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## SYSTEM AND ANALYTICAL RESEARCH OF THE DEVELOPMENT OF TRANSPORT AND TECHNOLOGICAL SYSTEMS OF RAILWAY FERRIES

Об'єктом дослідження є процеси розвитку транспортно-технологічних систем залізничних поромів як складних технічних систем. В ході дослідження використано системний підхід до вирішення науково-технічної проблеми підвищення ефективності технічного обслуговування залізнично-поромних сполучень, для чого застосовано графічний метод аналізу формування причинно-наслідкових зв'язків з побудовою діаграми Ісікави. За найбільш інформаційний критерій обрано резерв прискорення оборотів вагонів на залізничних поромках – якісну характеристику ефективного використання вагонного парку, яка безпосередньо залежить від скорочення простоїв вагонів у припортовій зоні, що є перспективним. Результати досліджень надають багатопланову картину, яка показує можливість скорочення часу знаходження судна у порту за рахунок підвищення технічного рівня організаційних робіт з рухливим складом на під'їзних шляхах і їх завантаженням на пором. А також виявляє вплив стану матеріально-технічної бази обслуговування рухомого складу та бази порту для завантаження поромів, сумісності дій роботи диспетчерських служб та необхідності відповідної інформаційної підтримки. Проте розвиток цих напрямів не можливий без забезпечення умов надійності засобів залізничної автоматики, автоматизації та телемеханіки, а також підвищення кваліфікації кадрів з їх обслуговування. Сумісність дій роботи диспетчерських служб реалізується через застосування гнучких форм організації вантажопотоків зі складанням оптимального каргоплану завантаження залізничного порому. Впровадження інформаційного забезпечення повинно враховувати синхронізацію дій інформаційних систем залізниці та порту, а також взаємозв'язок засобів автоматики з роботою поромної переправи, постійно оновлюватись за рахунок нових програмних продуктів. На підставі проведеного аналізу складено програму заходів щодо розвитку транспортно-технологічних систем залізничних поромів.

Одержані результати спрямовано на підвищення оперативності, обґрунтованості та ефективності управлінських робіт з експлуатації засобів транспорту та можуть бути використані при виконанні дослідницьких робіт інших об'єктів залізнично-водного сполучення, зокрема припортових залізниць.

**Ключові слова:** залізничні пороми, технічне обслуговування, транспортно-технологічна система, залізнично-поромні сполучення, системний аналіз, складні технічні системи.

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### 1. Introduction

The use of ferry complexes is a promising and competitive way to deliver goods and is aimed at expanding international transport and economic ties. According to [1], in the Black Sea region, there are 23 ferry services that provide transportation of freight vehicles between Ukraine, Georgia, Turkey, Bulgaria, Russia: 5 of them are railway ferries. Therefore, increasing the efficiency of maintenance of railway ferry services is an important scientific and technical problem, the solution of which will contribute to an increase in freight traffic.

Ferry stations are a highly developed infrastructure for processing ferry ships, loading them with cars and railway cars, forming and disbanding trains. This requires the synchronized operation of the railway and port services, is ensured by the reliable operation of transport and technological systems (TTS) – a complex technological complex that serves ferry berths, coastal devices

and connecting loading bridges equipped with bag and head switches [2]. In [3], the mechanisms of technological processes for promoting car flows are considered: uninterrupted loading of ferries with the formation of a reserve of cars is economically beneficial. Transport and technological systems are complex technical systems [4]. Characteristic features for them are: a change in external operating conditions, the presence of a large number of direct and reverse ties with significant significance of each of the elements. Continuous improvement of existing and the introduction of new operational measures require a system-analytical study of the TTS to identify promising ways to improve the efficiency of their maintenance. Therefore, *the object of research* is the development processes of transport and technological systems of railway ferries as complex technical systems. *The aim of research* is, as a result of a system-analytical study, to identify and establish causal relationships between measures that positively affect the increase in the efficiency of operation

of the TTS of iron ferries, with the identification of promising development paths.

## 2. Methods of research

Critical situations, the possibilities of reducing risks and failures can be investigated using the FMEA-analysis (Failure Mode and Effects Analysis) [5]. This research technology includes the compilation and analysis of object models (complete, structural, functional, flow) and the construction of Ishikawa diagrams. The determination of cause-and-effect ties using the Ishikawa diagram [6] gives a visual representation of primary and secondary factors. The criterion for increasing the efficiency of technical maintenance of the transport and technological system of a railway ferry was chosen as a reserve for accelerating the speed of wagons on railway ferries. This characteristic depends on the time spent by the cars in the port area and indicates the efficient use of the car fleet.

The research process is a systematization and analysis of measures, the use of which will contribute to the development of transport and technological systems of railway ferries. The scientific and methodological basis for determining the factors and their mutual connection are the scientific works of scientists in the field of:

- design features of coastal structures and ferries [7];
- design of ferry vessels of the «Ro-Ro» type and formation of a cargo plane [8, 9];
- organization of joint work of railway junctions and port [10];
- use of system analysis in questions of the functioning of port railways [11];
- maintenance of railway automation [12] and the implementation of monitoring systems in water transport [13];
- development and implementation of information technology at railway facilities [14];
- management of intellectual resources in transport enterprises [15].

## 3. Research results and discussion

On the constructed Ishikawa diagram (Fig. 1), which has the form of a «fish bone», the objective function is depicted by a large horizontal arrow («fish ridge»). «Big fish bones» on the diagram represent important factors that directly affect the effective use of the entire TTS of a railway ferry as a complex organism, which vital activity is associated with highly qualified specialists in the interdisciplinary fields of railway and water modes of transport. «Compatibility of actions of the work of dispatch services» of the railway and the ferry station (port) is the main condition for successful transport servicing of cargo turnover. This factor depends on secondary factors: «The use of flexible forms of organization of cargo flows» and «Optimal cargo plan of a railway ferry». They are depicted on the diagram as «small bones». No less important factors should be considered «Reliability of railway automation equipment» and «Advanced training of personnel», which, in turn, directly affect the «Material and technical base for servicing rolling stock».

The «material and technical base of the port for servicing ferries», a less important component of the process of increasing the efficiency of technical maintenance of the ro-ro TTS, depends on the «Reliability of automation and telemechanics» and «The relationship of railway automation with the operation of the ferry». These «small bones» are also important for the use of «Information Support2 for the project, the prerequisites for which are «Synchronization of the information system of the railway and port» and «Development of new software products».

The revealed pattern shows the possibility of reducing the time spent on the ship at the port (ferry station) by increasing the technical level of organizational work with rolling stock on access roads and loading them onto the ferry.

Uninterrupted loading of ferry vessels with the formation of a reserve of wagons is possible as a result of improving the condition of the material and technical base for servicing rolling stock and the port base, organizing joint actions of dispatch services of the railway and port and introducing new means of information support.

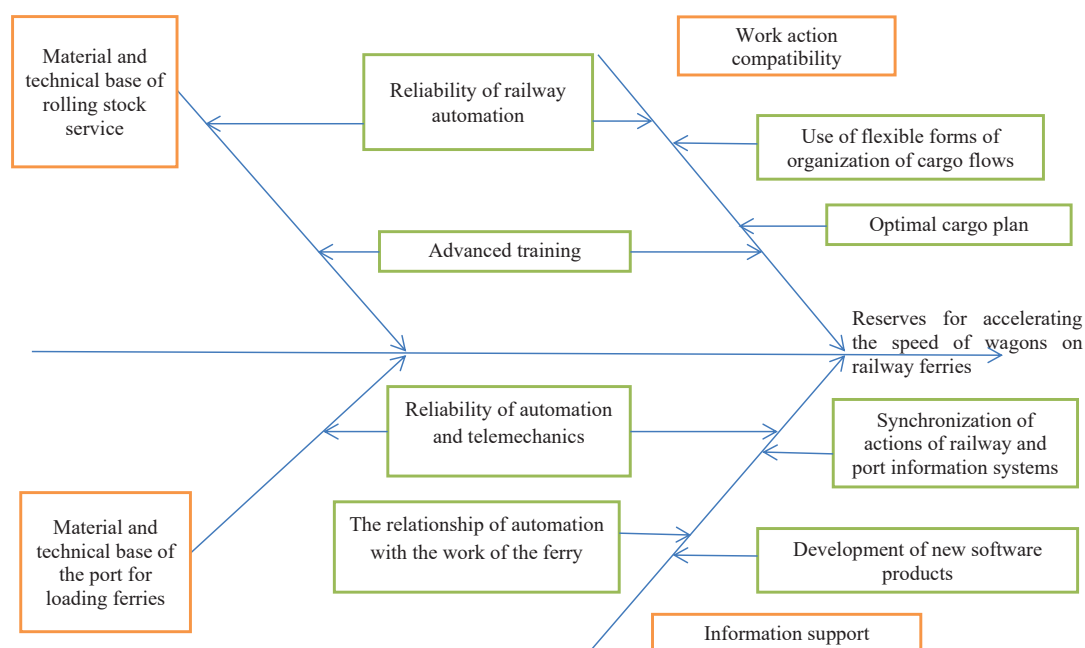


Fig. 1. Ishikawa diagram

However, the development of these areas is impossible without ensuring conditions for the reliability of railway automation, automation and telemechanics, as well as advanced training of personnel for their maintenance. The compatibility of operations of dispatch services is implemented through the use of flexible forms of organization of cargo flows with the preparation of an optimal cargo plan for loading a railway ferry. The implementation of information support should take into account the synchronization of the information systems of the railway and port, as well as the relationship of automation with the work of the ferry, constantly updated with new software products.

Based on the analysis, a program of measures has been drawn up for the development of transport and technological systems of railway ferries (Table 1).

**Table 1**

Program of measures for the development of transport and technological systems of railway ferries

Activity	Event description
Improving the state of the material and technical base	Updates and modernization of merchant marine vessels, track facilities, vehicles and equipment
Organization of joint activities of the railway and port dispatch services	Implementation of information interaction systems between stevedoring services, dispatchers, station technicians and railway automation technicians
Development and implementation of new information support tools	Development and adaptation of new and improved information systems for data exchange, electronic journals, catalogs
Improving the maintenance of railway automation, automation and telemechanics	Implementation of systems for technical diagnostics and monitoring of railway automation and telemechanics
Further training of managerial and technical personnel	Deepening managerial knowledge, acquaintance and acquisition of skills to work with new software products, retraining and advanced training of electricians, in particular control and measuring devices

The obtained results are aimed at increasing the efficiency, validity and effectiveness of management work on the operation of means of transport and can be used in carrying out research work of other objects of railway-water communication, in particular port railways.

The prospects for further research by the authors are related to the development of a functional model for the operation of a railway ferry and the development of systems for technical diagnostics and monitoring of automation equipment.

#### 4. Conclusions

According to the information criterion for increasing the efficiency of technical maintenance of transport and technological systems of railway ferries, reserves for accelerating revolutions are selected. Using the Ishikawa diagram, a relationship is established between this objective function and operational factors that will determine the synchronization of the actions of the seaport (ferry station) and railway services. Based on the analysis, a program of measures is developed to develop the transport and technological system of railway ferries, which includes:

- improving the state of the material and technical base;
- organization of joint activities of the dispatch services of the railway and port;
- development and implementation of new means of information support;

- improving the maintenance of railway automation, automation and telemechanics;
- advanced training of managerial and technical personnel.

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