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Application of it tools in optimization of logistics problems

Wykorzystanie narzędzi informatycznych do optymalizacji problemów logistycznych

Abstract

This paper presents IT tools supporting logistics processes. Such processes include, for example, planning the optimal route for the transport of packages or proper packing of these packages in the car. The paper discusses selected computer tools that can be successfully used to improve logistics processes.

Keywords: optimization, logistics, supply chain management

Streszczenie

W artykule przedstawiono narzędzia IT wspierające procesy logistyczne. Procesy te obejmują na przykład planowanie optymalnej trasy transportu paczek lub właściwe rozlokowanie tych paczek w samochodzie. W artykule omówiono wybrane narzędzia komputerowe, które z powodzeniem można wykorzystać do usprawnienia procesów logistycznych.

Słowa kluczowe: optymalizacja, logistyka, zarządzanie łańcuchem dostaw

1. Introduction

Optimal planning (e.g. time, resources) is very desirable in logistics because it gives real profits. Many complex logistics processes can be significantly improved by using IT tools. This is not only registration of these processes in the IT system, which seems indispensable nowadays, but one step further: supporting these processes in order to obtain optimal results in terms of time saving and good use of human and equipment resources.

The most common problem of deliveries – Vehicle Routing Problem – is to minimize transport costs from one warehouse to any number of customers [1].

The problem of determining the optimal plan for transporting products between suppliers and customers is an NP-difficult problem, which means that there is no algorithm solving this problem in polynomial time [1].

The Polish language dictionary PWN [4] defines optimization as follows: organizing some activities, processes, etc. in such a way as to give the greatest possible results with the least amount of effort; searching by the mathematical methods for the best, due to the selected criterion, solutions of a given economic issue, taking into account certain restrictions.

In the current computerized times, IT tools provide great opportunities to optimize logistic processes.

2. Materials and methods

Vehicle route planning is one of the main logistical problems. It is not easy to find the best solution with many restrictions, such as:
- ► – availability of points,
- ► – availability of drivers,
- ► – limiting drivers' working time,
- ► – availability of appropriate cars,
- ► – car load capacity and other car features (speed, equipment),
- ► – accessibility of roads for specific types of cars and
- ► – ban on the joint transport of certain products.

The expected result is the shortest sum of routes and the least used cars.

Michlowicz shows [1], among others, such variations of currently existing supply problems:
- ► – CVRP (Capacity Vehicle Routing Problem) – the problem of deliveries with defined load capacities of vehicles; all vehicles have identical loads,
- ► – OVRP (Open Vehicle Routing Problem) – the vehicle does not return to the initial warehouse,
- ► – VRPTW (Vehicle Routing Problem with Time Windows) – CVRP extension for time windows for each customer,
- ► – SDVRP (Site-Dependent Vehicle Routing Problem) – the problem of deliveries with different load capacities of vehicles,

► – MDVRP (Multi Depot Vehicle Routing Problem),

  ► – MDVRPTW (Multi Depot Vehicle Routing Problem with Time Windows).

The distribution of packages in the car is yet another problem which is crucial for optimization. In this case, the following factors should be taken into account, e.g.:

  ► – where to take the packages (order of loading),

  ► – package sizes,

  ► – package shape,

  ► – dimensions of the car,

  ► – the possibility of stacking packages and

  ► – ban on the joint transport of certain products (cannot be transported together).

The OptaPlanner open source tool [3] is useful to solve the first of the described problems. It contains many examples and its code is officially available. One can modify it for their own purposes. OptaPlanner includes an example called "Vehicle Routing". For test purposes, one can also use the supplied example input data or prepare new data, modify restrictions and "reprogram" the operation way. OptaPlanner has a user-friendly interface (see Fig. 1).
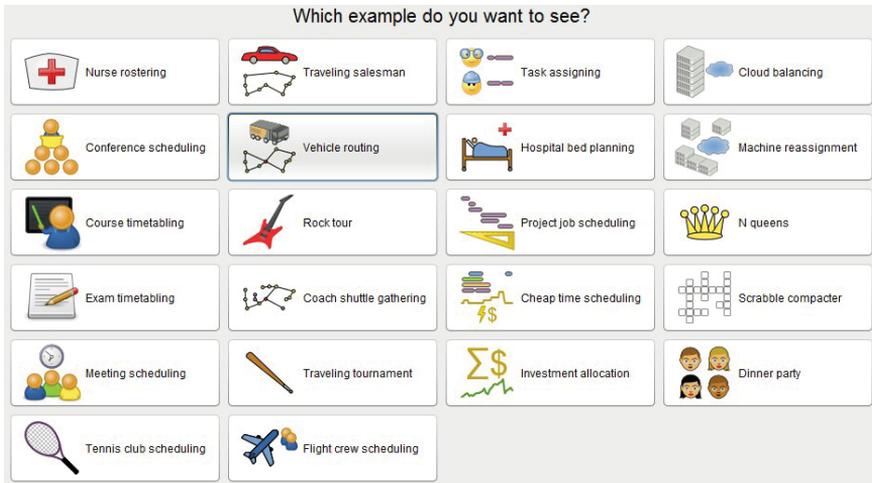

Fig. 1. OptaPlanner – sample GUI

The basic optimization task is as follows:

1. Input data:
    ▷ a fleet of vehicles with a certain capacity,
    ▷ points of delivery (coordinates),
    ▷ customer service time and
    ▷ time windows - in variant.

2. Problem:
    ▷ Receipt of shipments from customers and transport to the warehouse.

3. Solution (optimization):
    ▷ minimization of the total distance covered by all vehicles.

3. Results

Let's prepare simple input data:

```
TYPE : CVRP (basic case, without time windows)
DIMENSION : 3 (three points where the car stops)
EDGE_WEIGHT_TYPE : EUC_2D (euclidean distances)
CAPACITY : 50 (capacity of vehicle)
NODE_COORD_SECTION (points and coordinates)
 1 10 20 (the first point with coordinates 10, 20)
 2 40 70 (the second point with coordinates 40, 70)
 3 10 100 (the third point with coordinates 10, 100)
DEMAND_SECTION (points, three because "DIMENSION : 3")
1 0 (ordinal number and load to be delivered, nothing is delivered
to the first point)
2 1 (ordinal number and load to be delivered)
3 1 (ordinal number and load to be delivered)
DEPOT_SECTION (depots)
 1 (the first point is depot)
 -1
VEHICLES : 2 (two vehicles)
```

The result is shown in a graphical form in Fig. 2. The figure is a screenshot, with the contrast enhanced and descriptions improved.
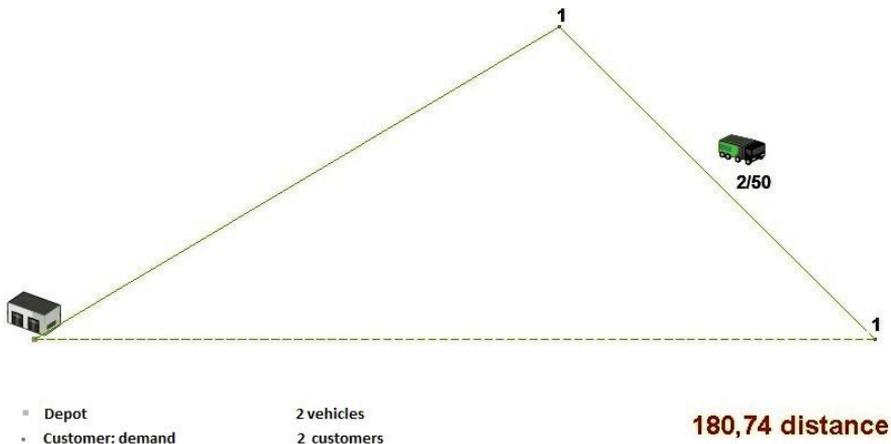

Fig. 2. OptaPlanner – the result of the planning for the example discussed

As shown in Fig. 2, one of the two available cars has been used. Description 2/50 is the reference of the load (2) to the capacity of the vehicle (50). The numbers next to the points indicate the load to be delivered to the point. Let's increase the load now:

1. Input data:

```
TYPE : CVRP
DIMENSION : 3
EDGE_WEIGHT_TYPE : EUC_2D
CAPACITY : 50
NODE_COORD_SECTION
 1 10 20
 2 40 70
 3 10 100
DEMAND_SECTION
1 0
2 40
3 12
DEPOT_SECTION
 1
 -1
VEHICLES : 2
```

Result is shown in Fig.3. The illustration is a screenshot, with the contrast enhanced and descriptions improved.
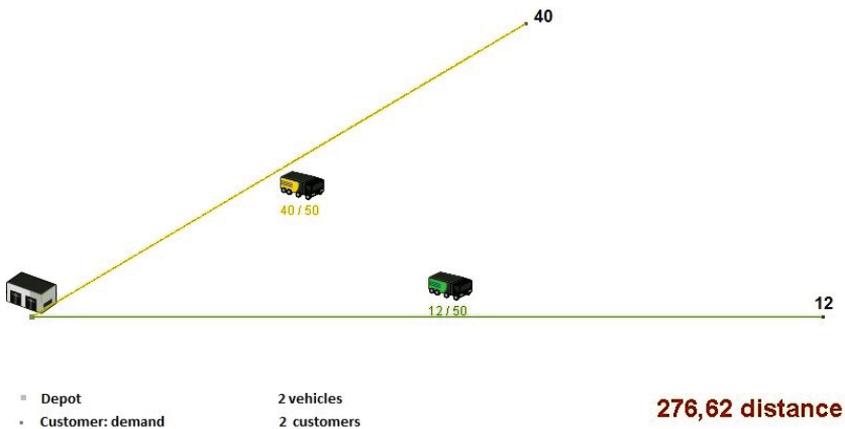

Fig. 3. OptaPlanner – the result of the planning
after the modification of the first example (two vehicles)

Due to the load increase, the second car should be used. As shown in Fig. 3, both available cars have been used because the load exceeds the capacity of a single vehicle.

Let's consider another example: add a second depot, increase the number of locations and cars. The modified problem is shown in a graphical form in Fig. 4.

2. Input data:

```
DIMENSION : 10
EDGE_WEIGHT_TYPE : EUC_2D
CAPACITY : 50
NODE_COORD_SECTION
 1 10 20
 2 40 50
 3 10 100
 4 20 100
 5 25 80
 6 30 20
 7 35 40
 8 40 60
 9 45 65
 10 50 100
DEMAND_SECTION
1 0
2 0
3 12
4 40
5 50
6 5
7 5
8 5
9 10
10 2
DEPOT_SECTION
 1 (the first point is depot)
 2 (the second point is depot)
 -1
VEHICLES : 3
```

The obtained result is shown in Fig. 5. Let's now show a much more complicated example that the OptaPlanner can optimize: 100 customers, time windows (Fig. 6). The temporary solution obtained after interrupting the optimization a couple of seconds after launch is shown in Fig. 7. The final solution after optimization is presented in Fig. 8. One can easily notice that the total distance was decreased in comparison with the preliminary solution presented in Fig. 7.
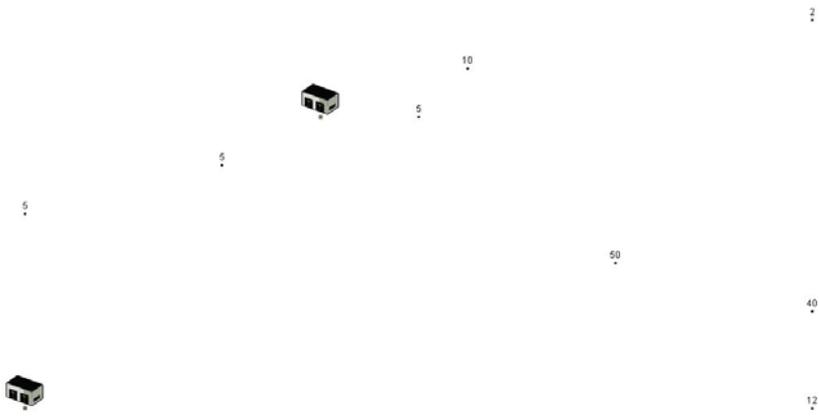
Fig. 4. OptaPlanner – planning problem: ten points, two depots, three vehicles.
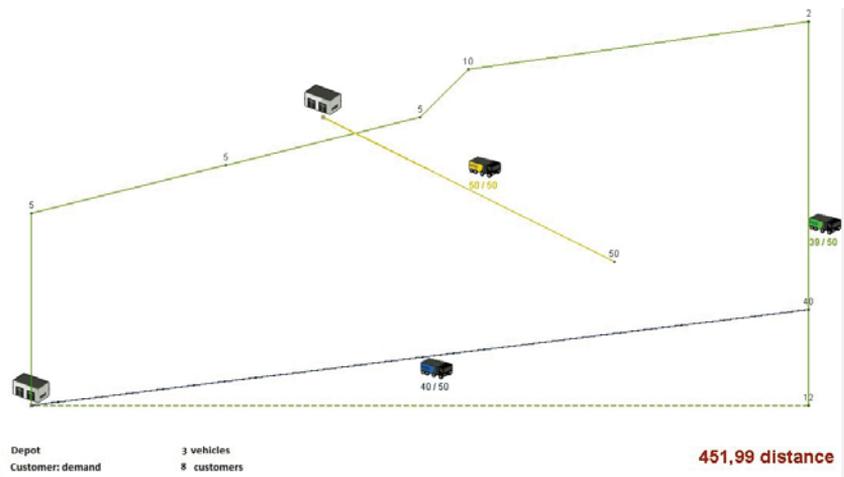This is a screenshot, with the contrast enhanced

Fig. 5. OptaPlanner – the result of the planning: planned routes for three vehicles.
This is a screenshot, with the contrast enhanced and descriptions improved

Another problem that is crucial for optimization is the arrangement of packages in the car. It can be assumed that this is a typical optimization problem - knapsack problem. It is a problem of choosing objects so that their total value would be as large as possible and simultaneously fit in the backpack. In our case, the items are parcels and the car is a backpack. IT tools can also be used for this problem.

Additional restrictions which often occur are, for example:

► where to take the packages (order of loading),
► package shape,
► dimensions of the car,
► the possibility of stacking packages or
► packages cannot be transported together.

Fig. 6. OptaPlanner – planning problem which points time windows.
This is a screenshot, with the contrast enhanced and descriptions improved
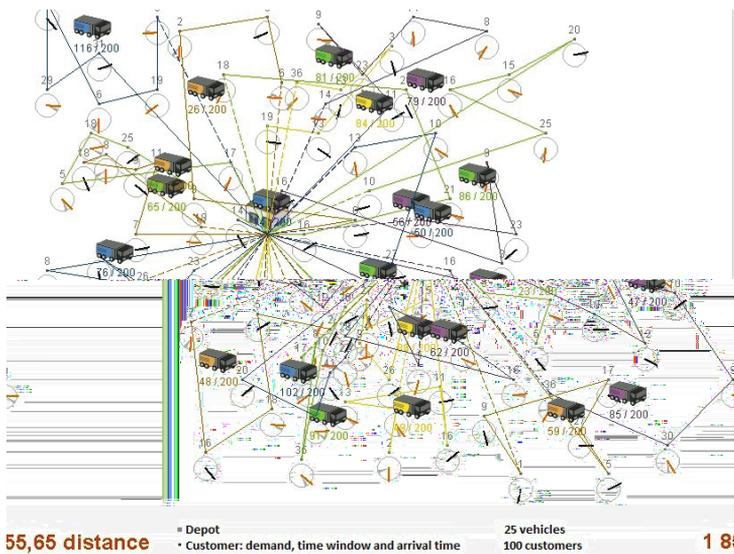

Fig. 7. OptaPlanner – the result of planning for problem which points time windows (an interrupted optimization with a temporary solution). This is a screenshot, with the contrast enhanced and descriptions improved
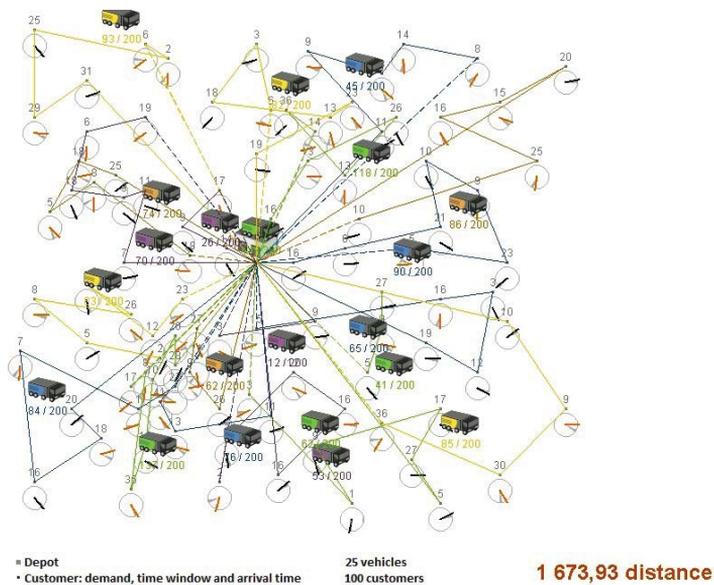
Fig. 8. OptaPlanner – result of planning for problem which points time windows (full optimization). This is a screenshot, with the contrast enhanced and descriptions improved

IT tools can also be used to solve such problems. An example is the freeware Goodloading application [7], which supports the optimal placement of cargo in the car. It optimizes positioning of cuboidal parcels of specified dimensions in a car (set) of specified dimensions. It also supports the situation of stacking packages.

4. Discussion/Conclusion

IT tools significantly contribute to improving the efficiency of logistics processes. The examples presented in this paper show that there are many problems in logistics that require optimization. There are different IT tools to cope with this task. The ones described here – OptaPlanner [3] and Goodloading [7] are commonly available. The former also allows one to create new solutions. This is a big advantage, because one can add a way of optimization for a specific situation.

Goodloading [7] gives a quick answer to how to optimally place the load in the car. However, there is a lack of planning packages with unusual shapes (one can only plan cuboids), taking into account the axle load or planning several cars at the same time (sets).

Logistics is a good domain to implement optimization algorithms and combine them with other solutions to achieve cost and time minimization. Simultaneously, this area seems to be excellent environment for testing efficiency of various optimization tools.

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