1 Introduction

Calculations based on the compilation of algorithms may be included as a part of the significant field of use of mathematical calculations for the optimization and Operations Research of traffic problems. Generally, these calculations relate to the distribution of goods from source (sources) to the scattered destinations. One of the possibilities for solving the traffic problems is the use of the “Simplex method”.

This example deals with the special group of traffic problems which can be called as “shuttle traffic problems”. The goods must be delivered from the supply warehouse $S_0$ (for example cross-dock warehouse) to the selected customers, the shopping centers placed in the area of the city of Žilina in our case, $(S_1, S_2, \ldots, S_n)$, which are supplied one by one [1], [2].

Let $d_i$ denotes the distance between $S_0$ and $S_i$ and the determination of the optimal supply sequence which minimizes the total waiting time of customers for supplied goods is the target problem [1], [2].

This particular example relates to the typical “shuttle traffic problems”, which means that the individual problems depend on the total waiting time of customers.

2 Analysis of the utilized logistics solutions for supplies

The hypermarkets supply utilizes four types of goods supply [3]:

a) direct – the goods is supplied directly to the customers,
b) cross – docking – the goods is not stored (system of immediate goods reloading),
c) central warehousing – supply from one or more central warehouses,
d) direct full truck loads – the goods is supplied to the customers in full truck loads.
Cross-docking

Nowadays, cross-docking is more and more used type of the storage systems. It represents the immediate goods reloading from the place of goods input through the warehouse directly to the place of goods expedition. It is one of the many techniques in the supply chain which aims to reduce the inventory, improve the space utilization and increase the efficiency of equipment used to supply.

Cross-docking technique is also known as “bulk with order”, “pick to zero“, “pick by line“ and “over the bank“. It includes the unloading the partially assembled products for integration with other key orders prior to the next delivery to retail stores.

Enterprises that meet at least two of the following criteria should consider the introduction of the cross-docking system [3]:

- after the receipt of goods in the warehouse, its destination is already known (for example the hypermarket department),
- customers are ready to take the goods immediately,
- daily, the goods supplies are distributed to less than 200 localities,
- the enterprise receives a large number of items,
- received goods is already marked (tags or codes),
- certain kinds of goods are time sensitive items.

3 Simple Shuttle Problem

The operation of shopping centers with one vehicle from one CROSS-DOCK warehouse

The essence of a “simple shuttle problem” is to minimize the customers total waiting time for goods

\[ \sum_{i=1}^{n} t_i \]  

(1)

where \( t_i \) is the waiting time of the customer \( S_i \)

It is assumed that carriage of goods between \( S_0 \) - supply (cross - dock) warehouse and the customer \( S_i \) is carried out by one vehicle and also that the vehicle returns to the starting warehouse \( S_0 \) after the supply of goods.
For constant vehicle speed, waiting times $t_i$ may be replaced by the traveled distance $d_i$ between the starting supply warehouse and the individual customers $S_i$ [2].

\[
\begin{align*}
  t_1 &= d_1 \\
  t_2 &= t_1 + (d_1 + d_2) = 2d_1 + d_2 \\
  &\vdots \\
  t_n &= t_{n-1} + (d_{n-1} + d_n) = 2d_1 + 2d_2 + \ldots + 2d_{n-1} + d_n \\
\end{align*}
\]

(2)

where $d_i$ is the traveled distance between the starting supply warehouse and the customer $S_i$.

In order to substitute the values $d_i$ to the formula, it is necessary to determine the actual distances between a particular cross-dock warehouse (potential warehouse is located on the P. O. Hviezdoslava Street - the premises of the railway station) and the individual shopping centers in the city of Žilina. These distances are shown in the following Table 1.

**Tab. 1 Distances between the cross-dock warehouse and the individual shopping centers in the city of Žilina**

<table>
<thead>
<tr>
<th>$S_i$</th>
<th>$S_1$</th>
<th>$S_2$</th>
<th>$S_3$</th>
<th>$S_4$</th>
<th>$S_5$</th>
<th>$S_6$</th>
<th>$S_7$</th>
<th>$S_8$</th>
<th>$S_9$</th>
<th>$S_{10}$</th>
<th>$S_{11}$</th>
<th>$S_{12}$</th>
<th>$S_{13}$</th>
<th>$S_{14}$</th>
<th>$S_{15}$</th>
<th>$S_{16}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_i$ [km]</td>
<td>1,2</td>
<td>1,1</td>
<td>2,3</td>
<td>3,6</td>
<td>1,0</td>
<td>3,2</td>
<td>1,8</td>
<td>5,9</td>
<td>2,2</td>
<td>4,7</td>
<td>1,6</td>
<td>1,0</td>
<td>3,4</td>
<td>3,3</td>
<td>2,9</td>
<td>5,3</td>
</tr>
</tbody>
</table>

Source: Authors

The next step in the process is to order the distances between the cross-dock warehouse and individual shopping centers from the shortest to the longest distance (see Table 2).

**Tab. 2 Order of the distances between the cross-dock warehouse and individual shopping centers**

<table>
<thead>
<tr>
<th>$S_i$ original</th>
<th>$S_1$</th>
<th>$S_2$</th>
<th>$S_3$</th>
<th>$S_4$</th>
<th>$S_5$</th>
<th>$S_6$</th>
<th>$S_7$</th>
<th>$S_8$</th>
<th>$S_9$</th>
<th>$S_{10}$</th>
<th>$S_{11}$</th>
<th>$S_{12}$</th>
<th>$S_{13}$</th>
<th>$S_{14}$</th>
<th>$S_{15}$</th>
<th>$S_{16}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_i$ new</td>
<td>$S_5$</td>
<td>$S_{12}$</td>
<td>$S_2$</td>
<td>$S_{11}$</td>
<td>$S_7$</td>
<td>$S_6$</td>
<td>$S_2$</td>
<td>$S_{15}$</td>
<td>$S_6$</td>
<td>$S_{14}$</td>
<td>$S_{13}$</td>
<td>$S_4$</td>
<td>$S_{10}$</td>
<td>$S_{16}$</td>
<td>$S_8$</td>
<td></td>
</tr>
<tr>
<td>$d_i$ [km]</td>
<td>1,0</td>
<td>1,0</td>
<td>1,1</td>
<td>1,2</td>
<td>1,6</td>
<td>1,8</td>
<td>2,2</td>
<td>2,3</td>
<td>2,9</td>
<td>3,2</td>
<td>3,3</td>
<td>3,4</td>
<td>3,6</td>
<td>4,7</td>
<td>5,3</td>
<td>5,9</td>
</tr>
</tbody>
</table>

Source: Authors
The total waiting time may be expressed by the objective function:

$$\sum_{i=1}^{n} t_i = (2n - 1).d_1 + (2n - 3).d_2 + \ldots + 3d_{n-1} + d_n$$

(3)

Since \( n \) is fixed to minimize the total waiting time it is necessary to select for \( d_1 \) the shortest distance, for \( d_2 \) the second shortest distance, etc, and for \( d_n \) the longest distance, this means to use the supply sequence from Table 2.

Individual distances, which one vehicle travels when supplying the shopping centers from one starting cross-dock warehouse, are determined using the selected algorithm.

The Table 3 contains the results of above mentioned procedure, where the distances are shown and ordered. These distances concerning the supply of the shopping centers by one vehicle when operating from the cross-dock warehouse to the customers with the resulting data on total traveled distance \( t_i \) of one vehicle to new shopping center \( S_i \).

<table>
<thead>
<tr>
<th>( S_i )</th>
<th>( S_1 )</th>
<th>( S_2 )</th>
<th>( S_3 )</th>
<th>( S_4 )</th>
<th>( S_5 )</th>
<th>( S_6 )</th>
<th>( S_7 )</th>
<th>( S_8 )</th>
<th>( S_9 )</th>
<th>( S_{10} )</th>
<th>( S_{11} )</th>
<th>( S_{12} )</th>
<th>( S_{13} )</th>
<th>( S_{14} )</th>
<th>( S_{15} )</th>
<th>( S_{16} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_i )</td>
<td>( S_5 )</td>
<td>( S_{12} )</td>
<td>( S_2 )</td>
<td>( S_{11} )</td>
<td>( S_7 )</td>
<td>( S_9 )</td>
<td>( S_15 )</td>
<td>( S_6 )</td>
<td>( S_{14} )</td>
<td>( S_{13} )</td>
<td>( S_4 )</td>
<td>( S_{10} )</td>
<td>( S_{16} )</td>
<td>( S_8 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d_i ) [( \text{km} )]</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td>1.6</td>
<td>1.8</td>
<td>2.2</td>
<td>2.3</td>
<td>2.9</td>
<td>3.2</td>
<td>3.3</td>
<td>3.4</td>
<td>4.7</td>
<td>5.3</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>( t_i ) [( \text{km} )]</td>
<td>1.0</td>
<td>3.0</td>
<td>5.1</td>
<td>7.4</td>
<td>10.2</td>
<td>13.6</td>
<td>17.6</td>
<td>22.1</td>
<td>27.3</td>
<td>33.4</td>
<td>39.9</td>
<td>46.6</td>
<td>53.6</td>
<td>61.9</td>
<td>71.9</td>
<td>83.1</td>
</tr>
</tbody>
</table>

Source: Authors

In this particular case, the optimal supply sequence is 5, 12, 2, 1, 11, 7, 9, 3, 15, 6, 14, 13, 4, 10, 16 and 8.

Determination of the total driving performance and also the total waiting time of the customer (given in km) when using one supply vehicle for operating the shopping centers is the final output of above realized calculations. This driving performance is $$\sum_{i=1}^{n} t_i = 497.7$$ km.
4 Conclusion

The paper is focused on the simple algorithm which helps to solve the traffic problems, as well.

Generally, the algorithms for typical optimization problems go through a sequence of steps with simple choices of steps until complete solution. This particular algorithm, also known as “Greedy” algorithm, consists of small parts of work. Determination of the total customer waiting time for goods, which refers to the transport distances, is the final output of this algorithm. These distances do not contain time required for loading and unloading.

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References


Resume

The paper presents a specific class of traffic problems when the supplier, the supply warehouse in this case, expedites the goods to the group of customers. The paper presents a simple but powerful "greedy" algorithm, classed among heuristic methods, that provides good results close to the optimal solution.

Key words

"Greedy" algorithm, supply, operation, shopping center, cross-dock warehouse

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