertion.

At the beginning the loop has been created, which gradually passed through all the possible pairs of the initial points. Among the selected pair was created segment and these two items were removed from the matrix. It was determined the remaining number of points in the array. It was subsequently determined distance remaining points from the resulting lines and was selected point, which was located farthest from the segment. With this item was created the triangle that formed the basis of partial routes. Point was eliminated from a matrix and there was a re-conversion points from the remaining distance lines. Again, it was chosen farthest point. Into partial routes has been incorporated so that there is a disconnection of the existing lines, and created two new line segments with a given point. The procedure of finding and subsequent inclusion in the farthest point to an existing partial route was repeated until the matrix was left in no point. If using a loop attempting to find a better pair of starting points, the result was a shorter route than in the previous selection, initial route was replaced by a new shorter route. The last step listed the course of the route point by point by the assigned serial numbers and calculated the total distance of the route. Optimal route created be using Maple were graphically displayed and for individual folders sorted waste are presented with descriptions for the following part of this work.

**RESULTS AND DISCUSSION**

Initial analysis of the data held in the program Bjornson's application, which is available online (Bjorson 2008). This application offers to solve the traveling salesman problem using four optimization methods. The disadvantage is that the points to be placed manually on a preformed grid so it is necessary to take into account human error factor. Bjornson's application may well serve for an initial analysis of data, based on which it is possible to opt for a more appropriate selection algorithm or choose a different approach. Thanks to the preliminary data analysis for the next steps of this work chosen algorithm of farthest insertion. The algorithm of farthest insertion showed the best results in comparison with the
other three algorithms (next neighbour, nearest insert and cheapest insert) from Bjornson’s blog (Novotná 2016). Also Cook (2012) reported that algorithm of farthest insertion is best out of these four.

Table 1 All of optimized routes for separated waste with manual adjustment

<table>
<thead>
<tr>
<th>Waste</th>
<th>Bjornson’s application</th>
<th>Petřík’s algorithm in Maple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>Plastic</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>Colored glass</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>White glass</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>Biodegradable waste</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

For collecting paper occurs in 31 municipalities, plastic is collected from 34 municipalities, colored glass from 31 municipalities, white glass from the 30 municipalities and biodegradable waste from 21 municipalities (Novotná 2016).
In the Maple system was created five optimized routes using the Petřík’s algorithm of farthest insertion. Some of the routes were manually adjusted. Adjustment was necessary to satisfy the conditions set TSVM. This condition is weighing of a collection vehicle on vehicle weight and his move to the headquarters TSVM after the vehicle clears all the collection container of optimized routes. For these adjustments were not used special methods. But as Cook (2012) says in his publication, can be used for further modification n-opt algorithms. The optimized routes were created in Bjornson’s application too. All of these routes are included in the Table no. 1. Manual adjustments are displayed by red lines.

The outputs of the two applications cannot be combined. Therefore, there was a measuring lengths of optimized routes by independent tool. It was made by tools "Measuring lengths", which is available online on server www.mapy.cz/. The measurement results are shown in Table no. 2 and individual data are compared with each other. The table presents the types of separated waste for which routes has been optimized. The first column indicates the type of the optimization and final difference in length. All figures are shown in meters.

The output of Bjornson's applications were routes for collection of paper, plastic and white glass, which were in line with the condition imposed by TSVM and these routes did not need to be changed. These routes have been measured airline ideal distance. The optimized route for the transport of paper contained 33 points, where cartage vehicle must pass in order to empty all containers collecting this kind of separated waste. This route with an accuracy of tens of meters has a length of 86,640 meters. The route for the transport of plastic is 88,310 meters and the car must pass 36 points. For the collection of white glass collecting vehicle must pass 32 points and the length of the optimized route is 81,160 meters. Routes for collection of colored glass and biodegradable wastes that were created using Bjornson's application had to be manually adjusted. Modifications were carried out with respect to all field conditions. Flying route for collection of of colored glass, after all editing has been reduced by 7,960 meters, its total length is 85,520 m. Pick-up truck has to pass 33 points. Air route length for collection of biodegradable waste is 68,570 meters, and the route was shortened adjustments of 770 m. For this kind of collection of separated waste collecting vehicle must pass 23 points.

Adjusted Petrik's algorithm in Maple created optimized routes for collection of plastic, white glass and biodegradable waste, which no longer need to be modified. The length of the route optimized for the collection of plastic is 88,470 meters. In comparison with the final route of Bjornson's application, the route created in Maple was extended by 160 m. This distance is negligible with respect to the total distance of the route. The route for the transport of white glass, which was created in Maple, is long 83,350 meters. Compared with optimized route of Bjornson's application is extended by 2,190 meters. The Maple created an optimized route for collection of biodegradable waste, which was long 65,020 m. This route compared with Bjornson's route is shorter by about 3,550 meters. Routes for the collection of paper and colored glass that were created in Maple, had to be manually adjusted. There was the condition set by TSVM. Both routes lead to modifications extension of these routes. At routes for collection of paper was an extension of the original route of 1580 meters. The final route has a length of 88,950 meters. It is about 2,310 meters longer than the route created by Bjornson's application. The route for the transport of of colored glass has been extended by 490 m. The final length of the routes is 87,440 meters, and the route is about 1,920 meters longer than the route created by Bjornson's application. After comparing the lengths of the final routes by using the system Maple was created a single route whose length is shorter than the route optimized through Bjornson's application. This route is designed for the collection of biodegradable waste. Another route for the collection of other types of separated waste were compared with Bjornson's applications longer. The smallest difference in comparison final routes was 160 m and the biggest difference 3,550 meters. These routes are of course ideal air optimization and they do not coincide with the real used routes. Solution does not include the municipality in which only leads one way or does not reflect the actual profile of the terrain and the condition of roads.

Author of Bjornson's application sees as a disadvantage that it is not possible to insert your own GPS coordinates to the application (Bjornson 2008). Points representing municipalities must be manually placed on a display grid. This can cause deviations in the route optimization and better results compared to the system Maple. The advantage of using the Maple program is that it enables complex processing of the problem. It allows input your own coordinates, transformations of coordinates,
calculations of the lengths of the routes and processing of already transformed data. Maple enables gradual simplification of the problem by using command of library Graph theory (Petřík and Bartoň 2016).

Current outputs of both systems offer further possibilities for reflection to optimize the routes. One possible suggestion is to create a command line that includes the condition set by TSVM directly into the algorithm. The next step could be to take account of municipalities, which leads to only one path, and also create arrays that would contain the actual distance between the villages.

Table 2 Length of optimized routes

<table>
<thead>
<tr>
<th>Application</th>
<th>Paper [m]</th>
<th>Plastic [m]</th>
<th>Colored glass [m]</th>
<th>White glass [m]</th>
<th>Biodegradable waste [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bjornson’s application</td>
<td>86 640</td>
<td>88 310</td>
<td>85 520</td>
<td>81 160</td>
<td>68 570</td>
</tr>
<tr>
<td>Petřík’s algorithm</td>
<td>88 950</td>
<td>88 470</td>
<td>87 440</td>
<td>83 350</td>
<td>65 020</td>
</tr>
<tr>
<td>Difference in length</td>
<td>2 310</td>
<td>160</td>
<td>1 920</td>
<td>2 190</td>
<td>3 550</td>
</tr>
</tbody>
</table>

CONCLUSION

This article shows how the Salesman problem may be used in the issue of waste management. Because there is currently no way to create the optimal route in a reasonable time, there are disclosed two methods, how the algorithm of farthest insertion can be used to optimize waste collection routes and how this algorithm behaves in two different programs. These programs are Bjornson’s application and algebraic system Maple. Both of these systems have been tested on five waste collection routes under management of TSVM.

System Maple exhibits a high accuracy because optimized routes are made with using the GPS coordinates of villages that can be loaded into the program. It is impossible to enter the same data to Bjornson’s application. Points representing municipalities must be manually placed on a display grid. This may cause deviations in the route optimization. But both of these methods can be used by the collecting companies for making waste collection more efficient processes while sparing the environment.

ACKNOWLEDGEMENT

The presented work has been prepared with the support of IGA MENDELU IP 10/2016 Verification of the model force action in a three-point hitch.

REFERENCES
