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ALGORITHM FOR A SIMULATION MODEL FOR THE SELECTION OF A RATIONAL TYPE OF VANS ON TECHNOLOGICAL ROUTES OF THE TRANSPORT AND RECYCLING SYSTEM FOR RECYCLING OF A METALLURGICAL ENTERPRISE

The article presents an algorithm of the simulation model for selecting the rational type of trucks on the technological routes of the transport and production system of waste transportation in the conditions of a metallurgical enterprise. The study was conducted on the basis of formalized models and queuing systems theory. In the simulation, a discrete-event model of a closed queuing system was chosen as the basic model. In this model, cars are represented as requests that go through the following phases of service: loading at the temporary waste storage dump; movement to the unloading point (crushing and sorting complex); unloading raw materials to the crushing and sorting complex; returning to the loading point along the same route; servicing of vehicle breakdowns. The following data were used to build the simulation model through statistical studies of the transportation process on technological routes: vehicle loading time, vehicle unloading time, and time determined by the duration of vehicle failure. When constructing the algorithm of the simulation model, the duration of one experiment and the number of simulation experiments were determined using the methods of mathematical statistics and the theory of experiment planning. The modeling process begins with the input of the following initial data: the number of vehicle units, the average vehicle travel time, the current amount of raw materials in the crushing and sorting complex, the vehicle carrying capacity, the intensity of raw material supply to the crushing and sorting complex, the vehicle unloading time, the intensity of minor vehicle breakdowns, and the intensity of vehicle repair. The algorithm is built in accordance with the principles of special states and meets the requirements for discrete-event models. As a result of the algorithm development, it will be possible to determine the required number (types) of vehicles necessary to ensure the smooth functioning of this transport and production system, to determine the idle time coefficient and the coefficient of time losses due to technological delays of vehicles.

Key words: modeling, simulation model, dump truck, carrying capacity, metallurgical slag, crushing and screening equipment.

INTRODUCTION

The efficient functioning of transport and production systems of mining and quarrying enterprises largely depends on the effective organization of the transportation process, which consists in the timely delivery of goods in accordance with the technology and production needs at minimal cost. Waste transportation and production systems are no exception, where the organization of freight transportation is associated with extremely difficult operating conditions for trucks and ensuring continuous technological processes for recycling waste from the main production. The use of heavy-duty dump trucks is due to the advantages of this transport: the relatively low cost of this transport compared to others, maneuverability, the use of diesel fuel (independence from electrical networks), mobility, which makes it possible to use them at any horizons in the quarry, a greater slope overcome by dump trucks when lifting, simplification of the process of creating quarry roads, small work sites, etc. [1, 2]

A number of works have been devoted to the study of transport and production systems [3, 4]. In today's conditions, enterprises are faced with the task of increasing profits and improving the efficiency of managing production processes, including transportation. For the sustainable development of transport and production systems, a new approach to research is needed that will allow to quickly take into account environmental changes, adequately respond to the changing behavior of consumers of transport services, and effectively influence supply and demand [5, 6].

The complexity and diversity of the processes of functioning of transport and production systems do not always allow obtaining separate mathematical models of the traditional form (analytical models: the objective function and constraints are presented in analytical form). In many cases, the problems of mathematical modeling that arise here can be successfully solved by using the simulation modeling technique [7]. The purpose of simulation modeling is to reproduce the behavior of the system under study based on the results of the analysis of the most significant relationships between its elements.

Simulation modeling is a research method in which the system under study is replaced by a model that describes the real system with sufficient accuracy. Experimenting with a model is called simulation, which is the study of the essence of a phenomenon without resorting to experiments on a real object. Simulation modeling is used when: it is expensive or impossible to experiment on a real object; it is impossible to build an analytical model; it is necessary to change the behavior of the system over time [8].

A number of papers [9-14] have been devoted to the study of the use of modern simulation modeling methods. The construction of a simulation model is to reproduce the behavior of the studied transport and production system, taking into account the interconnections between all its elements.

THE PURPOSE OF THE WORK

To develop an algorithm for a simulation model for selecting a rational type of truck based on formalized models and the theory of queuing systems, namely: determining the required number (types) of rolling stock necessary to ensure the smooth functioning of a given transport and production system, determining the vehicle idle time coefficient, and the coefficient of time losses due to technological delays.

RESULTS OF WORK

The functioning of a certain number of rolling stock units on technological routes for transporting metallurgical slag to crushing and screening complexes can be represented as a closed mass service system.

Suppose that the crushing and screening equipment is serviced by the maximum capacity of a specific device V_{MAX}, which cannot be filled or overfilled, as a result of which the technological process will be stopped. The crushing and screening equipment is serviced by a group of M dump trucks of a certain carrying capacity W or different carrying capacities W_I. Initially, the crushing and sorting equipment already has a certain amount of raw materials V in the simulation process, and it is gradually filled (unloaded by trucks). During the production process, changes in the production process of crushing and screening equipment are possible, namely, current repairs, driver breaks for lunch, refueling operations). After loading the raw materials at the temporary slag storage dump, the truck proceeds to the crushing and screening equipment for further unloading of the raw materials. After unloading, the truck is driven back to the loading point - the temporary slag storage dump, loaded and driven back to the crushing and screening equipment for unloading.

In the simulation, a discrete-event model of a closed queuing system was chosen as the basic model. In this model, we represent vehicles as requests that go through the following service phases:

- loading at the temporary waste storage dump;
- movement to the unloading point (crushing and sorting complex);
- unloading of raw materials to the crushing and sorting complex;
- return to the dump to the loading point along the same route;
- maintenance of rolling stock failure (probabilistic event).

A car may be in a queue if the crushing and screening complex is busy unloading other cars or the crushing and screening complex is overloaded with raw materials. In this model, such a situation is defined as downtime.

Thus, the proposed discrete-event model of a closed queuing system can be represented as follows (Fig. 1)

In order to build a simulation model, in addition to the above technological parameters, the following data should be obtained through statistical studies of the transportation process on technological routes

- the time during which the vehicle is loaded (vehicle loading time). This time can be discrete or determined by a random variable distribution function. It depends on the carrying capacity of the vehicle and is considered as an array;
- the time during which the vehicle is unloaded from the crushing and screening complex (vehicle unloading time). This time can be discrete or determined by a random variable distribution function;
- time determined by the duration of the vehicle failure. It is determined by the flow of breakdowns for each vehicle.

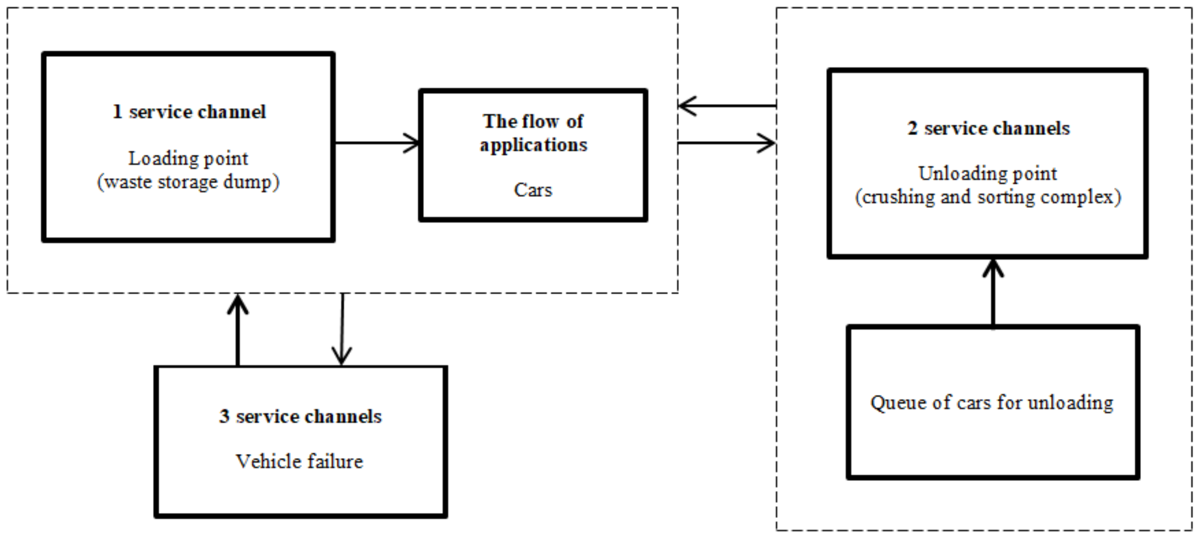

Figure 1 – Discrete-event model of a closed queuing system

When constructing the algorithm of the simulation model, using the methods of mathematical statistics and the theory of experiment planning, it is necessary to determine the duration of one experiment T_{OR} and the number of simulation experiments to obtain statistical reliability of the results.

The purpose of the study of this simulation model is to:

- determination of the required number (types) of rolling stock necessary to ensure the smooth functioning of a given transport and production system;
- determination of the vehicle idle time coefficient;
- coefficient of time losses due to technological delays.

The algorithm of this simulation model corresponds to one simulation experiment over time T_{OR} .

The modeling process begins by entering the following input data:

- M - is the number of rolling stock units, units;
- T_E - average rolling stock travel time to and from the waste storage dump, min;
- V_O - current amount of raw materials in the equipment, tons;
- V_{MAX} - maximum amount of raw materials in the equipment, tons;
- W - rolling stock carrying capacity, tons;
- T_Z - vehicle unloading time, min;
- IP - intensity of minor rolling stock breakdowns, 1/min;
- IR - intensity of rolling stock repair, 1/min.

The algorithm is built in accordance with the principles of special states and meets the requirements for discrete-event models. Random processes are also considered:

- time of arrival of cars to the crushing and sorting complex for unloading (1st group of M);
- time of the end of unloading (2nd group of M);
- start time of technological delays (3rd group of).

All these values are written to the array T [1..3M]. The initial situation is determined when the entire rolling stock arrives for unloading. According to the principle of special states, the process with the number in which the first event occurred in time is selected, and a specific car with the number $md1$ for which this event occurred is determined.

If the event is the arrival of rolling stock for loading, the status of the crushing and screening complex is checked (overflow or not), and if it is overflowing, the algorithm stops.

In this case, the flow of technological stops is considered as Poisson with a distribution function.

If other cars arrive during the loading of a given car, they queue up and wait for their turn to unload. The idle time of these cars (TX_i) is increased by the time required to complete the unloading of this car.

Next, the following condition is checked: if the next unloading time is the start time of the technological delay, then the time of servicing this delay is added to the time of arrival of this car for unloading. This delay service time is also added to the total delay service time. After that, the start time of the next delay is found.

The flow of technological stops in this case is considered as Poisson with the distribution function

$$K(t) = 1 - e^{-IP \cdot t},\ t \geq 0$$

The duration of the process delay has a distribution function

$$B(t) = 1 - e^{-IR \cdot t},\ t \geq 0$$

When the system time TO reaches T_{OR}, the simulation experiment ends and the average rolling stock downtime is determined

$$\overline{T_{ПР}} = \frac{\sum_{i=1}^{M} TX_i}{M}$$

The following is the rolling stock demurrage rate

$$k_{np} = \frac{\overline{T_{ПР}}}{TO}$$

The average time for technological delays (repairs) of rolling stock per vehicle is also determined

$$\overline{T_{Т3}} = \frac{\sum_{i=1}^{M} TЧ_i}{M}$$

The following is the idle time factor for technological delays

$$k_{m3} = \frac{\overline{T_{Т3}}}{TO}$$

It reflects k_{np} and k_{m3} the quality of the transportation process on technological routes.

CONCLUSIONS

In this study, an algorithm for a simulation model for selecting a rational type of trucks has been developed, namely: determining the required number (types) of rolling stock, determining the vehicle idle time coefficient, and the coefficient of time losses due to technological delays.

The necessity of practical implementation of the research results at a specialized enterprise that serves the technological routes of a metallurgical enterprise using software and hardware and information technologies has been identified, which will make it possible to model any situation on the technological routes of the structural units of a coal enterprise and obtain many values of the total queuing time, vehicle queuing time, idle time and repair coefficients for a group of vehicles with a given This enables the operation department to correctly select and deploy rolling stock on routes to ensure maximum productivity.

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Куш Є.І., Муковська Д.Я. **Алгоритм імітаційної моделі вибору раціонального типу вантажних автомобілів на технологічних маршрутах транспортно-виробничої системи рециклінгу металургійного підприємства**

У статті представлено алгоритм імітаційної моделі вибору раціонального типу вантажних автомобілів на технологічних маршрутах транспортно-виробничої системи перевезення відходів в умовах металургійного підприємства. Дослідження проводилось на підставі формалізованих моделей та теорії систем масового обслуговування. При імітації у якості базової, була обрана дискретно-подійна модель замкнутої системи масового обслуговування. У даній моделі автомобілі представлені у якості заявок, що проходять наступні фази обслуговування: завантаження на відвалі тимчасового зберігання відходів; рух до пункту розвантаження (дробильно-сортувального комплексу); розвантаження сировини до дробильно-сортувального комплексу; повернення до пункту завантаження за тим же маршрутом; обслуговування виходу з ладу автомобілів. Для побудови імітаційної моделі шляхом статистичних досліджень перевізного процесу на технологічних маршрутах були використані наступні дані: час завантаження автомобіля, час розвантаження автомобіля та час який визначається тривалістю виходу з ладу автомобіля. При побудові алгоритму імітаційнойної моделі, за допомогою методів математичної статистики та теорії планування експерименту було визначено тривалість одного експерименту та кількість імітаційних експериментів. Процес моделювання починається зі вводом наступних вихідних даних: кількість одиниць автомобілів, середній час їздки автомобіля, поточна кількість сировини у дробильно-сортувальному комплексі, вантажопідйомність автомобіля, інтенсивність надходження сировини до дробильно-сортувального комплексу, час розвантаження автомобіля, інтенсивність дрібних поломок автомобіля, інтенсивність ремонту автомобіля. Алгоритм побудований відповідно до принципів особливих станів та відповідає вимогам до дискретно-подійних моделей. В результаті розробки алгоритму буде можливим визначення необхідної кількості (типів) автомобілів необхідної для забезпечення безперебійного функціонування даної транспортно-виробничої системи, визначення коефіцієнту простою та коефіцієнту тимчасових втрат на технологічні затримки автомобілів.

Ключові слова: моделювання, імітаційна модель, самоскид, вантажопідйомність, металургійний шлак, дробильно-сортувальне устаткування.

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