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Automation In Search Of Optimal Plan Resolution Of Logistics Tasks With Georeferenced

V. Bychko*, Ramit Azad** and Biman Tanvir Ahmed***

This paper gives a complex algorithm based model for the formalization and automated method of finding the optimal georeferenced solution logistics tasks which can be implemented. In the work a complex algorithm was proposed that finds the optimal plan for transportation of cargo. This algorithm finds the shortest network routes of delivery of goods, distributes vehicle routes and calculates the amount of the costs for transportation of a certain quantity of goods. The algorithm was realized in software prototype and was analyzed solving a particular transportation problem.

Keywords: Optimization of transportation, logistics.

1. Introduction

Over till this time, the key to success in the market competitiveness of manufacturers is the ability to quickly create optimal distribution plan of raw materials between manufacturing facilities as well as products among consumers. Particularly relevant to this problem is the production of commodity with high costs of transportation of raw materials. This refers to the metals and mining industry. These areas are focused on rail transportation that do not depend on the weather. However, some industries with a significant amount of cargo traffic have oriented on the autotransport which heavily dependent on weather conditions. Commonly, this is the agriculture. Our work has been executed with the desire of reduce the cost of transporting cargoes of raw materials of agricultural company, which was engaged the recycling of sugar beet. The company has preliminary data on the amount of the harvest in the fields, the data on demand for raw materials to processing plants and a network of roads. The company can control the number of trucks of a certain type, turnaround time on transportation and the placing of temporary warehouses.

The paper is organized as follows. Section 2 presents the literature review on this issue. Section 3 describes the notation and formulates the criteria's of optimization in such logistic problem. Section 4 explains the solution strategy that is based on formulating the problem. Section 5 describes methodology of obtaining of optimal solution. Section 6 presents a series of experiments that demonstrates the effectiveness of the new technique on particular examples of logistics problem.

*Dr. V. Bychko, Chernihiv National Technological University, c. Chernigov, Ukraine
**Dr. Ramit Azad, American International University-Bangladesh (AIUB), Dhaka, Bangladesh, Email: ramit_azad@mail.ru
***Dr. Biman Tanvir Ahmed, Bangladesh Atomic Energy Commission, Bangladesh.

2. Literature Review

Evidently, in poor weather conditions, the faster we can get a new cargo transportation plan the lesser losses we shall bear. More than fifty years the scientists research in fleet management in the context of the “car distribution problem” of railroads. Most of this work consists of deterministic linear programming models (Feeney, 1957; Leddon and Wrathall, 1967; Mendiratta, 1981) provide a general stochastic, dynamic model for container distribution. Other authors provide a stochastic formulation of the empty car distribution problem (Jordan and Turnquist, 1983). In their structure, a car could be assigned to at most one demand, and cars could not be repositioned more than once. This model allowed the problem to be formulated as a nonlinear programming problem.

Presently great opportunities in the field of logistic solutions provide computer equipment. There exist to many computer analytical methods with mathematical tools which enable to receive optimal solution using stochastic programming which have been described by Powell and Topaloglu (2003) and other mathematical methods. However,the tools georeferenced in such systems are not well developed. On the other hand existing the GIS-systems are enable to find the best route, and so on (Rahmi Nurhan, 2004). However, such GIS-systems was adapted weakly to solve of individual logistical problems. Naturally, every practical logistical problem that has used in commerce has specific conditions. The SPAR algorithm was been proposed by Topaloglu and Powell (2002) is part of a broader class of algorithms that use stochastic gradients but maintain structural properties The authors applies similar techniques to stochastic multi-commodity flow problems. Multi-commodity problems which might be arisen in this paper was been combined with nonlinear approximations.

Moreover, Godfrey and Powell (2001) introduce an adaptive sampling technique, dubbed the CAVE algorithm produces nonlinear approximations of recourse function using stochastic gradients. The method is easy to apply and produces piecewise linear, separable approximations of a recourse function, as noted by Powell and Topaloglu (2003). Usually, to solve specific logistics challenges cal scientists develop heuristic algorithms that are capable to solve a narrow range of problems. So in papers of Kholodenko and Gorb (2015) was considered by the optimization process of container transportation. There's mathematical model was adapted to the features of sea transport. In this case, the Hamilton method was the basis for solving the problem (Rego et al, 2011). In paper of Palagin et al (2014) was considered by the parameters that influence the optimization of freight traffic by air transport. There's mathematical model was adapted to the chain of interaction of air transport with other modes of transportation. Such an approach is well used for the multimodal transport operators (Zelenika et al, 2011). Unfortunately, as a result of the search, we did not find the studies of optimization models that take into account the quality of the road network segments and individual features of transport types. Normally, in such cases, researchers use simulation techniques (Sarabia et al, 2013).

So, based on these considerations the algorithm development and the creation of a hybrid software module (SM) to be able to find optimal plans for transportation of the cargo (OPTC) becomes an actuality. On the other hand such SM must be adapted to

WCD with georeferenced. To obtain the solution of such a problem, in manual mode to compute one iteration need to spend 20-40 man-hours.

3. Notation and Problem Formulation

According to your requirements to our problem, we have focused attention on the determinacy of the model, which has two staged cargo transportation. Such model is suitable for transportation of agricultural raw, municipal waste for facility of recycle. In our work we've decided to abstract from imitation modeling and stochastic processes. For planning the number of used vehicles our algorithm count the number of flights for each type of machine for a certain route.

This paper describes how to solve automation tasks with the following conditions.
Input data:

1. Map of roads. parameters: spatial coordinates of segments ways and their quality.
2. The number of available vehicles (TU) of various types. Individual parameters: payload capacity, operating speed, the notional value of transportation, priority to quality of way.
3. The number of terminal objects (TO) . The facilities: Export terminal (ET) raw temporary storage (TS), import terminals (IT). Parameters: location, the Quantity of existing and planned cargo for delivery .

In this problem is necessary to find OPTC by criterion of the least cost.
Original data:

1. The optimal number of units of vehicle involved for transport
2. Optimum period for the performance of complex (OPPC), distributed vehicle types.
3. The optimal amount of time on the measures on cargo transportation (MCT).
4. Optimal placement of temporary storage.

As an additional condition considered the necessity to provide loading of production during OPPC, that means there should be direct deliveries of load between the ET and the IT.

In this paper we will focus on obtaining data described in the first three paragraphs.

4. Methods Optimal Solution

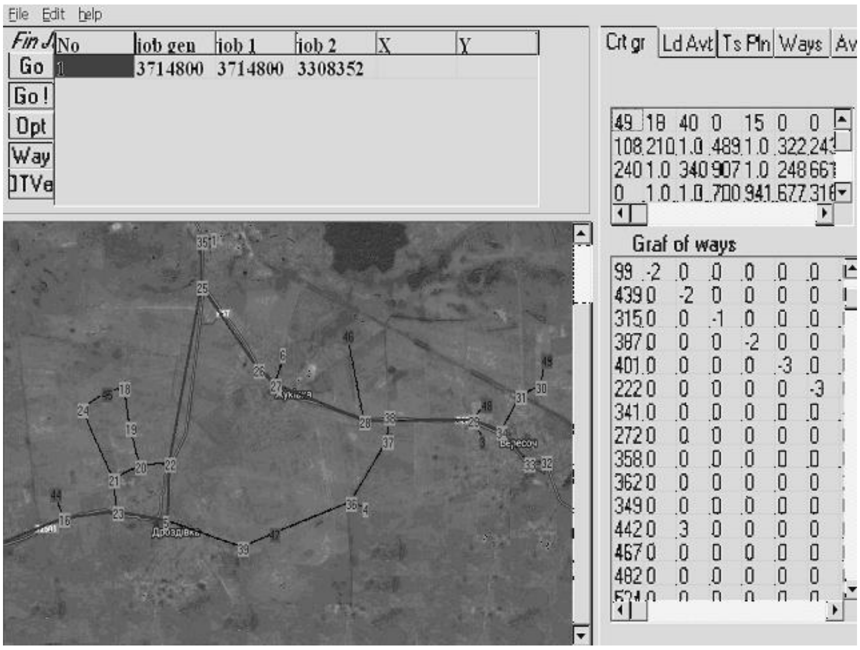
Note that this problem by criteria although belonging to the "linear programming", but does not allow it to solve by traditional methods. Therefore, when facing it was used heuristic approach. First, it was largely an automated procedure for obtaining primary data on the length and quality segments of routes directly from the electronic map (Figure 1). Then determined the optimal paths that connect.

Evidently that the tractor moving on highway with a loaded trailer is an inefficient choice. Similarly, you should not allow going a loaded lorry on a dirt road in the rain. Consequently, in the proposed model, the quality of the road surface is divided into 3 categories: highway, country road, dirt road. According to the requirements of the model the preferred of TU type, depending on the quality of the road surface when the distribution of transport routes take place.

5. Methodology of Obtaining of Optimal Solution

One should note that this problem by criteria although belonging to the "linear programming" (LP), but there does not allow it to solve by traditional methods. Therefore, when facing it was used heuristic approach. First, it was largely an automated procedure for obtaining primary data of the length and quality of road segments of immediately from the electronic map (Figure 1). Then determined the optimal paths that connect a TO.

Figure 1: The Fragment of SM Interface is Designed to Build Graph of Paths between Terminals



The next step, the problem can be seen as a particular case of the transportation problem [7] with additional conditions. The wording of it is as follows. There are N units of ET. Each of which have a cargo $a_1, \ldots, a_n$. As well an exist M units of IT which must receive $b_1, \ldots, b_m$ of cargo. It should be noted that TS can be considered as a ET and IT simultaneously. There is well as C -matrix of the cost coefficients of transportation between TO. Therefore the mathematical formulation of the problem is as follows:

Find

$$\min \varphi(x, c) = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} , \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

With constraints

$$\begin{cases} \sum_{j=1}^{n} x_{ij} = a_i,\ i = \overline{1,n} \\ \sum_{i=1}^{n} x_{ij} = b_j,\ j = \overline{1,n} \\ x_{ij} \geq 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

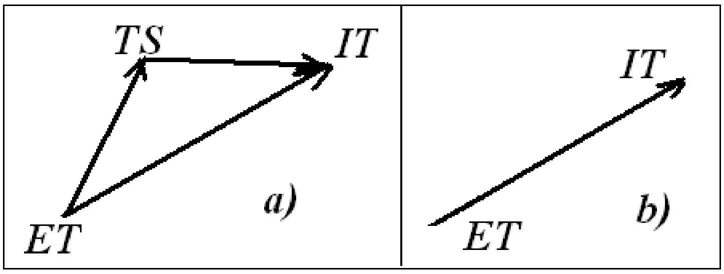
Where xij - the amount of cargo carried on a_i to b_j, $X = \| x_{ij} \|^{n \times m}$ - transport matrix and $C = \| c_{ij} \|$ - matrix tariffs(Wang, 2008).

To simplify the transport problem should be transformed in the task of enclosed type . That is, the balance equation is performed for it.

$$\sum_{i=1}^{n} a_i = \sum_{j=1}^{n} b_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

However, an additional condition on the availability of IT (Figure 2) and to ensure production (IT) of raw materials for MCT somehow corrects the problem.

Figure 2: Scheme of Transportation between Terminals: a. Using TS, b. without the use of ST



In addition, presented the task is different from classical task because the element of a tariffs matrix is not constant but depend on certain parameters:

$$C = \| c_{i,j}(T, P, Q) \| \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where $T_{i,j}$ - the relative transportation cost of a particular type of TU, $S_{i.j}$ - length of way transportation, $Q_{i,j}$ - the relative quality transportation routes. So as the target function φ (cx) is an irregular nature, therefore, the possibility is absent to solve this task only by classical algorithms of transport problem. So we have proposed the following search strategy of MCT:

1. Fill a primary data
2. Find a reference OPTC based on the distribution of vehicle routes, and calculates the total cost of transportation.
3. Find the best OPTC compared to the previous by checking neighbors or using genetic algorithm.

The basis of the method implementation solution were using by several traditional algorithms that have been transformed to specific conditions.
Total OPTIC search algorithm is as follows:

1. Using SM on the basis of geographical maps we build the Earl of transportation ways and TO on it.
2. Determine the optimal paths between all TO.
3. Calculate the optimal transport plan by the criterion of minimum cost, excluding TU component.
4. Form a general routing table with distribution of cargo transportation.
5. Distribute the TU on routes.
6. Calculate the total notional value of cargo transportation.
7. Looking for OPTIC by criterion of minimum cost with regard to the transport component.

When you create a graph that displays a grid of ways SM automatically generates an adjacency matrix that contains the coordinates of the vertices and weight of arcs .

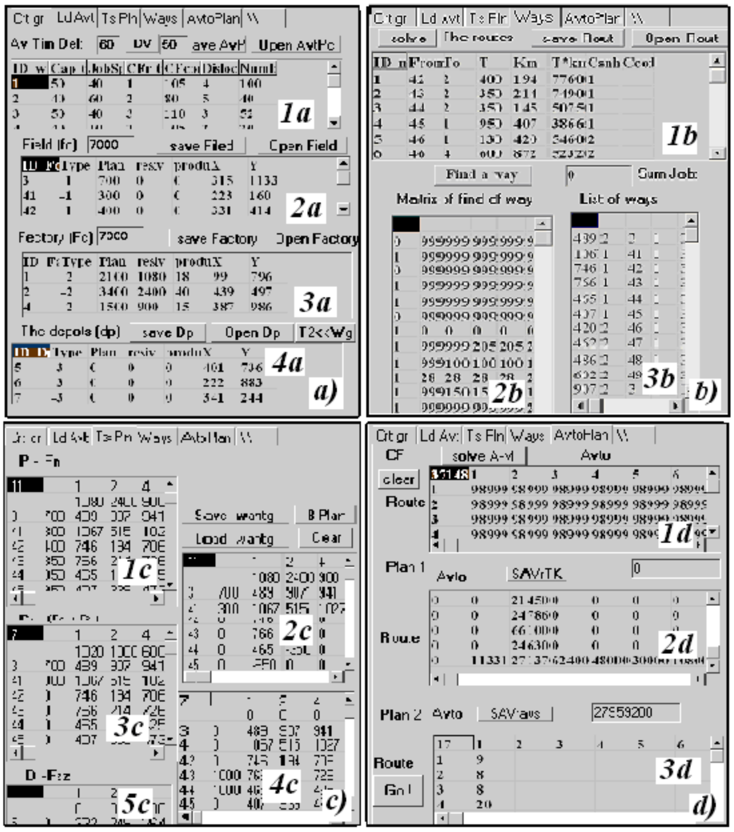
Dijkstra's algorithm has been applied by search an optimum paths between all TO .

The convention have accept that the weight of the arc is proportional to its length with consideration of the road quality, for simplicitywhichю It's not contrary to common sense . Then an optimality rating of certain path is defined as:

$$S = \sum k_i * L_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where k_i - quality factor segment path; L_i - segment -Length way.

Figure 3: The fragment of SM interface are defining of: a)data initialization and editing : 1a- available types of TU and their characteristics; 2a- characteristics of ET; 3a- characteristics of IT; 4a- characteristics of TS; b) the optimal plan distribution TU by routes 1b- the final distribution of cargo by route; 2b- the Dijkstra working matrix; 3b- the final matrix of optimal routs ; c) search of the cheapest ways; 1c- cost matrix of routes ET-IT; 2c distribution of cargo by routs ET-IT ; 3c- cost matrix of routes ET-TS and ET-IT; 4c- distribution of cargo by routs ET-TS and ET-IT; 5s- distribution of cargo by routs TS-IT d) distribution of TU by routs : 1d- matrix of coefficient for efficient allocation of TU by routes; 2d- matrix distribution of cargo by routs and by TU; 3d- distribution of trip by TU and by routs.



In calculating OPTC the additional condition of the need to ensure minimum of raw was adopted at the time of MCT. So, the problem is divided into two sub-tasks: 1)delivery cargo between TO without the use of TS 2) delivery cargo using TS (Fig. 2). So the SM is generating three traffic matrix (Fig. 3, fragment c)

Next step SM should calculate a quantity of cargo which must be delivered on each route. So it forms corresponding table (Fig. 3, tab.1b), and calculates the total WCD on cargo delivery (WCD). The total WCD is defined as:

$$A = \sum S_i * W_i \qquad \text{…………………} \quad (6)$$

Where Si - the length of the route; Wi - amount of cargo carried by the vehicle and one flights - the number of routes.

An individual coefficient of relative cost of transportation particular model vehicle should be considered to determine the total cost of MCT. To do this,a distribution vehicle between routes must be made (Fig. 3 fragment d). The initial problem has two alternative solutions depending on the requirements:

1. Distribution vehicle is carried out only on the criteria of optimal supplies vehicle specific route. This approach is effective when the process of work is not limited in time.

2. Distribution vehicle is made for reasons of maximum load vehicle for the duration of the job. This approach is justified when the process performance is limited in time. The total notional value of cargo transportation calculates a SM as

$$R = \sum k_i * S_i * W_i \qquad \text{……………………} \quad (7)$$

Where k - notional value of units of WCD, made by TU of certain type; i - the number of all flights. Si - the length of the route; Wi - the amount of cargo carried per trip vehicle. So the initial value of the target function that reflects the total notional value of cargo transportation has been received(Fig. 3 fragment d).

Therefore the automatically process to obtaining of the transportation plan and the relevant valuation traffic we consider as getting some value of the target function in the optimization problem. The controlled variables should be changed to find OPTC. Among them are the numbers of TU of different types, period of executing of MCT, the location of temporary storage.

6. Results and Discussion

As a result of the calculation SM offers cargo transport plan, with the distribution, on roads and on TU types (Figure 4). SM also enables to estimate thenumber of TU required for the task implementation.

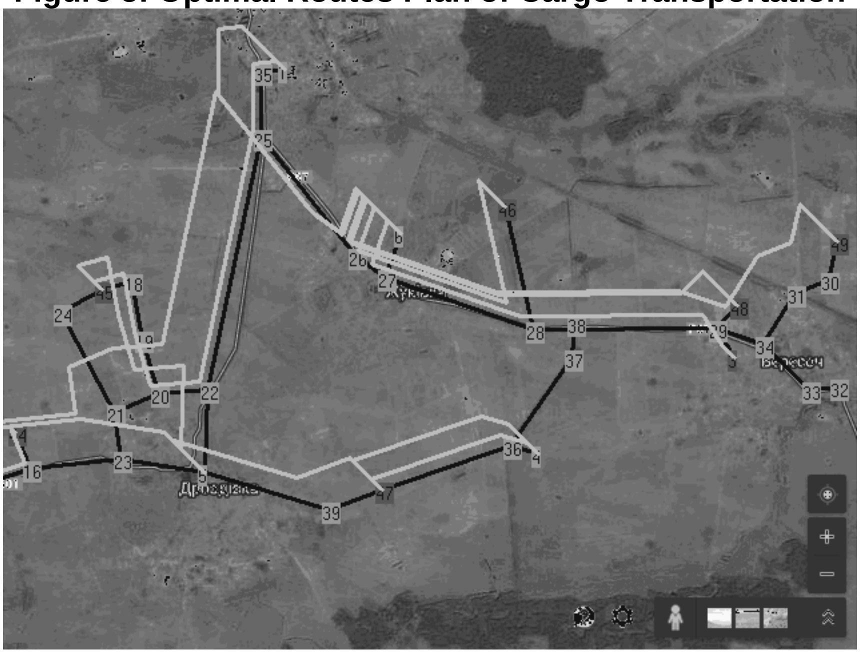
Figure 4: Table of Optimal Routes Plan of Cargo Transportation

List of routs

NIDrt	OIDrt	From	To	TypA	Nreys	Time	NAv
1	1	42	2	2	4	0,32	5
2	2	44	2	2	9	0,24	5
3	3	45	1	2	8	0,68	5
4	6	41	7	2	8	0,44	5
5	7	42	7	2	7	0,31	5
6	8	43	2	2	9	0,36	5
7	9	45	5	2	17	0,35	5
8	10	46	6	2	22	0,41	5
9	11	47	4	2	34	0,21	5
10	12	47	5	2	3	0,23	5
11	13	48	6	2	23	0,52	5
12	14	49	6	2	13	0,71	5
13	16	6	1	2	46	0,41	5
14	17	6	2	2	32	1,10	5
15	18	7	2	2	15	0,52	5
16	4	47	4	7	4	0,41	1
17	5	3	6	7	15	1,10	1
18	10	46	6	7	2	0,82	1

Moreover SM presents the results as well in tabular form (Figure 3, d and Figure 3, d) as in the graphic (Figure 5) also.

Figure 5: Optimal Routes Plan of Cargo Transportation



The task can be considered as the linear in n-dimensional space, provided the quantitative composition TU regarded as controlled variables, where n- is number of type TU. Obviously, the objective function depends linearly on the number of TU, under certain conditions,. In this case, the discrete condition imposed as additional conditions.

If the location of the TS is considered as controlled variables, then the problem can be considered as linear in m-dimensional space, where m- number of TS in certain areas because the objective function is a linear function of the distance betveen the TS and other terminals. However, it's impossible to use methods of linear programming in general by reason consideration georeferenced.

Formula (6) defines the total WCD of the MCT. The other hand the total WCD can be defined as a sum of WCDs of each TU.

Namely, each type of TU has individual “power” of transportation - P, defined as

$$P = V * W \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

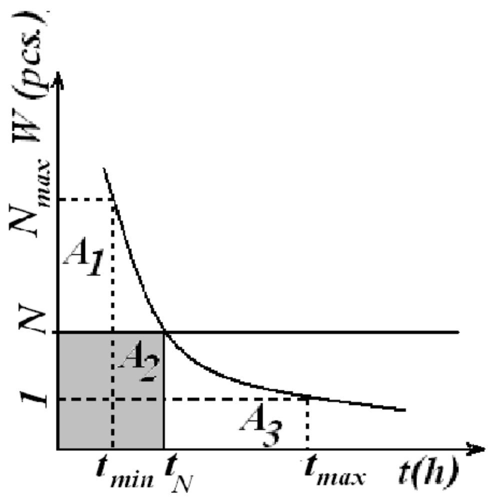
Where V denotes average speed of TU; and W denotes payload TU. If we consider the one type TU involved for MCT then the total WCD is defined as:

$$A = \sum N_i * A_i = \sum N_i * P_i * t_i * d \qquad \ldots\ldots\ldots \quad (9)$$

Where N_i- TU denotes the number of journey; t_i - duration of one journey; d – coefficient of considered all the technological downtime.

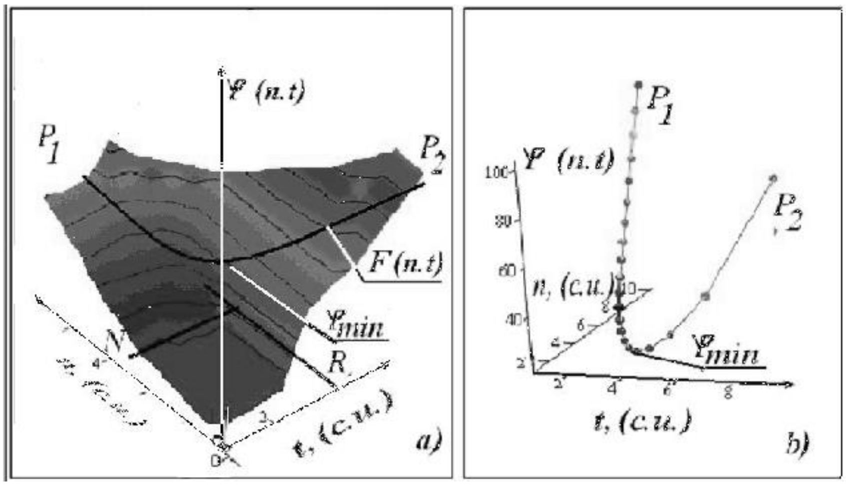
So the time of total WCD execution is inversely proportional to the number of TU involved for MCT (Fig. 6).

Figure 6: Dependence of the Time Working Performances versus the Number of TU: A1 -Maximal Number of TU; A2 - Optimal Number of TU; A3 -Minimal Number of TU.



Two limiting factors: time and the number of TU have analyzed to find the optimal time of MCT in the mathematical model of this problem. Namely the deadline of MCT has taken into account and thought the cost of different TU types are differ have assumed (Fig. 7).

Figure 7: a. The surface of the target function φ, which takes into account the depending of number TU involved by MCT (P1) and of time MCT (P2), the restriction function F; b. The Lagrangian function for the task.



So we have:

$$\varphi = k\,(n) * A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Where k - the transportation cost; depends on the TU type. If TU of different types involved to MCT, then k(n) is the non-linear depend. An availability of peak P_1 (Figure 7) explained by the certain costs involving TU are more than optimum.

Also, the target function must take into account the costs related to force majeure (FM) in the case of late completion of MCT. The nature of FM is likely to have a non-linear dependence on time.

$$\varphi = \begin{cases} r_1 * A\_if\ \_t < t_d \\ r_2(A_{rem}(t_d)) * A\_if\ \_t > t_{d\ 1} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

Where r_1 - cost ratio when MCT made the offensive FM and r2 - coefficient of costs when MCT did not have time to perform offensive FM; r_2 is non-linear dependence on time.

Peak P_2 due to the existence of losses related to the delay of MCT. The nature of the surface around the peak P_2 appears due to specific conditions.
So we need to find to obtain optimal plan, i.e.:

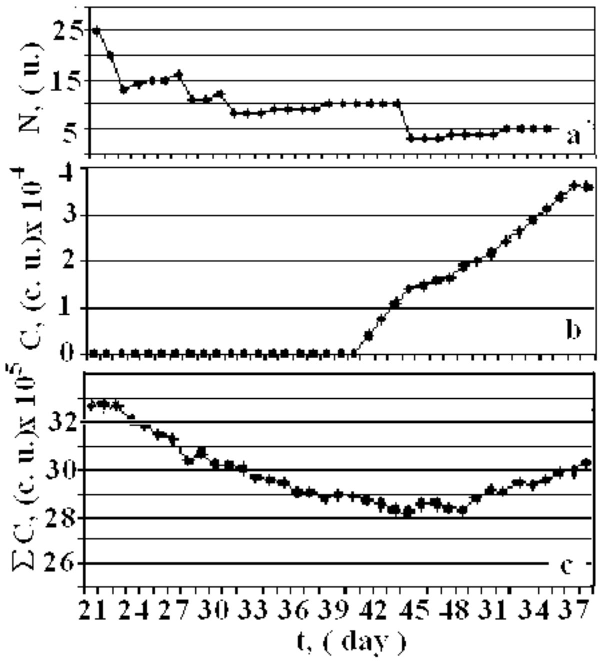
$$\min \varphi \ = \varphi(n.t, k(n), r(t)) \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

Where k (n), and w (t) - ratios of generalized costs.

Thus, even in a simplified case, the objective function φ is nonlinear and has dynamic character. So to solve logistical task of such type, linear programming methods are not suitable.

During the WCD the features of results of OPTC have been analyzed (Fig. 8).

Figure 8: Time dependence of a. the number of TU involved for MCT; b. raw material losses related by FM (t_d = 40); c) the total expenditure on transportation, which take into account the number of TU and losses resulting by reason FM



In particular, the total value of MCT considered depending on the time allocated for the MCT. When planning MCT promptly increasing number of TU (Figure 8a) it's quite natural If the amount TU of certain type is limited. In this case the non-effective TU will increase transportation costs occurring in the short interval time of MCT. (Figure 8a). On the other hand the FM was chosen, having place after t_d=40 days from the start of MCT as a limiting factor in time, (Figure 8b). The losses associated by FM have increased in an extended time interval at carrying of MCT caused by weather conditions (frost, flood, etc.), considered as FM. Within mathematical model the entire amount of not transported cargo up to critical moment later time t_d is lost (Figure 8b). Considering these two circumstances a dependence of MCT cost were obtained (Figure 8c). The dependence has characteristic minimum. In this case the optimal time for MCT is 42 days. Usually, in considering of problems like this, it is necessary to consider all alternative modes of transport for the cargo transportation optimization. But in this paper, the river transport was not considered as well as rail transport due to lack of extensive network of railways and navigable canals in the area. But the various types of truck have been considered as the alternative. In this paper as example it was obtained the optimum value for the particular case by the counting of large number of iterations in which different combinations of TU and the different intervals of time of MCT have been varied.

Our results do not contradict the judgment with the description by Godfrey and Powell (2001), but these authors considered the case of a stochastic effect on the transportation process. However, in their model does not take into account the individual characteristics of transport vehicles. Our model takes into account these features and allows you to get the best plan for changing the number of TU which is available. The transport costs minimizing by applying a trucks with high capacity and low cost transportation of cargo in accordance to formula (7). Although our model is deterministic in nature, but it is impossible to apply the methods of linear programming, as described in the work (Feeney 1957). The routes which consist of segments of different categories are remained debatable. In a simplified situation, our model for large trucks forbids the use of road segments of lower category. Similarly, for the tractors are prohibited from using the highway. These rules are set in the matrix of efficient allocation of TU (Figure 3d). But in some cases, these restrictions are not suitable.

7. Conclusions

Based on these results it could be argued, that during of work was proposed and implemented automated method for finding the optimal solution of logistics tasks which use georeferenced. In the work took into account the replacement of the concept of non-linear objective function with a large number of input parameters by software module/which adequately describes the strategy of optimal decision Thus there is no need to describe mathematically complex objective function which is piecewise linear. Its role is performed by a software module. Thus, changing the input parameters by the software module automatically, we can get an imaging about the hyper surface of objective function.

Furthermore, the use of such technology allows reacting quickly to changes in weather conditions. Since the topology of roads in many parts of the world depends heavily on the weather condition, therefore removing or add a segment of the road network graph allows you to quickly get a new optimal plan. Moreover, the algorithm give possibility minimizes the cost of cargo transportation by finding the optimal number of transshipment warehouses and choosing the optimal location for it. The essential novelty of our model is the preferred of TU type, depending on the quality of the road surface in the distribution of transport routes. This feature of the model greatly influences the reliability of the transport of goods and reduces the risk of traffic accidents. It should be noted that the gist of the work presented is not consist in test results of the algorithm on a concrete example. We have proposed a universal plan for optimal search strategy, which also takes into account the transportation network of roads available fleet and placement of temporary warehouses as control variables. In the carrying out the work the algorithm for obtaining of OPTC have implemented, which is able to search the optimal transportation plan of logistic task. If you want to study the use of alternative transport is enough to add the model of one more category of ways to supplement the garage with new means of transport as well as to set the weighting coefficient in the matrix of efficient allocation of TU (Figure 3d). In a sense, an algorithm is universal for all types of transport in solving of this type of problem.

The limitations of this algorithm are caused by the application of the homogeneity of cargo. Also limiting feature is a finite amount of cargo. Otherwise it is impossible amount of work that needs to be minimized during shipping. Also, unlike Godfrey & (2001), this model does not account for the impact of stochastic events in the process of transportation of cargo. Implemented algorithm is designed to solve the problems with 1 or 2 stages of transportation of cargo (Figure 3c). But the algorithm can be adapted to a larger number of transport steps. In the future, the possibility of to improve the algorithm by developing functional expansion of alternative methods of optimization and integration with other systems should be considered.

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