DECOMPOSITION OF THE ROUTING PROBLEM BASED ON THE CLARKE–WRIGHT HEURISTIC METHOD

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ABSTRACT

The article is devoted to decomposition of the task of transport routing based on heuristic estimates with the Clarke–Wright method. A procedure is proposed for designing an automobile transport system based on the criterion of minimizing the total mileage by various formalized decomposition methods, in particular, using the «benefit functions» algorithm and formation of zones (clusters, subsets) of vehicle maintenance. The advantages of the proposed method are clearly shown in comparison with the method of «the shortest distance matrix», at the example of delivery of ten cargo units from a supplier to ten consumers. The effect of reducing the total mileage on the designed routes was 9,45 %.

Keywords: transport routing, Clarke–Wright method, «benefit function», cluster, decomposition method, heuristic estimation, the shortest distances matrix.

Background. *The logistics of transport is involved in planning of small-lot shipments. In general, logistics is planning, control and management of transportation, warehousing and other operations performed in the process of bringing raw materials and materials to the enterprise, in-plant processing, bringing the produced products to the consumer, as well as transfer, storage and processing of related information.*

The task of transport logistics is to ensure technical and technological conjugation of participants in the transport process, harmonize their economic interests, and use common planning systems. At the same time, special attention is paid to planning of shipments of small-batch cargoes due to the increasing development of trade networks, a huge number of delivery points. Such transportation is usually characteristic of large cities and has a number of features:

- *failure to provide full loading of the vehicle on the whole route;*
- *tariff increase by carriers due to incomplete loading of vehicles,*
- *as a rule, short distances between recipients on routes;*
- *need for increased attention of employees when collecting lots of goods for delivery;*
- *labor intensity of loading and unloading operations.*

These features determine, first of all, high tariffs for transportation of small-lot cargo. The cost of transportation is significantly influenced by the length of the route covered by vehicels, the length of which directly depends on the degree of compactness of the mutual location of consumers in the service area of each car and the order of the rounds of correspondence points in the shift-daily assignments of drivers. And hence the need for methods of transport routing, formation of rational traffic routes, allowing to carry out the delivery of goods with the lowest transport component in the final cost of goods, also increases.

The wording of the routing task is as follows: it is necessary to effectively deliver cargo from the sender to the recipients given the specified fleet of vehicles, taking into account the specified technical, technological and organizational constraints. In the course of solving the problem, a scheme of rational distribution of consumers regarding the supplier is defined, following which the needs of consignees will be completely satisfied with minimal transport costs.

Objective. *The objective of the authors is to consider the issues of decomposition of the routing task.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, evaluation approach.*

Results.

Route planning methods

When planning the transportation, exact and approximate classes of methods of solution are used. To obtain accurate results, methods are used:

- *enumeration of options;*
- *linear and dynamic programming;*
- *branches and borders.*

Approximate solutions are obtained by methods:

- *random search;*
- *local optimization;*
- *heuristic;*
- *evolutionary and other.*

For algorithms of exact methods, it is possible to obtain an optimal result based on a given optimization criterion, but it takes a long time (often incompatible with the time allotted to shift-day planning). Therefore, such methods are used only when solving problems of small dimension and with a small number (absence) of constraints.

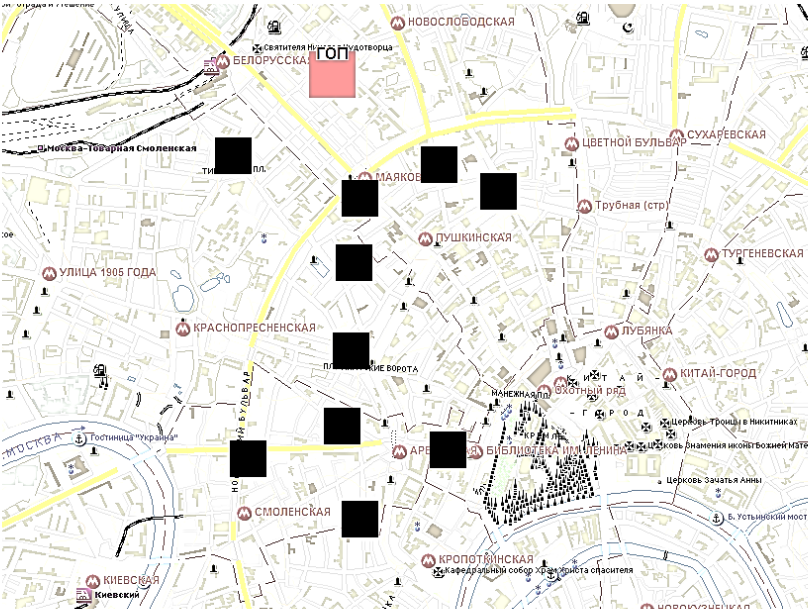
As for approximate solutions, then, of course, their main drawback is that they do not give an exact solution, but this is compensated by the speed of calculations for large-dimensional problems with a multitude of technical, technological and organizational limitations. Among approximate methods, in practice, heuristic and local optimizations are most useful, each of which is able to show the best efficiency in solving a problem using a wide range of factors specified for planning.

Shift-day planning

In general, the problem of large dimensions regarding shift-daily planning of the routes is solved in three stages.

At the first stage*, decomposition (splitting) of a set of consumers into subsets (clusters, zones, sets) is carried out, each of which does not violate the limits of the given constraints. The following are the existing and proposed formalized and heuristic methods for decomposition of the task of constructing routes depending on the given constraints, the optimization criterion and the proposed algorithm for solving:*

- *following the map of the area, based on a visual assessment of the priority of including items in the cluster;*
- *following the transport network model (TNM) graph and the smallest sum of edge lengths to the points included in the set;*
- *through the shortest distance matrix (SDM);*
- *through the shortest connecting network (SCN);*



Pic. 1. Location of the supplier and consumers of goods.

• through sectors with rigid territorial borders, previously plotted on the scheme (map, plan) of the transportation area and usually covering the central part of the city and the main lines;

• through distribution of the minimum amount of vehicles for the entire volume of cargo presented for carriage;

• by Svir method;

• through the model of the transport problem within linear programming;

• by collecting destination points into the clusters with the help of heuristics of the «benefit functions» method (Clarke–Wright).

***At the second stage**, the order of the rounds of destination points in subsets (clusters, zones) is determined.*

***At the third stage** shift-daily tasks for drivers are formed.*

Obviously, the efficiency of the solution of the problem depends to a large extent on the chosen decomposition method implemented at the first planning stage, in terms of the degree of compactness of the mutual location of consumers in the service area of each vehicle and the algorithm for formation of bypass routes.

Decomposition algorithm

We will outline the procedure for the example. The point of production of homogeneous types of products (GOP) and ten densely located to each other, load-absorbing points (GPP) with consumption volumes for one unit of cargo is set (Pic. 1). The cargo capacity of one car is five cargo units. A matrix of the shortest distances between points is given. It is necessary to form, by the criterion of the minimum of the total mileage, the system of transport routes when delivering goods from GOP to GPP.

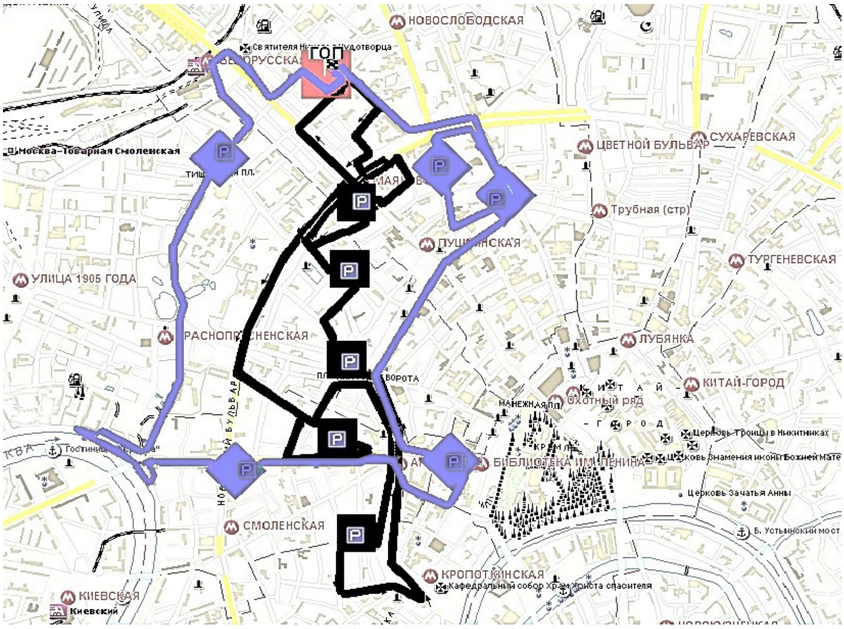
We solve the problem by using decomposition method based on the matrix of the shortest distances. Initially, the most remote from the GOP consumer is included in the cluster according to SDM. To the existing point the second is added, which is the nearest to it, then the third, having the smallest distance from either the first or the second. And so on, the actions continue for all consignees already included in the subset, following the principle of the minimum distance between the points, and checking if decisions satisfy the specified constraints.

The mode of shift-day planning of routes meets some restrictions, and one of the most difficult for implementation at the stage of decomposition is restriction on the time of turnover on routes in comparison with the time of finding cars on duty. It is offered at each step of construction of the cluster to forecast the time of turnover of the future route. Rationally, this operation should be carried out with electronic atlases of motorways that have a router for automatically plotting the trajectory of traffic along the streets and roads taking into account the organization of traffic. Thus, before the consumer of the goods is included in a subset of the points planned for servicing by a particular car, the possibility of expanding the boundaries of the formed service area of the vehicle is verified.

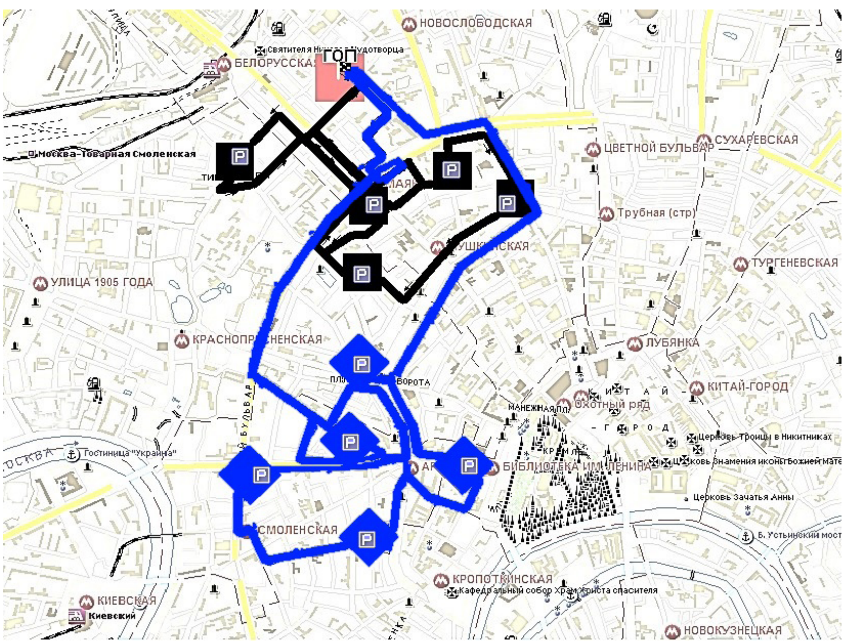
Upon completion of a cluster, we proceed to construct the route selected by the method of obtaining an approximate (exact) solution. If there are no restrictions on time of delivery (time slots) the route is actually already built at the first planning stage, but if there are required time slots, an adjustment may be required replacing part of the GPP previously included in the cluster. It is recommended that before the starting editing of a cluster to provide for the reserve time of car's stay on duty.

With reference to this example, two routes with a total mileage L_{tot} = 15,3 + 14,33 = 29,6 km are formed (Pic. 2). It can be clearly seen that the presented solution is not rational, since the both routes comprise points located very far from GOP, which leads to unreasonable, overestimated values of their total length.

Next, we perform the solution of the problem with decomposition tool using the heuristics of the Clarke–Wright method. In addition to the initial information, it is necessary to calculate the matrix of heuristics (estimates, «benefit functions», wins). At the beginning, as in the first case, the most remote from the GOP consumer is included in the cluster according to SDM. To the available point, a vertex is added, the combination of which, in pair with the already included GPP, has a maximum score. Then, with two points in the cluster, the pair with the highest score is determined, either from the combination



Pic. 2. Routes for clusters formed by the decomposition method by the matrix of the shortest distances.



Pic. 3. Routes for clusters formed by the heuristic decomposition method.

with the first point or with the second one. Then, from three GPP in the cluster, pairs of peaks are formed and the point with the highest rating is determined. And so actions continue for all consignees already in the subset, according to the principle of the maximum numerical value of the heuristic, and in the case of equality of «benefit functions», the smallest distance between points has an advantage.

Connection of the next consumer of cargo to the cluster is carried out after checking for satisfaction of the specified technical, technological and organizational limitations. Unlike decomposition by the shortest distance matrix, where the need to include points in a cluster is estimated only by the mutual arrangement of vertices relative to each other, the proposed method takes into account the dislocation of points with respect to the load-forming point. The formation of a subset ends when it is impossible to connect the next item without violating the specified constraints or all the GPP are serviced.

As a result, two routes with a run L_{tot} = 15,3 + 11,5 = 26,8 km were formed (Pic. 3). The effect of reducing the total mileage for the newly formed shift-daily plan is 9,45 %.

In the example considered, we can see that the application of the heuristics of the Clarke–Wright method can improve the efficiency of solving the problem due to the complex evaluation of location of the points in relation to each other and the point of production.

To test the decomposition algorithm, a test calculation was carried out for the practical task of shift-day planning.

There is one GOP and 84 GPP. The load-carrying capacity of the car is 1,5 tons, the loading time is 30 minutes, the unloading is 12 minutes, the time of car's stay on duty is not normalized (but no more than 10 hours), the time of preparatory-final operations is 18 minutes. The masses of delivered cargoes and technical speeds are set, depending on the location of the consumption points in the territory of Moscow. It is necessary to form by the criterion of the minimum of the total mileage the system of transportation routes when delivering goods from the GOP to the load-absorbing points.

The control calculation using the method of decomposition by the shortest distance matrix showed that it is necessary to have seven routes of cargo delivery with a total run of 963,9 km. Using a calculation with decomposition according to heuristics seven routes with a total combined run of 963,5 km were obtained.

Conclusion. *Control calculations confirm the assumption about the effectiveness of using the proposed method of decomposition. It makes sense to continue work on its study by developing a statistical base for comparative calculations using different versions of the original data.*

It is offered to formulate recommendations on variants of application of different decomposition methods for solving transport routing tasks, depending on the structure, reliability and volume of the initial information set for planning, as well as the density of clientele location in the transport service region.

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