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# Approaches to solve the vehicle routing problem in the valuables delivery domain

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**Abstract**

The various extensions of the vehicle routing problem with time windows (VRPTW) are considered. In addition to the VRPTW, the authors present a method to solve the SDVRPTW – the variation of the task allowing separate goods supply to the customers. The two developed metaheuristic algorithms (genetic and hybrid) are described that use the unique task-oriented operators and approaches, such as the limited route inversion, the upgraded heuristic procedure, the initialization of the initial population by ant colonies method, Pareto ranking.

The features of this problem solved are additional route restrictions, such as: the maximum time, the number of customers and cost, as well as the maximum number of vehicles required for delivery. This article is devoted to valuables delivery problems and methods to resolve them.

*Keywords:* vehicle routing problem, metaheuristic algorithms, VRPTW, SDVRPTW, Pareto ranking.

# 1 Introduction

Nowadays the logistics has great importance, since the delivery of goods and services covers almost all spheres of human activity. Therefore, optimization of this process is the important issue to explore. This challenge shows itself the most acutely in the valuables delivery. For example, in the banking need to save money spent both on the ATM service and their replenishment is increased. The transportation cost in its turn is calculated based on the distance traveled or time spent.

The main purpose of this article is to show how, using various approaches and algorithms, to reduce the costs of the valuables transportation and delivery by designing the routes in more efficient (close to optimal) way.

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# 2 Mathematical model

Let us formulate the main goals and restrictions of the vehicle routing problem with time windows.

*Objective*: Minimize the number of vehicles and the total travel distance.

*Restrictions:*

- Each vehicle corresponds to one route;
- Each route begins and ends at the depot;
- Overall customer demand for the route cannot exceed the carrying capacity of the vehicle;
- Each customer is served by one and only one vehicle.

We use the following symbols:

Assume N is a number of customers $(1, 2, \dots, n)$ that need to be serviced.

$c_{ij}$ – the transportation cost from the customer $i$ to $j$.

$t_{ij}$ – the sum of *i*-th customer service time and travel time from *i* to *j*.

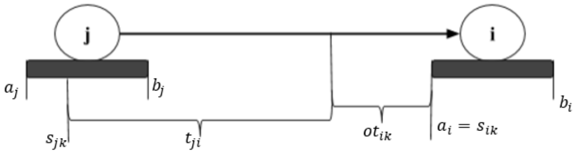


**Figure 1**. A schematic arrangement of introduced designations

$q$ – the vehicle's maximum capacity. In the sector of the valuables delivery the $q$ is the insurance amount.

$d_i$ – the demand of the customer *i*.

Because of the problem domain (valuables sector) limits the $d_i$ is the cost of requested goods.

$[a_i, b_i]$ – the hard time window within which the *i* -th customer should be serviced.

$V$ – the set of all available vehicles $k, k \in V$.

$x_{ijk}$ – a variable taking a value of *1* if the vehicle *k* is coming from the customer *i* to the customer *j*, and *0* if otherwise.

$s_{ik}$ – the start time to service the customer *i* with the vehicle *k*.

$ot_{ik} = a_i - (s_{jk} + t_{ji}), \forall i \in N, \forall j \in N, \forall k \in V$ – the waiting time to open the time window of the customer with k-th vehicle.

**Objective function:**

$$Z = \sum_{k\in V}\sum_{i\in N}\sum_{j\in N} c_{ij}\, x_{ijk} \to min \qquad \textbf{(1)}$$

**Restrictions:**

$$\sum_{k\in V}\sum_{j\in N} x_{ijk} = 1, \forall i \in N \qquad \textbf{(2)}$$

$$\sum_{i\in N}\sum_{j\in N} d_i x_{ijk} \le q, \forall k \in V \qquad \textbf{(3)}$$

$$\sum_{j\in N} x_{0jk} = 1, \forall k \in V \qquad \textbf{(4)}$$

$$\sum_{i\in N} x_{i,0,k} = 1, \forall k \in V \qquad \textbf{(5)}$$

$$\sum_{i\in N} x_{ihk} - \sum_{j\in N} x_{hjk} = 0, \forall h \in N, \forall k \in V \qquad \textbf{(6)}$$

$$x_{ijk}\left(s_{ik} + t_{ij} - s_{jk}\right) \le 0, \forall i \in N, \forall j \in N, \forall k \in V \qquad \textbf{(7)}$$

$$a_i \le s_{ik} \le b_i, \forall i \in N, \forall k \in V \qquad \textbf{(8)}$$

$$x_{ijk} \in \{0,1\}, \forall i \in N, \forall j \in N, \forall k \in V \qquad \textbf{(9)}$$

A unique feature of this task formulation is the possibility to replace the objective function in order to obtain the best possible solution regarding various criteria.

$$Z_1 = \sum_{k\in V}\sum_{i\in N}\sum_{j\in N} t_{ij}\, x_{ijk} \qquad \textbf{(10)}$$

$$Z_3 = \sum_{j\in\{N\setminus 0\}}\sum_{k\in V} x_{0jk} \qquad \textbf{(11)}$$

$$Z_2 = \sum_{k\in V}\sum_{i\in N}\sum_{j\in N} t_{ij}\, x_{ijk} + \sum_{k\in V}\sum_{i\in N}(s_{ik} - ot_{ik}) \qquad \textbf{(12)}$$

$$Z_4 = \alpha * Z + \beta * Z_1 + \gamma * Z_2 + \delta * Z_3 \qquad \textbf{(13)}$$