DECISION MAKING AND OPTIMISATION OF TRANSPORT OPERATIONS WITH REAL TIME FREIGHT-FLOW CORRECTION

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Abstract: *The article is devoted to the study of shipping processes optimization problem for liquid products on oil terminals. An algorithm for optimal choice of tanks for loading is given. The article describes the approach to the freight flow optimization during realization of technological operations on marine oil terminals with an extensive system of tank parks and cargo pipelines. The proposed structure and algorithms for computer decision support system (DSS) provides optimal routes forming for product transportation while the process of lading the marine tankers and their correction in case of occurring emergency situation on the separate zones of freight pipelines.*

Keywords**:** *freight flow route, optimization, ramose graph*

1. INTRODUCTION

Oil-trade companies and complexes, that have their own oil terminals and fuel warehouses, are often faced with the fact that most oil terminals and warehouses use equipment and technologies that do not provide adequate levels of technological and environmental safety of loading and unloading of fluid products and accurate accounting of oil. Implementation of integrated automation systems will solve these problems by improving production and financial efficiency of oil transshipment complexes to reduce and minimize environmental risks.

Outdated technologies are leading to environmental pollution and direct losses of products [4] – by evaporation, spills [7], use of measuring devices and devices with significant error. Creating a modern automated systems for control and accounting of products enables significantly reduce the loss of petroleum products, particularly when loaded tankers at sea ports [5,6], pumping production between separated objects of oil complexes.

Actuality of creation of the decision support system (DSS) for planning and optimization [10] of liquids freight flows is growing with the increased number of orders for loading oil [12] from the oil terminals, increasing of tank parks and number of reservoirs, during the reconstruction pipelines. For the effective functioning of major oil stations such problems should be optimally solved and the best of all possible alternatives for a concrete order must be found. Solving a class of problems can be made using computer decision support systems, which allow realizing the search of optimum decisions in the interactive modes and intended for support of different types of activity at a decision-making, which deals with the decision of lowstructured or unstructured problems.

2. STRUCTURE OF DECISION SUPPORT SYSTEM

The purpose of this article is to develop the structure and software for proposed DSS [11], which provides in the automatic mode selection of optimal tanks for shipment of desired product mass according to order. The decision support system also can find the best route for the oil transportation [9] on large marine oil complexes [13]. Thus DSS should provide possibility for correction of the optimal route in case of emergency situations occurring, based on the information about technological oil shifting complex and his components, which are saved in a database (DB) of DSS. Corrected (new) route will be based on defined by human operator coordinates of the initial and final points of liquid cargo transfer.

Structural DSS scheme that helps operator interactively plan the optimal path for oil products shipment, shown in Fig. 1. It should be noted that in order to ensure the optimal way to implement the shipment of the liquid cargo, DSS should carry out continuous monitoring and analysis of all current parameters, which may affect the efficiency of delivery of products in real time.

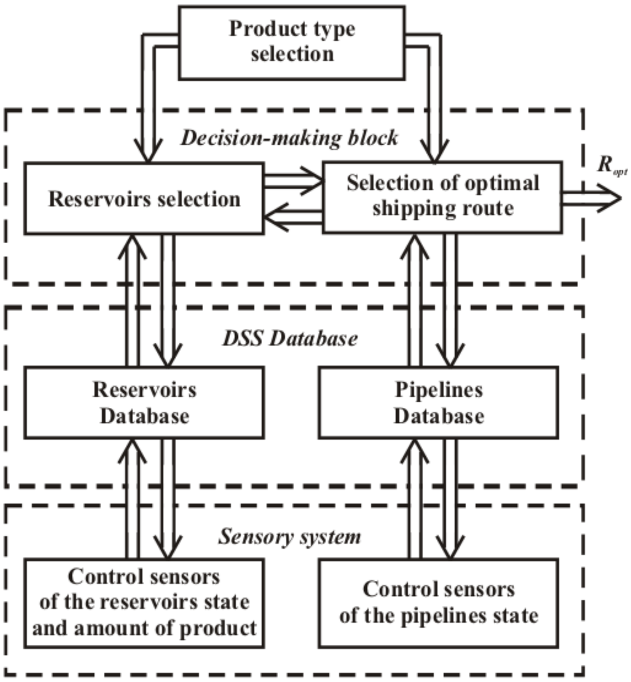

Fig. 1 - Flow diagram of DSS for optimization of freight flows

3. OPTIMIZATION OF RESERVOIRS SELECTION

Each type of oil products are store in several reservoir parks, which consist of group of tanks. During the process of the optimal reservoirs (tanks) selection from chosen parks it is expedient to take into account the remains of oil product in each reservoir. Empty reservoirs after oil loading are the best results of such selection process.

Problem statement. Find such *k* tanks from *n* (where *n* is a number of tanks with ordered product), which need to be shipped, that the total mass amount of product in *k* tanks will be maximally closed to the mass of ordered product.

The goal function for reservoirs selection problem. Find the minimum value of objective function [9]

$$\min \left(\sum_{i=1}^{n} c_i^j x_i^j - P^j \right), \qquad (1)$$

where P^j – total mass of *j*-th type of product, which should be loaded;

x_i^j – mass of *j*-th type of product in *i*-th tank;

$c_i^j = \{0;\ 1\}$ – excluding coefficient.

Initial settings:

a) $c_i^j = \{0;\ 1\}$, when the status of *i*-th tank is «ready for shipment»;

b) $c_i^j = 0$, when the status of *i*-th reservoir is “repairing”, “prohibited shipment”, “shipping at this moment” or “analysis of product samples”;

c) $c_i^j = 0$ for all tanks, which included to remain not examined parks of reservoirs with *j*-th type of product;

d) $c_i^j = 1$, when operator assigns several tanks for shipping in the hand mode.

The decision of the problem by running over all possible combinations may be used only for a small number of tanks [11]. The total number of combinations K_j in binary tree is

$$K_j = 2^{N_j}, \qquad (2)$$

where N_j – number of tanks with *j*-th type of product.

More expedient is the way of decision finding for (1) using the methods of the binary programming, such as a method of branches and scopes [3]. Output of this phase is a bit array *T*, which consists of excluding coefficients for each oil tank with *j*-th type of oil product. Thus, the mechanism of reservoirs choice is presented in Fig. 2. The desired value of shipment cargo is $P^j = 1150$. The total mass of product in chosen tank should be greater or equal P^j. Preliminary selected oil park consists of 10 tanks with *j*-th type of product. Mass amount of *j*-th product for each tank is (in mass units): $Tank_1 = 596$, $Tank_2 = 143$, $Tank_3 = 13$, $Tank_4 = 87$, $Tank_5 = 24$, $Tank_6 = 59$, $Tank_7 = 331$, $Tank_8 = 663$, $Tank_9 = 332$, $Tank_{10} = 292$. The resulting array of *T* has the form:

$$T = \{0110001100\}. \qquad (3)$$

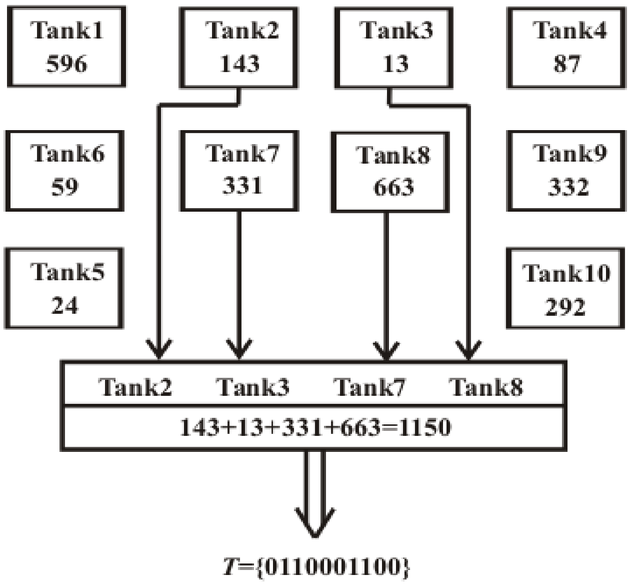

Fig. 2 - Selection of optimal tanks for loading

4. THE ALGORITHM OF OPTIMAL ROUTE PLANNING

It is appropriate to represent the pipelines structure of cargo complex for oil shifting as ramified graph with non-negative weight of arcs (Fig. 3).

As initial vertexes according (3)

$$Tank = \{Tank_2, Tank_3, Tank_7, Tank_8\}, \qquad (4)$$

of current graph (Fig. 3) are marked selected tanks from the chosen park with *j*-th type of oil product. Excluding coefficients c_i^j in array *T* for these tanks are equal to one, $c_2^j = 1$, $c_3^j = 1$, $c_7^j = 1$, $c_8^j = 1$.

As eventual vertexes *L* are marked (Fig. 3) the connection knots of freight pipeline with loading units (piers, railways platforms etc)

$$L = \{L_1, L_2, L_3, L_4\}, \qquad (5)$$

where L_m is oil station loading unit, $m = 1...4$.

In addition for other vertexes on a graph (Fig. 3) the followings denotations are used:

$$S = \{S_5, S_6, ..., S_{34}\}, \qquad (6)$$

where S_h is pipeline network valve $h = 5...34$.

To find the optimal route R_{opt} for shipment [14,19], it is possible to use algorithms of finding the minimum path between two graph vertexes. At present there are considerable number of algorithms for finding the shortest path on graphs [1,8], in particular, to the class of such algorithms are belong wave algorithm, Bellman-Ford’s algorithm [16], Floyd–Warshall’s algorithm [16], Dijkstra's algorithm [16] and their modifications. The Dijkstra's algorithm realisation [5,6,8] for developed DSS (Fig. 1) is based on connectivity matrix [2,20]. The elements of this matrix are lengths of pipeline separate areas, divided by valves and other technological components S_h of oil pipelines. These components are the set of vertices (6).

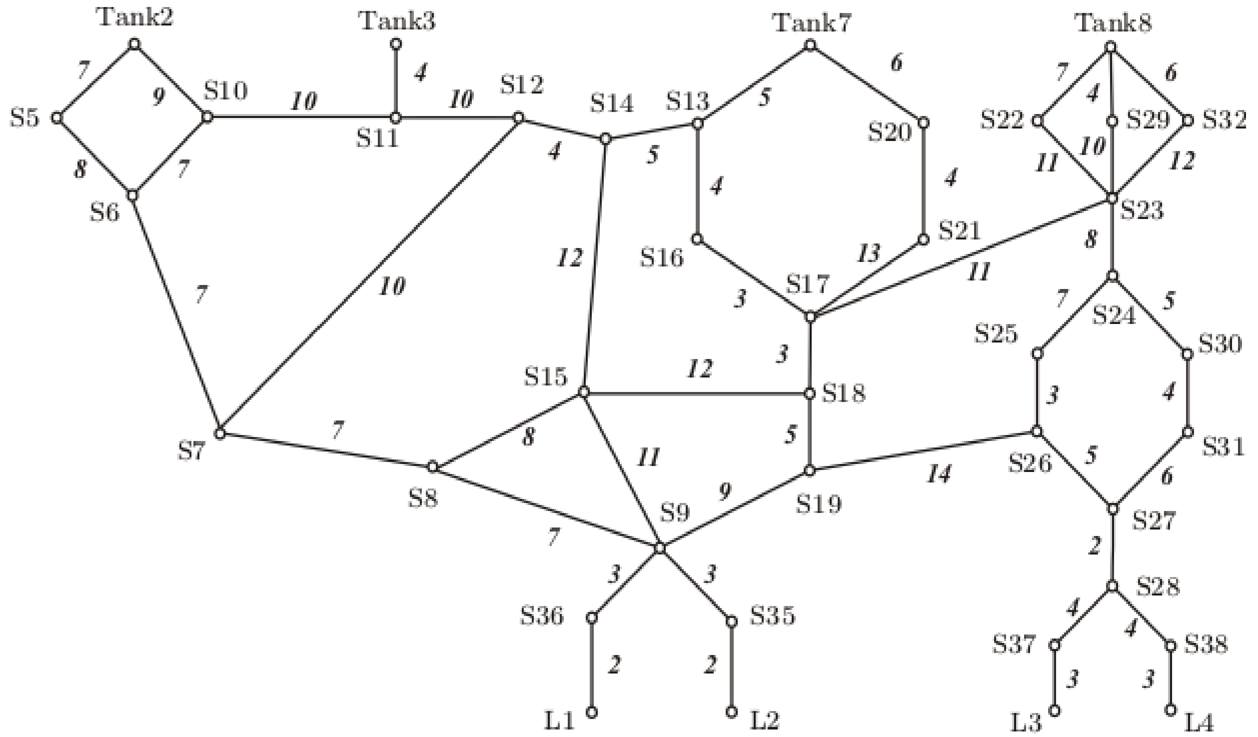

Fig. 3 - Graph of the freight pipelines system

5. FEATURES OF DSS SOFTWARE REALIZATION

Decision support system database was created in a package of MS Office Access 2003 using two tables: table of names $\{Tank, S, L\}$ and identifications (IDs) of graph vertexes and table of relations between vertexes $w[i, j] \in W$, based on IDs.

The weight of arc $w[i, j]$ is accepted as the volume of the pipeline link that is divided by adjacent vertexes. By the vertexes in database are presented tanks, piers of oil shifting complex and also all valves of the oil pipeline system. The developed software for DSS with proposed structural organization (Fig. 1) ensures the effective DSS functioning in two interactive modes: off-line (search for the optimal route) and tracking (automatic control of the database changes in real time).

While the process of oil products loading [15] it is possible that may be emergency damage on some sections of pipelines, which is detected on base of information recorded by measurement-sensory system (Fig. 1). On the basis of the relevant sensors DB of DSS can be adjusted, including table of.

During realization of the tracking mode, DSS continuously checks up the state of table of relationships between vertexes in the developed database. If system exposes any changes in the table of relationships DSS automatically starts the correction process for route R_{opt} .

6. SIMULATION RESULTS FOR PROPOSED DSS IN EMERGENCY SITUATIONS

Shipping of oil product takes place stage-by-stage, separately for every tank. On every stage the optimal route [21] of liquid freight flow is calculated and his control is carried out while the operation is running. So in the case of a shipment from tanks:

$$Tank = \{Tank_2, Tank_3, Tank_7, Tank_8\} , \quad (7)$$

to loading point L_1 the optimal routes are:

$$R_{opt}^{T2-L1} = \{Tank_2, S_5, S_6, S_7, S_8, S_9, S_{36}, L_1\} , \quad (8)$$

$$R_{opt}^{T3-L1} = \{Tank_3, S_{11}, S_{12}, S_7, S_8, S_9, S_{36}, L_1\} , \quad (9)$$

$$R_{opt}^{T7-L1} = \{Tank_7, S_{13}, S_{16}, S_{17}, S_{18}, S_{19}, S_9, S_{36}, L_1\} , \quad (10)$$

$$R_{opt}^{T8-L1} = \{Tank_8, S_{29}, S_{23}, S_{17}, S_{18}, S_{19}, S_9, S_{36}, L_1\} . \quad (11)$$

General lengths (in length units) of the calculated optimal routes are:

$$\text{Length } R_{opt}^{T2-L1} = 41, \text{ Length } R_{opt}^{T3-L1} = 43 \quad (12)$$

$$\text{Length } R_{opt}^{T7-L1} = 34, \text{ Length } R_{opt}^{T8-L1} = 47, \quad (13)$$

Fig. 4 shows the simulation results for designed DSS at forming of optimal route between initial ($Tank_7$) and eventual (L_1) vertexes of graph, presented in Fig. 3. Planned by DSS optimal route R_{opt} is marked by dotted line (Fig. 4).

Let an emergency situation will appear on the section $S_{16} - S_{17}$ of pipeline (Fig. 2). For this purpose will make alteration to weight of arc $w[S_{16}, S_{17}]$ of graph from amount 3 to amount 700.

DSS in the tracking mode will automatically initiate the correction of the preliminary found route R_{opt} . New corrected optimal route is

$$R'^{T7-L1}_{opt} = \{Tank_7, S_{13}, S_{14}, S_{15}, S_9, S_{36}, L_1\} . \quad (14)$$

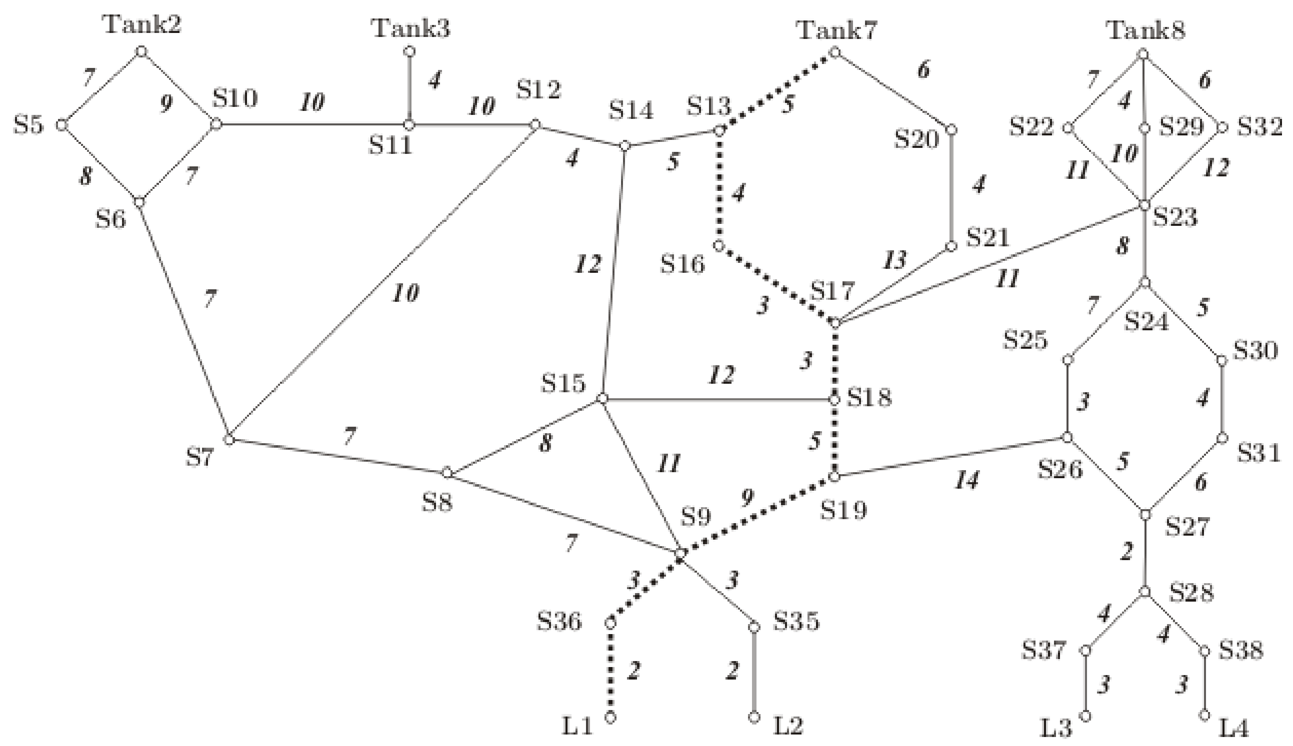

Fig. 4 - Optimal route on a graph

Optimal route R'_{opt} was formed taking into account an emergency situation in a freight pipeline. New route and pipeline failure are shown in Fig. 5. It should be noted that length of new route:

$$\text{Length } R'^{T7-L1}_{opt} = 38, \quad (15)$$

is greater, than length of initial route R_{opt}^{T7-L1} (10), (13) and consequently a new route is optimal only because of the abovementioned emergency situation.

Simulation results for different damages of pipeline sections confirm the efficiency of developed DSS.

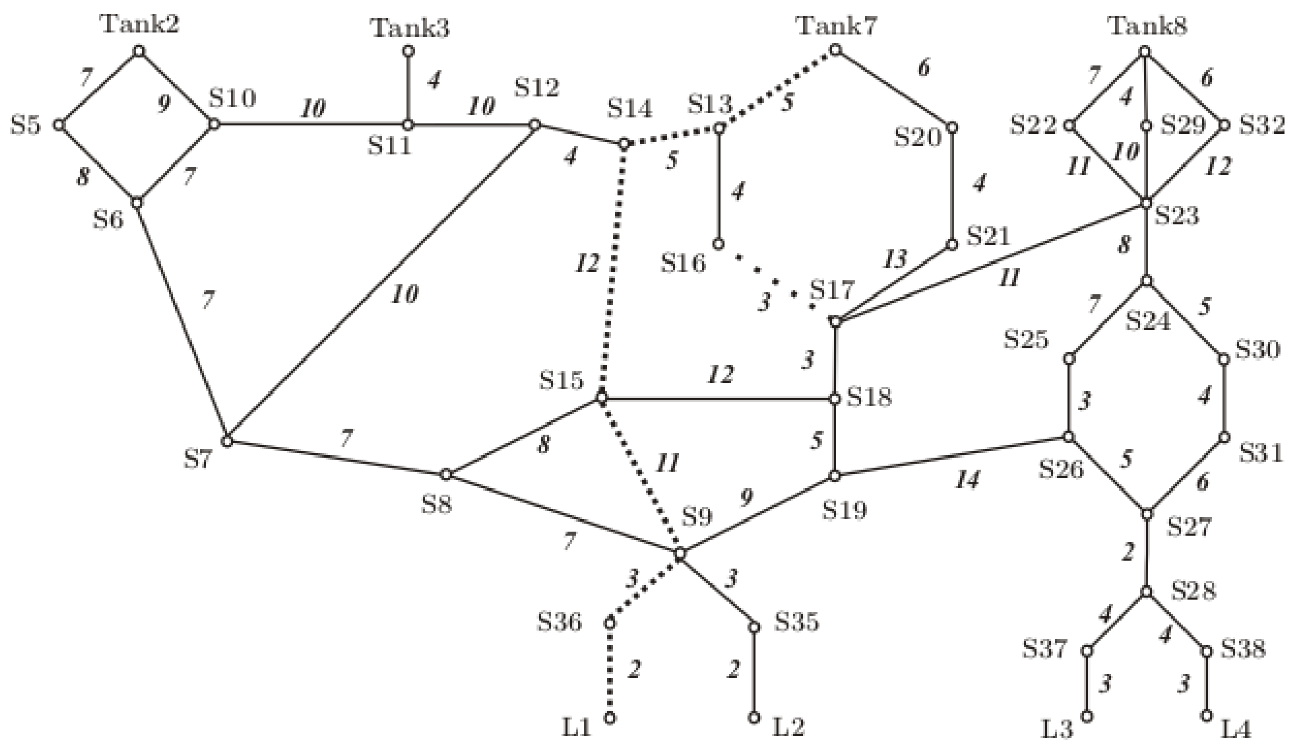

Fig. 5 - Corrected route on a graph

7. CONCLUSION

Developed DSS allows in the interactive modes decide the problem of liquid freight flows optimization during realization of technological operations on marine and combined oil stations with the ramified system of tank parks and freight pipelines. Proposed algorithms for decision support system functioning provide forming of optimal routes of liquid loads transmission at the process of marine tankers loading [15,18] and their correction in case of occurring emergency situation on the separate sections of freight pipelines. A synthesis and correction of liquid freight flows is carried out on the basis of optimization algorithms on graphs. A structure and algorithms of synthesized DSS allows promoting safety and efficiency of decision-making processes in the real time, including extreme terms.

Developed software, proposed algorithms and design methods can be used for design of the real control systems of automated oil complexes. It is thus necessary to provide the terms of synchronization of DSS database with the signals of sensors or microcontrollers which are install on oil stations. As next step it is expedient to explore the possibility of co-operation between DSS and PC-based control systems on the basis of the modern SCADA-systems, in particular TRACE MODE 6 [22,23]. Such kind of SCADA-systems provides human-controlled management, collection and processing of data, guided co-operation of all technological process parts in the real time, real-time control of technological parameters and forming of Alarm-signals for warning of emergency situations.

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