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Abstract. The factors affecting the activities of the aluminum industry like the supply interruptions of raw materials are described in the article. The article proposes the improvement of the optimal alternative routes and enterprise risk management system using the ant algorithm modification.

1. Introduction
Russian's aluminum industry by comparison with other non-ferrous metal industries is characterized by the largest scale of production. At the same time, the key feature is the geographical fragmentation of production processes: alumina production is focused on sources of raw materials; metal production – on sources of electricity. Geographical segmentation for enterprises is expressed by a high dependence of transport links. The aluminum industry as the main consumer of railway services assesses the high level of railways' as one of the most negative factor of operational risk. In the conditions of railroads limits and the large volume of raw-material supplies any interruptions on the tracks could be critical for the enterprise. This is due to the impact on the continuity of supply and as a consequence the continuity of the main production.

2. Justification of route network development as a tool for operational risk decreasing
The enterprise risk management system is an element of the internal control mechanism, which is a part of general corporate management, a technological tool and a tool that ensures the efficiency of risk management [1].

The risk-management process in the metallurgical industry includes the following basic stages: identification, description and evaluation of risk; deciding on risk; development of risk management activities; monitoring risks. The risk management policy, which defines the general concept and responsibilities, risk management regulations, describing the main tools and methods for identifying, assessing and minimizing risks is used by enterprises as the main risk-management regulatory document [2].

According to [2] United Company RUSAL Plc attributed to the main factors influencing the company's activities the following: volatility of prices and demand; increase in electricity prices (in particular, as a result of deregulation of electricity tariffs), power supply failures; change in the tax situation; exchange rate fluctuations; supply disruptions; risks associated with the regulatory, social, legal, tax and political environment.

Since interruptions in supply are estimated by the enterprise as one of the most important factors, the risk of supply disruption classification was carried out using the methodology of Failure Mode Effect and Criticality Analysis (hereafter called FMECA).

FMECA -analysis appeared as a result of the risk-management needs for complex and critical systems (projects in the field of aerospace and nuclear technology). The method is described in the interstate standard GOST 27.310-95 "Analysis of types, consequences and criticality of failures" [3].

According to this methodology (figure 1), interruptions in the supply of raw materials for the metallurgical industry can be attributed to the third area of the criticality matrix, because of levels of failure probability is B (probable failure) and degree of the consequences of failures is 9 (catastrophic consequences). At the same time, production shutdown and disruption of production schedules is a consequences of supply interruptions.

Probability level of occurrence of failure	**Degree of the consequences of failure**								
	1	2	3	4	5	6	7	8	9
A									**3**
B									Supply disruption
C				**2**					
D	**1**								
E									

Figure 1. Matrix failure probability – consequence of failure for aluminum industry.

The annual report of United Company RUSAL Plc [2] in the field of sustainable development shows several types of risks and a number of measures for their management and control, which includes:

- preventive maintenance of equipment;
- conducting regular training on occupational health and safety;
- quality control of finished products, quality control of raw materials;
- timely obtaining permits for emissions/discharges of pollutants;
- negotiations with carriers, ports and other transport infrastructure agencies, reorientation of cargo flows.

In order to ensure uninterrupted supply and, as a consequence, protection of production shutdown the company works only in the direction of reorientation of freight traffic by rail, not including road traffic in the system. It can be concluded that finding the best way by road, can be one of the tools of transport network reservation system and also can be considered as an element of risk-management system. It is important to note that the reservation as a method of risk management is proactive and creates conditions that exclude the appearance of causes and risk factors.

Modeling of cargo delivery routing by road transport seems to be relevant because of there are precedents for the use of road transport for the supply of large batches of homogeneous cargo [4], methods of road transportation of bulk cargo are developed as well as road transport has an extensive infrastructure of roads of different types.

3. Tools development

Routing - the process of determining the network on which the goods are moved from one point to another. The routing problem can be reduced to the traveling Salesman Problem [5]. Its essence is to find the shortest, the best way, passing through certain points once, followed by a return to the starting point:

$$\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\, x_{ij} \rightarrow \min_{x\in\Delta_\beta} V, \tag{1}$$

where, c_{ij}=h (v_i,v_j) is the length of the segment (i, j) of the original graph; the variable x_{ij} = 1 if the arc (v_i, v_j) enters the desired route of minimum length, i.e. the salesman directly moves from the i - th city to the j - th city, and x_{ij} = 0 if the arc (v_i, v_j) does not enter the optimal route, i.e. the salesman does not move from the i - th city to the j-th city.

Review of the literature [6-9] on methods of solving the traveling salesman problem allowed us to conclude that the ant colony optimization, (ACO) is the most optimal because of:

- able to adapt to changes, which is an important factor of car routes modeling;
- quite effective with a small number of nodes;
- less prone to suboptimal initial solutions.

In the context of this problem, the most important modeling parameters of the route network are: route complexity estimation (K) and time (T). Accordingly, the weight of each arc will be calculated by the following formula:

$$W_{ij} = (K * \mathrm{T})^{\beta}, \tag{2}$$

The probability of transition along this arc is calculated by the formula:

$$P_{ij} = \frac{\sum(\tau_{ij}{}^{\alpha} * W_{ij})}{\tau_{ij}{}^{\alpha} * W_{ij}}, \tag{3}$$

where, τ_{ij} - the pheromone value on this arc, α и β - the coefficients that affect the operation of the algorithm, the greater the α, the stronger the ant solution depends on the pheromone level, the greater the β, the more the ant solution depends on the arc weight.

It is important to note that arc in the case of the automotive modeling the arc has no length, as in the classical algorithm, and the weight is rather an inverse characteristic - the smaller the weight, the" more attractive ".

In the classical model of the ant algorithm, after the ant successfully passes the route, it leaves a trail inversely proportional to the length of the traversed path on all traversed arcs. In our implementation the pheromone value will be increased by the specified values in two cases – if the ant chose a composition that satisfies the constraints (for example, in cost optimization – restrictions on the minimum reliability and evaluation of the successful implementation of the system) and in the case when the composition replaces the optimal solution.

This change is made for reasons of the same number of traversed arcs by all ants (by the number of modules, each arc is a specific combination of versions in the module) and the lack of a length metric that is replaced by a weight metric.

In addition, pheromone traces are evaporating, that is the pheromone intensity is decreasing on all arcs at each algorithm iteration. Therefore, the intensity value must be updated at the end of each iteration.

4. Software implementation.

The tool is based on the ant algorithm, allows finding the best route in time, in complexity of the route and combined route (complex). Optimal time route is characterized by optimal complexity of the route with minimal time. The optimal complexity route is characterized by minimum complexity of the route with optimal time. The complex optimal route is characterized by an optimal combination of two parameters - complexity and time.

The implementation of several optimization methods is due to the internal processes of the aluminum enterprises and the nomenclature of the delivered goods. The delivery time is prioritized in case of ensuring continuity of production and supply of raw materials. In the case of finished products delivery the basic condition is safety of the cargo, therefore, a lower complexity of the route.

Figure 2 shows the application's user interfase. The starting and ending points of the route are specified in forms as well as optimization conditions: time, complexity or complex optimization.

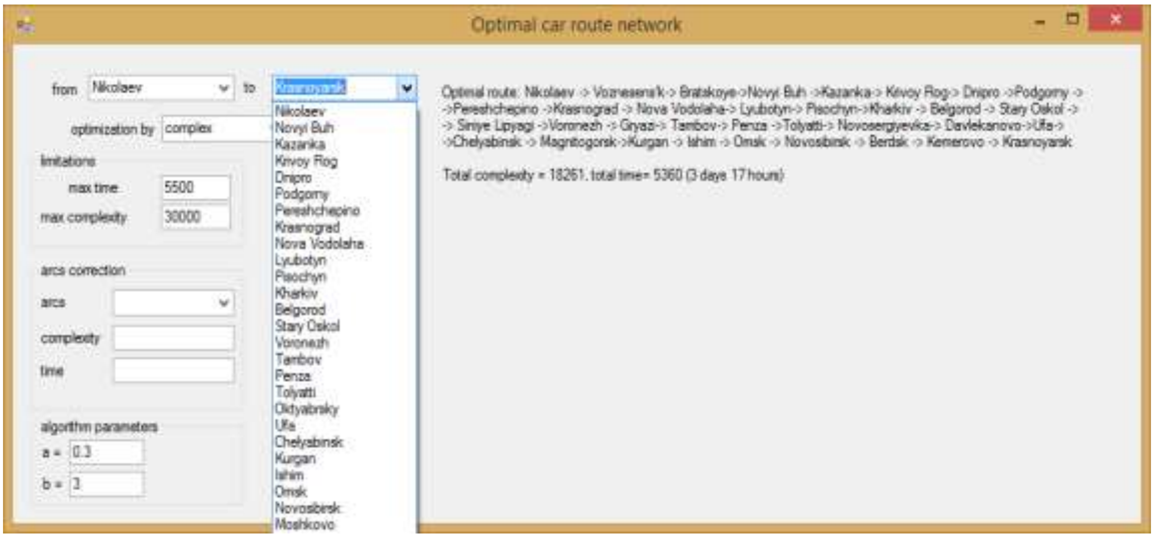

Figure 2. Software implementation of optimal route search.

The input parameters of the system are the following characteristics of the route:

- the list of possible parts of the route (areas between major cities, train stations, etc.)
- the difficulty level, which consists of such parameters as the directness coefficient and the road conditions assess;
- the average time of arcs passing.

It is important to note that freight railway stations are considered as the starting point of the route, since in case of an emergency situation with railway transport, delivery will be carried out from the nearest freight railway station by road. The output of the system is the optimal route, including the main points of the route; the total complexity of the route and the total time of the route in days.

The software application provides the function of arcs correction (figure 3), which allows to get more addeptive results of decisions making process. For example, repair work or road closures increase complexity of an arcs and time of its passing which can be changed and considered in the software application.

Figure 3. Function of arcs correction.

Presented software application which is based on the ant algorithm, provides the possibility of best route searching variations of optimization results depending on the external conditions and requirements of the enterprise.

5. Conclusion

Due to the high risk of failures in the supply of raw materials by rail the development of alternative transport networks could be considered as one of the ways of operational risk minimization, that is, forced interruptions in production due to the loss of current assets.

The software application is based on a modification of the classical ant algorithm, allows finding the best routes according to complexity of the arcs and their time.

Correction the settings of individual route network arcs provide flexibility to changing external conditions.

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References

[1] Kiseleva I A 2017 VaR – Valuation model of investment projects *Innov: electronic journal* **2** 1-7
[2] United Company RUSAL Plc sustainability report 2017 https://sr.rusal.ru/upload/iblock/658/UC%20RUSAL%202017%20Sustainability%20report%20RUS.pdf
[3] GOST 27.310-95 *Nadezhnost' v tekhnike. Analiz vidov, posledstvij i kritichnosti otkazov. Osnovnye polozheniya* (Moscow: Gosstandart)
[4] Lyustritsky D 2019 Stage restore *Expert Siberia* **43 (308)**
[5] Olifer V G and Olifer N A 2000 *Computer networks. Principles, technologies, protocols* (St. Petersburg: Peter)
[6] Shi X H, Liang Y C *et al* Particle swarm optimization-based algorithms for TSP and generalized TSP *Information Processing Letters* **103(5)** 169-76
[7] Sutton A M and Neumann F A 2010 Parameterized Runtime Analysis of Evolutionary Algorithms for the Euclidean Traveling Salesperson Problem *Proceedings of the Twenty-Sixth AAAI*

Conference on Artificial Intelligence pp 1105–11

[8] Hentenryck P V and Vergados Y 2007 Population-based simulated annealing for traveling tournaments *Proceedings of the 22nd AAAI Conference on Artificial Intelligence* pp 267–71

[9] Lamartin J P and Martins J S B 2010 AntBeePath: A Hybrid Bio-Inspired Algorithm for Path Determination *AAAI Technical Report FS-12-04 Human Control of Bioinspired Swarms* pp 38-43