Optimization of transport flows of the grain storage

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Abstract.

Ensuring uniform supply of wagons for loading and unloading of goods is one of the main tasks of the transport process. Existing methods for solving the issues of ensuring the rhythm of the supply of wagons for loading grain are not often allowed to identify the causes of the technological shortage of wagons. In this regard, within the framework of this work, the aim of the study is to increase the efficiency of the organization of providing grain storage with wagons using models.

1 Introduction

The Lotka–Volterra model has gained huge popularity and is often referred to as the "predator–prey" model. This model can be used to study the interaction of two systems (railway and grain storage), considering the effects of seasonality, the presence and changes in grain reserves in silos, etc. For example, during peak periods of grain harvesting, the interaction of the two systems occurs according to the classical Lotka–Volterra equation, and the rest of the time there is downtime of rolling stock. Taking these factors into account leads to a complication of the classical model, which leads to the appearance of additional terms. The relevance and practicality of this study is that models can describe the interaction of a railway with a grain storage.

2 A brief analysis of the literature sources

The issues of interaction between various transport companies and improving the quality of transport services are considered in the works of many scientists. The study developed a methodology that allows classifying much more symbiotic models. In [2], the application of the Darcy equation was considered. In [5], the transport service was investigated based on the Lotka–Volterra model. The study [6] examined the impact of railway transit on a transport hub using the Lotka–Volterra model. In the article [8], using the Simulink software, the interaction of a highway with motor transport was modeled based on the Lotka–Volterra model. In [9], a new approach to the study of marine clusters using the Lotka–Volterra model was investigated.
3 Task conditions

Railway station (A) in accordance with the contract and requests delivers wagons to the grain storage receiving and departure park (B) (see figure 1).

Fig. 1. The scheme of movement of wagons on the tracks of the grain storage for processing grain cargo: 1 – receiving park; 2 – wagon scales; 3 – loading area; 4 – running track; 5 – grain storage; 6 – park for accumulation of empty wagons.

It is possible that there may be a certain number of wagons in the grain storage receiving and departure park B, and then, according to the schedule, wagons are rhythmically fed from the technological section B to the section C for grain loading. In accordance with the loading technology, loaded wagons are moved to area D for further processing of accompanying documents. After that, loaded wagons are served to station A. This completes the full cycle of work with the company's rolling stock. It should be noted that the described technological process is continuous during peak harvest periods, and the rest of the time occurs periodically.

4 Arrival of wagons at the junction station

Fig. 2. Schedules for the arrival of empty wagons at the railway station, their delivering for loading on the grain storage driveway and departure of loaded wagons from the station during the calendar month.

Further delivery of these grain carriers to the loading area of the grain storage is an incoming flow of requirements for the grain storage driveway. The parameter of the incoming flow of requirements is the intensity of the flow.

5 Modeling the interaction of transport processes based on the classical Lotka-Volterra model

The model based on the Lotka–Volterra equations is used not only in nature but is also often used in modeling economic and technical systems [7]. The logical relationship between the main factors of grain cargo transportation is shown in figure 3.
Fig. 3. Wagon turnover in the transport and logistics system for grain cargo transportation

In the relationship between the two states of wagons “empty” and “loaded”, between which there is a confrontation, can be applied the mathematical model “predator-prey”, and for the parameters – quantitative indicators of the qualitative characteristics of the wagon turnover.

The arrival of empty grain carriers $N$ is provided by grain reserves at the grain storage, which are characterized by the value $E$. Loaded grain carriers are sent exclusively after loading grain from the release bins and the dynamics of sending loaded grain carriers depends on the number of empty wagons arriving for loading. Sometimes there is the arrival of faulty empty wagons, which reduces the ability to ship grain. In logarithmic form, the interaction of two states of cars can be described as follows.

$$\begin{align*}
\frac{dN}{dt} &= aN - bNP \\
\frac{dP}{dt} &= -cP + dPN
\end{align*}$$

where $N(t)$ – the number of empty grain carriers at time $t$ waiting to serve from the station in the path of the grain storage, wag; $P(t)$ – the number of loaded grain carriers after loading grain at time $t$, wag; $a$ – the input factor of empty grain carriers for loading; $b$ – coefficient of influence of loaded grain carriers at the rate of arrival of empty; $c$ – coefficient of reduction of the loaded grain carriers; $d$ – coefficient of influence of empty grain carriers at the rate of decrease in the loaded wagons.

The system of equations is based on the following assumptions:
- if there is no grain on the grain storage for shipment by rail, empty grain carriers are idle waiting for loading according to the equation $\frac{dN}{dt} = \frac{aN}{2}$;
- if there are no empty wagons on the market, there is a deficit of grain according to the equation $\frac{dP}{dt} = -\frac{dP}{2}$;
- terms proportional to the derivative of $NP$ are considered as the result of loading grain into wagons and consists in reducing the rate of arrival of wagons for loading by an amount proportional to the grain supply in the grain storage.

For a given initial ratio of the number of empty wagons 15 to loaded wagons 10, will be set the coefficients that characterize the arrival of wagons on the grain storage driveway, and then on the loading area, which has a dimension of 1/day: $a = 0.2; b = 0.02; c = 0.19; d = 0.02$.

Will be used Mathcad 15 to solve the system (1) with automated mathematical calculations.

Figure 4 shows that when the initial ratio of the number of empty wagons to loaded wagons is 15:10, the process is repeated, as in figure 4. the interval along the abscissa axis can be plotted in any time range. It should be noted that the non-elliptical shape of the trajectory covering the center reflects the inharmonic nature of the oscillations.

Thus, the transport process is repeated again (see figure 5).
6 Modeling the interaction of transport processes based on the Lotka-Volterra model with logistic correction

\[ \begin{align*}
\frac{dN}{dt} &= aN - bNP - eN^2 \\
\frac{dP}{dt} &= -cP + dPN - fP^2
\end{align*} \]

where \( e \) and \( f \) – coefficients that characterize the decrease in the number of empty and loaded wagons due to "competition" between the types of wagons, respectively.

In this case, the transport process changes depending on the value and sign of the parameter \( e \). Given the initial ratio of the number of empty wagons to loaded wagons, will be additionally set the coefficients \( e = 0.001 \) и \( f = 0.001 \).

7 Discussion of the results
Fig. 6. Phase portrait of the system with logistic correction.

In figure 7, the graph shows the change in the number of empty and loaded wagons over time (year). Figure 7 describes the effects of "competition" between wagon types that results after damped oscillations.

Fig. 7. Graph of dynamics of changes in the arrival of loaded and departure of empty wagons.

If the coefficient $e$ is negative ($e = -0.001$), the stationary point is unstable (see figure 8), and the amplitude of fluctuations in the number of empty and loaded wagons increases (see figure 9).

The models make it possible to study cyclical changes in the number of wagons that are often observed in the transport process.
Fig. 9. Graph of the dynamics of changes in the arrival of loaded and departure of empty wagons.

8 Conclusion

Based on the conducted research, the following main conclusions can be drawn:

1. The analysis of the arrival and departure of cars shows an initial imbalance between the arrival of empty wagons and the required number of rolling stocks.

2. To implement the problem of studying a mathematical model describing the movement of wagons on the grain storage driveways, a phase portrait of the solution system is obtained, which corresponds to the values of the parameters and the initial conditions of the problem.

3. Rational values of the system parameters are found by the method of directed search, for which the phase portrait view is characterized by a family of elliptic shapes. This type of phase portrait corresponds to ensuring stable operation of the grain storage.

References


