за результатами реальної роботи та за результатами тестування, незалежні і рівнозначні

$$P = \frac{P^{реал} + P^{тст}}{2}.$$

При розрахунку відповідних значень $P^{реал}$ та $P^{тст}$ на основі відповідних значень імовірностей безпомилкового виконання оператором дії технологічного процесу, імовірностей своєчасного виконання оператором дії технологічного процесу, коефіцієнтів готовності виявилось, що надійність виконання оператором дії технологічного процесу при проведенні тестування оператора вище на 4%, ніж надійність оператора працюючого тільки в реальних умовах.

Список використаних джерел

1. Мунипов, В. М. Эргономика: человеко-ориентированное проектирование техники, программных средств и среды [Текст] : учебник / В. М. Мунипов, В. Л. Зинченко. – М. : Логос, 2001. – 356 с.
2. Бантюкова, С. О. Підвищення ефективності експлуатації сортувальних гірок з урахуванням безпеки їх використання : дис. на здобуття наук. ступеня канд. техн. наук: спец. 05.22.20 – Експлуатація та ремонт засобів транспорту [Текст] / С. О. Бантюкова. – Харків : УкрДАЗТ, 2014. – 135 с.

УДК 656.072.2

Butko T., Dr. Sc. (Tech.), *professor,*
Yashchuk Yu., *post graduate*
Ukrainian State University of Railway Transport (Kharkiv)

DETECTING ANOMALIES AND ADAPTING RAILWAY NETWORK MODELS DURING WARTIME

In the context of the ongoing armed conflict in Ukraine, railway transport has become one of the key elements of the national transport infrastructure. Evacuation of the population, movement of humanitarian aid, and strategic cargo largely depend on it. Massive and prolonged disruptions caused by both direct hostilities and infrastructure damage significantly affect the efficiency of railway transportation. War leads to unpredictable changes in routes, demand, and availability of railway services, making the management of transport flows an extremely challenging task. The relevance of detecting anomalies and adapting network models under such conditions is increasing exponentially, as each failure or malfunction can have critical consequences for passenger safety and the overall stability of the transport system.

Under such conditions, passenger travel network models become vulnerable to significant changes in demand structure, making it relevant to study the impact of disruptions on passenger behaviour and overall transport system efficiency. This requires a revision of network demand models, which may become irrelevant if they are based on old data and do not take into account changes in demand and new passenger priorities. In addition, the need to consider the risks of disruptions and their impact on the network comes to the fore [1].

War forces the constant adaptation of the transport system to new conditions. Due to unpredictable changes in demand and routes, rail transport faces numerous challenges that require rapid adaptation of network models. Adaptation strategies may include dynamic model updates based on new data, as well as the development of scenarios for real-time decision-making. The conditions of unpredictable changes in demand caused by massive and prolonged disruptions require operational adaptation of network models. The importance of dynamic updating of forecasting systems is increasing in conditions where data quickly lose relevance. One of the key approaches to adaptation is incremental learning [2], which allows for the gradual retraining of models without the need for their complete retraining. This methodology allows models to remain relevant as new data become available. The use of a sliding window for modelling allows adaptation to the latest changes in passenger behaviour by limiting the analysis to only the most recent data. Another effective approach is the application of models that combine several forecasting models to increase resilience to changes in demand. In addition, the automation of the update process reduces the time and human resources required to maintain models in an up-to-date state. The challenges associated with dynamic updating include the need to ensure data quality, speed of data processing, and selection of the optimal model. The prospects for the development of such approaches include the introduction of deep learning to process large amounts of data and identify complex dependencies, as well as the creation of intelligent systems that can independently adapt to changing environments. Integration of forecasting systems with traffic management systems and other transport systems can significantly improve management quality in cases of prolonged interruptions.

However, in addition to adaptation, it is important to detect potential anomalies in transport flows that may indicate new threats or problems in the infrastructure. Anomalies in rail passenger travel network, especially during mass disruptions, may indicate hidden problems or unforeseen situations that require immediate intervention. Anomaly detection methods allow for the rapid identification of unusual changes in passenger flow, routes, or passenger behaviour. The main methods for detecting anomalies include statistical methods, machine learning, time series analysis, and geospatial analysis. These approaches allow for the detection of sudden changes in passenger flow, unusual travel routes, or significant train delays. For example, a sharp increase or decrease in the number of passengers may be the result of accidents or natural disasters, while unusual travel routes may indicate infrastructure problems or changes in passenger behaviour. Key aspects of anomaly detection include defining a baseline level of normal system operation and selecting appropriate metrics for analysis. The use of visualisation can help better understand the nature of anomalies and their causes. Integrating data from various sources, such as meteorological data or social networks, can improve the accuracy and speed of response to unexpected situations.

Therefore, massive and prolonged disruptions have a significant impact on the models of the railway passenger travel networks, which require rapid adaptation of forecasting systems. The use of dynamic model updates and modern anomaly detection methods is a key element in minimising the negative consequences of prolonged disruptions and ensuring the stable operation of the railway transport system.

[1] Butko T., Yashchuk Yu. Enhancing passenger rail transportation efficiency through integrated intermodal hubs and risk management technologies. *Матеріали V Міжнародної науково-практичної інтернет-конференції «Напрями розвитку технологічних систем і логістики в АПВ»* – Харків: ДБТУ, 2024. – С. 7-8

[2] Nallaperuma, Dinithi, et al. Online incremental machine learning platform for big data-driven smart traffic management. *IEEE Transactions on Intelligent Transportation Systems* 20.12 (2019): 4679-4690.

UDK 621.39:656.2

***Kharchenko I.V.**, PhD student*
Ukrainian State University of Railway Transport, Kharkiv
***Lysechko V.P.**, Sc.D. Professor*
Ukrainian State University of Railway Transport, Kharkiv

METHOD FOR EVALUATING THE EFFICIENCY OF QUASI-ORTHOGONAL ACCESS AT SUBCARRIER FREQUENCIES

This paper explores the method of quasi-orthogonal access at subcarrier frequencies (QOFDM), which enhances the efficient use of frequency resources in railway transport systems. The proposed method is based on individual subcarrier frequency allocation for each frequency plan, thereby reducing multiple access interference and enhancing system capacity.

The methodology includes an algorithm for forming ensembles of complex signals using various subcarrier frequency allocation schemes. The spacing between subcarrier frequencies is determined based on the spectrum width and the number of subcarriers in each channel. This approach minimizes overlapping frequency positions between different channels, thus mitigating internal system interference.

The implemented methodology allows for precise evaluation of the amplitude and phase of any combination of components at the output of a non-linear system, modeled through a Taylor series expansion. The impact of interference is assessed based on the analysis of cross-correlation between frequency plans, which helps identify the most vulnerable frequency positions for minimizing interference.

In this study, four distinct frequency plans were simulated, each with a different number of subcarriers and spacing. The analysis demonstrated that even with a significant increase in the number of subcarriers, the level of interference remained within acceptable limits, confirming the effectiveness of the proposed approach.

A field experiment involved transmitting pilot signals between two transmitters with different frequency plans and analyzing signal reception under conditions of internal system interference. The results confirmed that the quasi-orthogonal access method significantly reduces the number of overlapping frequency positions, improving communication quality when multiple users operate simultaneously.

This method can effectively optimize the operation of railway transport control systems, especially in scenarios with many simultaneously operating transmitters.

References:

1. Mitola, J. III, "Cognitive Radio: Making Software Radios More Personal," IEEE Pers. Commun., vol. 6, no. 4, Aug. 1999, pp. 13-185 .
2. Svergunova, Yu.O., "Method for determining the coincidence of subcarrier frequency positions with quasi-orthogonal access at subcarrier frequencies," Information-Control Systems on Railway Transport, Kharkiv: UkrDUZT, 2015 .
3. Haykin, S., "Cognitive Radio: Brain-Empowered Wireless Communications," IEEE J. Areas Commun., vol. 23, no. 2, Feb. 2005, pp. 201-220 .

UDK 51-74

***V. Lazariev** (NURE)*
***O. Lazarieva** (V.N. Karazin KhNU)*
Ukrainian State University of Railway Transport, Kharkiv