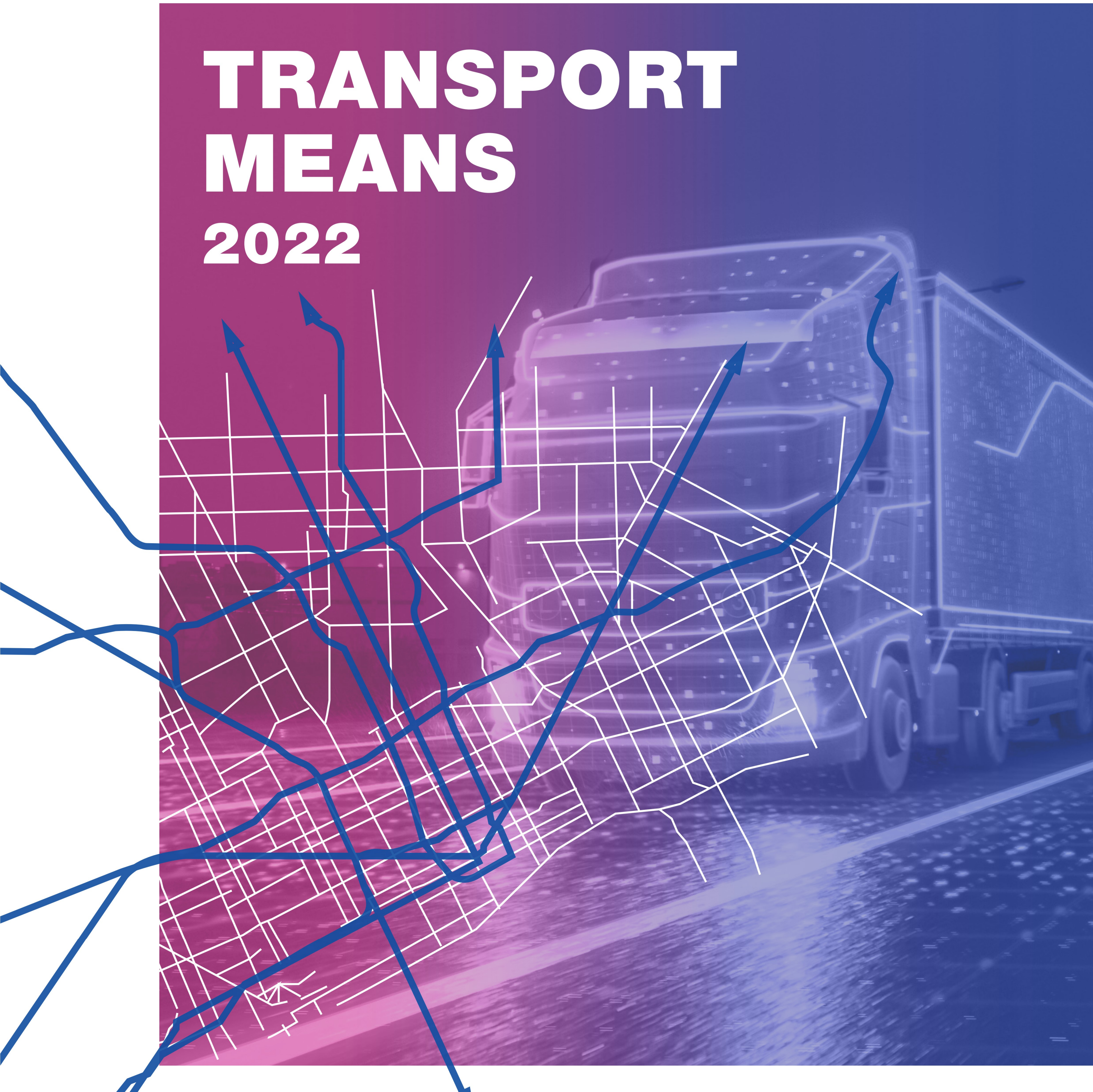
26th International Scientific Conference

October 5–7

TRANSPORT MEANS 2022



Proceedings

Part I

ISSN 1822-296 X (print)
ISSN 2351-7034 (on-line)

KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPĖDA UNIVERSITY
IFToMM NATIONAL COMMITTEE OF LITHUANIA
LITHUANIAN SOCIETY OF AUTOMOTIVE ENGINEERS
THE DIVISION OF TECHNICAL SCIENCES
OF LITHUANIAN ACADEMY OF SCIENCES
VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

TRANSPORT MEANS 2022

Sustainability: Research and Solutions

PROCEEDINGS OF THE 26th INTERNATIONAL SCIENTIFIC CONFERENCE

PART I

October 05-07 , 2022
Online Conference - Kaunas, Lithuania

KAUNAS•TECHNOLOGIJA•2022

CONFERENCE IS ORGANIZED BY
Kaunas University of Technology,
In cooperation with
Klaipeda University,
IFToMM National Committee of Lithuania,
Lithuanian Society of Automotive Engineers,
The Division of Technical Sciences of Lithuanian Academy of Sciences,
Vilnius Gediminas Technical University

The proceedings of the 26th International Scientific Conference Transport Means 2022 contain selected papers of 9 topics: Aviation, Automotive, Defence Technologies, Fuels and Combustion, Intelligent Transport Systems, Railway, Traffic, Transport Infrastructure and Logistics, Waterborne Transport.

All published papers are peer reviewed.

The style and language of authors were not corrected. Only minor editorial corrections may have been carried out by the publisher.

doi: 10.5755/e01.2351-7034.2022.P1

e.book, 2022

Proceedings of 26th International Scientific Conference. Transport Means 2022.

Logistics Approach in Energy-Efficient Technology for Shunting Work at the Marshalling Station

O. Ischuka[1], D. Lomotko[2], M. Lomotko[3]

[1] *Riga Technical University, Institute of Transport, Azenes str.12, Riga, Latvia, E-mail: oksieca@inbox.lv*
[2]*Ukrainian State University of Railway Transport, Feuerbach sq. 7, Kharkov, Ukraine, E-mail: den@kart.edu.ua*
[3]*Ukrainian State University of Railway Transport, Feuerbach sq. 7, Kharkov, Ukraine, E-mail: kolyanl890@gmail.com*

Abstract

At the present time, operational planning of shunting work at marshalling station using logistics energy-efficient technologies is becoming extremely important. The article deals with actual issues of using the logistics approach in the energy-efficient technology of shunting work at marshalling station to determine the optimal sequence for the assembling of multi-group (transferred) freight train. The purpose of the research is to increase the efficiency of the process for assembling of multi-group freight trains by reducing the number of shunting movements. It is proposed the reducing of multiple re-sorting of cars both at marshalling station and at unloading station, which will lead to the significant reduction in the time consuming on maneuvers, the decrease in diesel fuel consumption, the cutting down in the corresponding operating costs of the station and the improvement in environmental performance of harmful emissions. Such approach is in line with the “Just In Time” logistics concepts and resource-saving. In this article, the analysis of the existing methods for the assembling of multi-group freight train at marshalling station was carried out. As the object of study, the definite multi-group freight train was considered, which was assembled on the Latvian Railway at Shkirotava marshalling station by appointment to Zemitany freight station. Particular attention is paid to the factors influencing the optimal sequence for assembling of multi-group freight train at marshalling station: the rational scheme for the assembling of car groups in the train, synchronization of interaction between the logistics intermediary (consignee and consignor) and at the railway carrier in the logistics chain of goods delivery. The use of the logistics approach to solving of the reviewed problem will easily permit to make the operational planning of the train-assembling process and the formation of logistics chain for goods delivery, taking into account the specific technological situation, which dynamically changes depending on the volume and nature of local operations at marshalling station. The use of logistics energy-efficient technology based on decision-making using the scheduling theory will reduce the time consuming by multi-group freight train at marshalling stations, which in turn will increase the efficiency of organization of shunting work, and ultimately will benefit all participants in the goods delivery chain.
KEY WORDS: *logistics approach, energy-efficient technology, marshalling station, shunting work, operational planning, train assembling*

1. Introduction

At the present time, one of the strategical directions for transport logistics optimization is to increase the energy-efficiency of the transportation process [1], which depends on the choice of rolling stock of new generation with improved technical and economic indicators [2], the reliability of locomotives, the prevention of failures of the rolling stock of individual units (assemblies), the quality of maintenance and repair of rolling stock [3-5], the quality of maintenance of railway track and switches [6, 7], ensuring the safety of train traffic on this basis.

On the other hand, the operational planning of shunting work at the marshalling station significantly influences the energy-efficient technology. This technology should be achieved by strict interaction in the work of the station elements at all stages of the technological process (from the arrival of the car at the marshalling station to the arrival of the car at the destination station for unloading or loading). This is done in order to fulfil the transportation plan in the specific conditions of the up-coming day and shift, at the necessary time and place with minimal fuel and energy costs, that is, in accordance with logistical approaches to the technology formation.

As a rule, in the sorting yard, when the certain number of cars for the multi-group train is accumulated, the shunting dispatcher is faced with the urgent question of which optimal train formation scheme to choose? Today, the effectiveness of the train assembling process with a large number of groups of cars and with a small number of sorting tracks largely depends on pre-obtained logistical information about the arriving cargo. This information is data on the number of cars, name of the cargo, consignee and destination station, data on customs declaration of cargo [8], data on the place of loading (unloading) of cars. In the traditional way of operation, complete information of transportation only appears at the destination station and not at the marshalling station. As a result, the number of shunting run is overestimated, and energy and labour costs for the assembling of such trains are growing. The significant reduction in the number of shunting runs when the assembling of multi-group train is possible with the logistical approach that allows to receive operational information about the train composition at all stages of its movement.

To solve this urgent problem, it is necessary to develop the logistics energy-efficient technology based on decision-making using the scheduling theory [9].

2. Object of the Research

In this article, as an example, the local car-traffic is considered, which is organized into the multi-group train at Shkirotava marshalling station with the appointment to Zemitany freight station. According to statistical data, it has been found that the specific multi-group train was assembled on four sorting tracks of Shkirotava marshalling station. The accumulation (location and standing) of groups of cars on these sorting tracks is shown in Fig. 1.

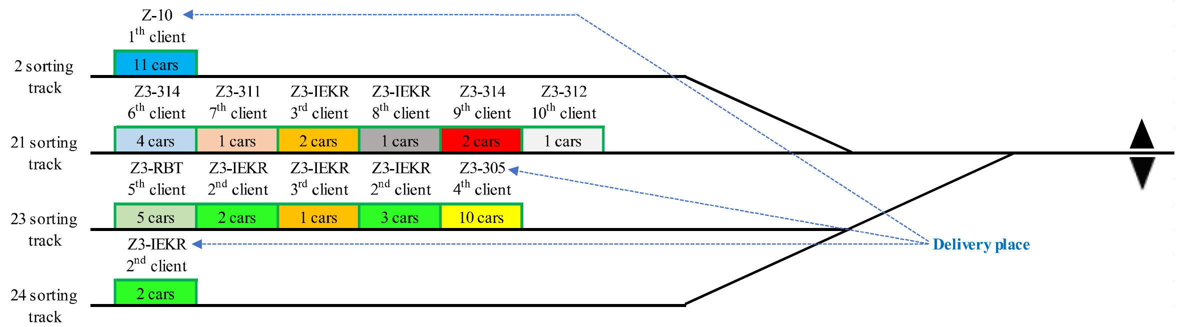
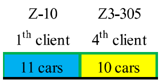
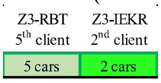


Fig. 1 Accumulation of the multi-group train on four tracks in the sorting yard

Conditional designations:



– the certain colour indicates: the number of cars in given group (11 cars, 10 cars), the name of specific consignee (1^{st} client, 4^{th} client), Zemitany freight station (Z-), Zemitany port station (3 km Riga-Krasta) (Z3-), number of track (branch line) at Zemitany station (Z-10) and Zemitany station (3 km Riga-Krasta) (Z3-305);



– abbreviated name of the specific cargo area (RBT, IEKR), where cars are delivered.

As a result, the multi-group train was formed by car groups in accordance with the geographical location of the stations on Shkirotava-Zemitany section (1^{st} station: 1^{st} client; 2^{nd} station: 2^{nd}-10^{th} client). The composition of the location of car groups in the multi-group train is shown in Fig. 2.

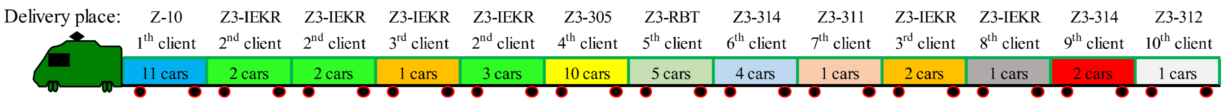


Fig. 2 Scheme of assembling of multi-group train by appointment to Zemitany freight station

After arriving at the destination station, this train split into separate groups of cars, which were delivered to the branch lines of Zemitany freight station (destination station) and Zemitany port station (3 km Riga-Krasta). The scheme of mutual location of marshalling, freight and port stations and branch lines connected to them is shown in Fig. 3.

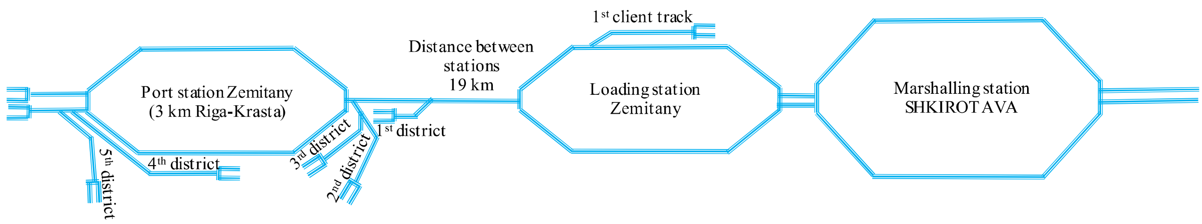


Fig. 3 Scheme of mutual location of marshalling, freight and port stations and branch lines connected to them

As a rule, in accordance with the contract for the supply of cars to the cargo front, it is carried out only after the consignee has fulfilled “credit clearance” of the cargo. Namely, he has completed part of the logistics procedures, the complex of which includes the drawing up of issuance of cargo according to transportation documents with the issuance of the railway bill to the consignee against receipt in the road statement. The time of drawing up of the issuance of cargo and the order of supply of cars is shown in Fig. 4.

At the fact that the train arrived at night and not all consignees work around the clock, the cars are delivered to the branch lines in such sequence in which the consignees have drawn up of issuance of cargo at the goods office. As a result, this leads to the fact that there is an unproductive multiple sorting of cars according to the districts of cargo work.

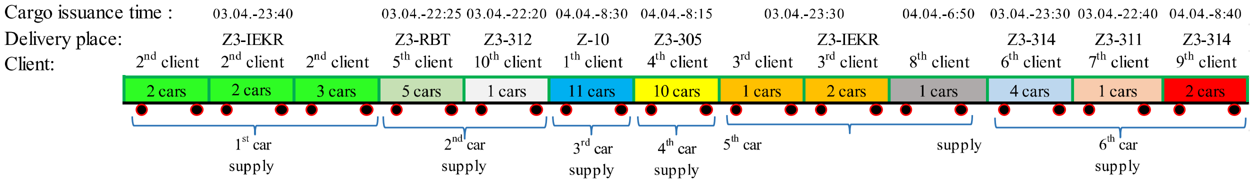


Fig. 4 Order of supplies of cars to branch lines, depending on the time of drawing up of issuance of cargo

3. Problem Statement

Currently, the operational planning of local work is not aimed at achieving the optimal scheme for the assembling of the multi-group train, does not take into account the real situation at unloading (loading) stations and branch lines, does not provide for resource-saving technology to achieve energy performance.

The existing technology for delivering loaded cars to the free zone of the port of Zemitany station (3 km Riga-Krasta) requires the consignee simultaneously to submit to the goods office the permission of the port to accept the car (container) and the drawing up of issuance of cargo at the Zemitany station. In other cases, when the cargo is unloaded to a customs warehouse or to a place of temporary storage is necessary only drawing up of the issuance of cargo. Depending on the working hours of the consignees, the “credit clearance” of the cargo at the station takes place at different times. Despite the assembling of the train, which was carried out by groups of cars in accordance with the sequence of stations on the section, the example shows that the sequence of supply of cars occurs precisely depending on the time of drawing up of the issuance of cargo.

As a rule, practice shows that to organize the supply, sorting and collection of groups of cars, three or more station tracks are required at the same time. Such sorting and collection of cars cannot be done at the Zemitany station (3 km Riga-Krasta) due to the fact that in the adjoining port, due to the unevenness of approach of trains, many operations can occur simultaneously. Namely, receiving and departing of forwarder routes, loading (unloading) cars and several forwarder routes, supply cars to branch lines, overtaking of shunting and train locomotives. Therefore, the delivery of cargo from the Zemitany station to the Zemitany station (3 km Riga-Krasta) occurs in groups due to the lack of track development of the Zemitany station (3 km Riga-Krasta), which has only 9 receiving and departure tracks.

As a result of the supply of cars, an extra mileage of the rolling stock occurs (the distance is 19 km between the Zemitany freight station and the Zemitany port station (3 km Riga-Krasta)), which increases the energy costs for shunting movements and worsens the environmental performance of the emission of harmful substances. The organization of local work at the destination station becomes much more difficult.

Thus, it raises the urgent task of increasing the energy-efficiency of the transportation process and reducing operating costs for fuel and energy resources when performing shunting work both at the marshalling station and at the destination station. To solve this problem, it is required to apply the logistics approach to the organization of shunting work, which consists in finding the best organizational and technically possible solutions that ensure the maximum efficiency of the logistics process of delivering goods from the marshalling station to the unloading (loading) station in the single operational information space.

4. Materials and Methods

Today, mainly traditional methods of intensification for the assembling of the multi-group train at the marshalling station are used, which are achieved with the help of technical, organizational and information solutions.

One of the technical ways to accelerate the assembling of the multi-group train is the design of small sorting devices (low-power hump, semi-hump) in compliance with the requirements for saving of energy costs. In paper [10], it is proposed to use a sorting device in the form of a so-called non-brake semi-hump, if it does not exceed 6-8 sorting tracks. The disadvantage of this method is the large capital investment and reconstruction of the sorting park, which is not always possible to implement in urban conditions.

The following technical method was proposed as the implementation of sectioning the tracks of the sorting yard of the station to speed up the sorting of local cars by shunting areas, by loading and unloading points and by individual warehouses [11]. The specified technical solution makes it possible to form such trains practically without drawing-out, assembling and re-sorting of cars. However, this method has the disadvantage. At marshalling station, when laying such sections, the useful length of the sorting track is significantly reduced, and each section has the fixed length, which can create additional problems if the length of the certain group of cars exceeds the length of the corresponding section. In this case, you will have to perform additional manoeuvres to assemble the multi-group train. This method is more suitable for stations where sorting tracks have a large useful track length and there is a possibility of technical reconstruction of the station.

One of the organizational ways to improve the technology of assembling of multi-group trains is the combinatorial method [12]. Its essence consists in multi sorting of cars in the given order and one-time assembly from one sorting track. This method makes it possible to form the multi-group train at the marshalling station for the minimum number of sorting under conditions when the number of car groups significantly exceeds the number of tracks used for their selection in the sorting yard. In addition, this method makes it possible to eliminate multiple processing of local cars before supply under cargo operations (selection by areas of shunting work, by consignees and by individual fronts), replacing it with a single reprocessing. The advantage of this combinatorial method when assembling the multi-group train is:

- reduction of the volume of shunting work;
- reducing the use of manoeuvring facilities;
- obtaining an optimal scheme for the arrangement of groups of cars on the tracks of the sorting yard;
- assembling of composition for any number of groups and different number of used sorting tracks or ends of the tracks.

However, the combinatorial method has the disadvantage, assuming a minimum number of shunting runs it does not guarantee the formation of the train in the minimum time and with minimum operating costs.

The papers [13, 14] describe the choice of the car delivery order, which is possible using two efficiency criteria. The first criterion makes it possible to minimize the demurrage of cars in waiting of their delivery to the cargo fronts. The disadvantage of this criterion is that it does not fully take into account the performance of cargo points and, therefore, does not reflect the summary operating costs. Since, largely, the demurrage of cars at freight stations depends on the acceleration of the duration of cargo operations; the second criterion is the objective function in the form of summary car-hours spent on the supply of cars and on carrying out cargo operations on cargo fronts. Because of applying of the second criterion, the maximum number of unloaded (loaded) cars is obtained by the given point in time (for example, at the end of the day). When calculating the sequence of cars, depending on the current situation at the station, the shunting dispatcher can apply the first or second criterion using the software system of decision support.

The first attempts to use simulation models (information solution) to evaluate the proposed technological solutions in production were the creation of the automated system “Electronic yard conductor” [15]. This system allows, under specific conditions, to obtain the optimal variant of the assembling of the multi-group train, in which the minimum number of shunting run and processing of cars is achieved. This takes into account the actual number of cars, the size of each group and their actual location, the presence of free assembling tracks or sections of these tracks, the presence of cars that can only be sorted by backing-up, the arrival of cars in excess of the capacity of the cargo fronts. The output document issued by the system is the sorting sheet for the assembling of the multi-group composition.

The analysis of the reviewed literature has showed that the issue of the logistic approach to the organization of shunting work has not been sufficiently considered. With the help of this approach it is possible to describe the exact real process of assembling of the multi-group train, as well as take into account the energy costs of a shunting locomotive, which is especially important when forming the multi-group train at marshalling stations (drawing-out tracks) and sorting (collection) of car groups according to cargo fronts.

In modern conditions, transport logistics [16], when optimization of design solutions and technological processes operating on the railway, actively uses probabilistic (stochastic) calculation methods:

- simulation modelling methods for production processes;
- linear and stochastic programming;
- scheduling theory [17].

The criterion for the implementation of energy-efficient technology of shunting work is that the arriving goods at the marshalling and freight station must be processed on time; the applications of consignees for the supply of cars must be fully satisfied. Therefore, there is the direction of logistics management of technological processes, which consists in finding of optimal solutions for incoming car-flows (applications) for processing, using the FIFO logistics approach [18]. The essence of this logistics system lies in the fact that the consignee is firstly served with cars that are located the first in the train and no shunting movements with cars are required. Thus, consideration of the interrelation of operational and logistical management of the production of shunting movements implies the expansion of the optimization capabilities of the railway in the direction of increasing its competitiveness among other modes of transport and improving the quality of transport services.

Mathematical modelling of shunting work, taking into account the organization and mode of operation of the relevant consignees, will provide optimal conditions for achieving of “Just-In-time” logistics delivery of goods. This logistics technology can be provided with the help of operational logistics information about the arriving cargo to the address of the corresponding consignee, using the technical solution using GPS geopositioning or RFID cargo identification [19]. This information must arrive at the automated workstation of the operational worker in advance and on time, as required by many logistics technologies, especially those based on “Just-In-time” concept. The timeliness of information is important for almost all complex logistics functions.

The additional way to achieve the increase in the energy-efficiency of the production of shunting work is to apply the scheduling theory to these technological operations at the marshalling station [8, 9], which will ensure rational loading of the cargo fronts of branch lines and shunting facilities.

5. Research Results

The technology of the marshalling station is based on the method of dispatching management, which ensures the best use of technical means and the shortest time of location by cars at the station. Efficient control of the station operation is achieved by using automated systems that provide the dispatcher with the necessary preliminary and accurate information. Based on the logistics information about the arriving cargo, shunting dispatcher will plan the optimal scheme for the formation of a multi-group composition according to the criterion of minimum operating costs for fuel and energy resources when performing shunting work.

To assess the effective assembling of the multi-group train, the summary fuel consumption is compared both at the marshalling station ($G_{st.}^{marsh.}$) and at the unloading or loading station ($G_{st.}^{load.}$). In this case, two cases are possible. In the first case, for the traditional method of organization of shunting work at the marshalling station, the summary fuel consumption should be less than the summary fuel consumption at the destination station ($G_{st.}^{marsh.} < G_{st.}^{load.}$), and in the second case, for the logistic method of work – vice-versa ($G_{st.}^{marsh.} > G_{st.}^{load.}$).

The summary fuel consumption by shunting diesel locomotive for performing a shunting operation is determined by the formula [20].

$$G = \sum_{i=1}^{n} g_i^T \cdot \Delta t_i^T + \sum_{i=1}^{m} g_i^I \cdot \Delta t_i^I + \sum_{i=1}^{l} g_i^{BR} \cdot \Delta t_i^{BR} \,, \tag{1}$$

where $\sum_{i=1}^{n} g_i^T \cdot \Delta t_i^T$ – fuel consumption in thrust mode per time interval, kg; $\sum_{i=1}^{n} g_i^T \cdot \Delta t_i^T$ – fuel consumption in idle mode per time interval, kg; $\sum_{i=1}^{l} g_i^{BR} \cdot \Delta t_i^{BR}$ – fuel consumption of a diesel locomotive in the mode of braking by an electric brake per time interval, kg.

Depending on the analysed logistics information, the shunting dispatcher should decide on the accumulation of cars on two tracks (Fig. 5, a), and then should sort the accumulated train twice from the hump (Fig. 5, b and c). After that, four parts of the train are grouped into one multi-group train (Fig. 4).

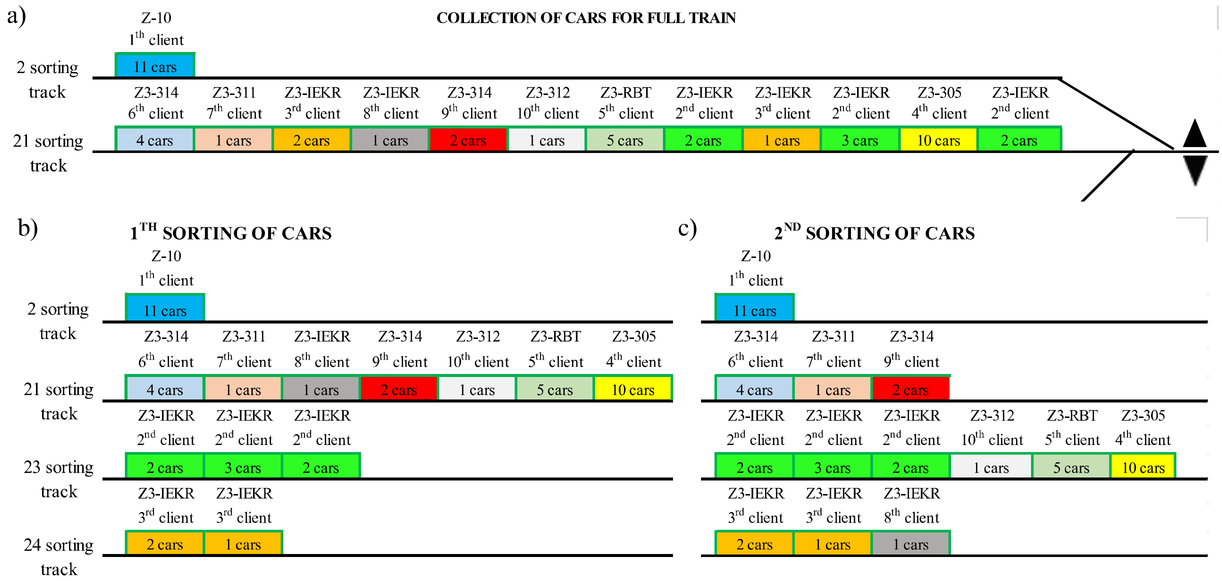


Fig. 5 Location and standing of groups of cars: a) accumulation of cars on two sorting tracks; b) first sorting of cars; c) second sorting of cars

When choosing the optimal scheme for the assembling of the multi-group train, indicators of shunting work have been obtained for the traditional and logistic approaches. As a result, with the logistic approach, the summary fuel consumption by shunting diesel locomotive at the marshalling station increased by 70-75%, and at the destination station it decreased by 80-85% (time for sorting and selection of local cars is completely excluded). However, in general, energy costs have been significantly reduced by 40-45% compared to the traditional approach of the marshalling station.

6. Conclusions

As a result of the study, the main factors, influencing the optimal scheme of the multi-group train, have been identified. Namely, the time of drawing up of issuance of cargo, the receipt of logistics information about the arriving cargo in advance and on time, the place of car (container) loading or unloading, the quality of operational planning of shunting work, the level of information support.

In the course of the study, the reasons for the extra mileage of the rolling stock between the freight and port stations have been established, namely, the lack of track development due to the accumulation and unevenness of train and freight work at the port station.

The paper has analysed the existing methods for the assembling of the multi-group train at the marshalling station. In order to improve these methods, it has been proposed to use the logistic principle of timely receipt of information about the arriving cargo, as well as to use mathematical modelling of shunting work based on the scheduling theory. The main criterion for evaluating of energy-efficient technology is the general summary consumption of fuel both at the marshalling station and at the destination station.

The analysis of the example of the assembling of the multi-group train for the traditional and logistical approach of organization of shunting work at the marshalling station has been carried out. As a result, with the logistic method of station operation, the operating costs for fuel and energy resources when performing shunting work are less by 40-45% than with the traditional method.

The search for the rational technological solution for the assembling of the multi-group composition is the very difficult task. Therefore, for the operational management of the marshalling station, the shunting dispatcher should be able quickly to get the rational plan for the process realization of the assembling of the certain composition. For this purpose, it is necessary to integrate the simulation model into the software of the corresponding automated workplace.

In result of the use of energy-efficient technology, resources saving indicators will have been improved, energy costs for shunting work in the system for assembling of multi-group trains in the marshalling - cargo station system will have been decreased.

Acknowledgement

We thank our colleagues from Ukrainian State University of Railway Transport who provided information on logistics approach in energy-efficient technology for shunting work at the marshalling station, as also for the valuable advice and comments on the article.

References

1. All about energy efficiency targets [online cit.: 2022-05-05]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32018L2002
2. **Zaripov, R.; Gavrilovs, P.** 2020. Assessment of the economic efficiency of modernization of railway wagons, Transport Means 2020, Proceedings of the International Conference, 906-909.
3. **Gavrilovs, P.; Dmitrijevs, A.** 2016. Research in passenger car bogie central suspension roller and rod base metal and welded metal structure, Engineering for Rural Development, 618-623.
4. **Zaripov, R.; Gavrilovs, P.** 2021. Mechanical connection of metal structures in wagon buildings, Engineering for Rural Development 20: 596-604.
5. **Gavrilovs, P.; Gorbachovs, D.** 2020. Hardness testing and chemical composition analysis of ER2 and ER2T series emus traction transmission rubber-cord coupling bolts, Engineering for Rural Development 19: 326-330.
6. **Zaripov, R.; Gavrilovs, P.** 2017. Research Opportunities to Improve Technical and Economic Performance of Freight Car through the Introduction of Lightweight Materials in their Construction, Procedia Engineering 187: 22-29.
7. **Sergejevs, D.; Tipainis, A.; Gavrilovs, P.** 2014. The restoration of worn surfaces of railway turnout elements by a flux cored arc welding (FCAW), Transport Means Proceedings of the International Conference, 24-26.
8. **Ischuka, O.; Lomotko, D.** 2021. Application of Logistic Information Flow in Customs Clearance of Cargo at Marshalling Station, Transport Means Proceedings of the International Conference, 58-63.
9. **Ischuka, O.; Lomotko, D.; Eiduks, J.** 2020. Modelling of Technology of Disassembling and Assembling of Freight Trains at Marshalling Yard, Transport Means Proceedings of the 24th International Scientific Conference, 463-468.
10. **Chislov, O.N.; Lebedeva, V.A.; Khan, V.V.** 2017. Design and calculation of marshalling hump: Textbook, Rostov n / D: FGBOU VO RGUPS: 83.
11. **Aksenov, V.I.** 1974. Efficiency of sectioning the tracks of sorting yards of the station for processing the local car-traffic, Tashkent, 44-51.
12. **Koreshkov, A.N.; Kiselev, A.N.; Borodina, E.V.** 2007. Optimization of technical and technological parameters of operation of the marshalling station, Guidelines for graduation design, M.: MIIT: 89.
13. Calculation of order of supply and taking away of local cars [online cit.: 2022-05-05]. Available from: https://studref.com/557415/tehnika/raschet_ocherednosti_podachi_uborki_mestnyh_vagonov#666
14. **Sotnikov, I.B.** 1984. Railway operation. In examples and tasks: Textbook, M.: Transport: 224.
15. **Makarov, V.M.** 1988. Use of computers in the control of the process of assembling of multiple compositions, Series “Automated control systems”, CNRSHTEI MPS, Express-inform, Issue. 2: 20.
16. **Eremeeva, L.E.** 2013. Transport logistics: Textbook, Syktyvkar, SLI: 260.
17. **Lazarev, A.A.; Gafarov, E.R.** 2011. Theory of Schedules. Tasks and algorithms: Textbook, M., MGU: 222.
18. All about the limited FIFO queues [online cit.: 2022-05-05]. Available from: https://www.management.com.ua/qm/qm135.html
19. All about the identification of cargo flows with RFID tags [online cit.: 2022-05-05]. Available from: https://wireless-e.ru/rfid/rfid-zigbee/
20. **Fadeev, G.M.** 1988. Methods of traction calculations for shunting work, M.: MPS: 132.

Proceedings of 26th International Scientific Conference Transport Means
ISSN 1822-296 X (print)
ISSN 2351- 7034 (online)

Design by Rasa Džiaugienė, Rolandas Makaras, Robertas Keršys
Cover Design by Publishing House "Technologija"

SL 344. 2022-10-26. 59.5 printer's sheets (Part I). Order No. 227.
Publishing House "Technologija", Studentų 54, LT-51424, Kaunas

transportmeans.ktu.edu

ISSN 1822-296X (print)
ISSN 2351-7034 (online)