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Unification of Passenger Trains when Organising Irregular Railway Transportation

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ABSTRACT

Passenger transportation by rail can be divided into regular (travelling with labour or recreational purposes, weekend trips), and irregular (tourist, rotational, migration and others). The organisation of regular transportation is based on medium- and long-term planning of number of transported passengers, which is not applicable to irregular transportation.

Determining the optimal layout of a passenger train, the number of main types of sleeping cars (with compartments and reserved seats without compartments) is one of the key tasks in organising railway passenger transportation, including irregular one.

One of the promising improvements in development of long-distance railway passenger transportation is unification of passenger trains, which makes it possible to organise a comprehensive rotation of trains, thereby reducing non-operational downtime and increasing the efficiency of using rolling stock.

Studies to assess the optimal composition of a long-distance train were carried out for regular railway transportation. However, considering several features of irregular passenger transportation, such as short-term planning of the volumes, high differentiation in the number of groups of passengers, a possibility of using free seats on trains on existing routes, it is necessary to re-evaluate the effectiveness of using unified passenger train composition schemes under these conditions.

The development of standard compositions of passenger trains is carried out using the cluster analysis method. The use of three unified compositions is proposed. When developing proposals for unifying the layouts of passenger trains in circulation, it is necessary to consider the additional passenger traffic in irregular transportation, which cannot be absorbed using the remaining free seats. The results of the study were applied to a fragment of the North-Eastern part of railway network.

Keywords: irregular railway passenger transportation, passenger train compositions, remaining free seats on passenger trains, unification of passenger train compositions.

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INTRODUCTION

Irregular railway passenger transportation is an important component of overall passenger traffic.

Research in the field of improving passenger transportation usually considers the development of an optimal plan for formation of passenger trains, using various optimality criteria and constraints.

For example, several studies have developed theoretical and methodological foundations for choosing the optimal plan for formation of long-distance passenger trains to increase profitability of passenger transportation, while increasing the degree of meeting passenger demand for travel in different types of coaches [1, 2]. The research [3] is devoted to a method intended to optimise the circulation pattern of long-distance passenger trains at a segment of railway network, based on the most convenient time for passengers to depart and arrive at the station. Research described in [4–6] is devoted to development of scientific and methodological foundations for a system for mastering the flow of passengers, luggage and cargo luggage on the railway network while ensuring transportation of passenger flows without changing trains at a given level and meeting the demand for seats in cars of different types. Methods described in [4–6] are applicable both for models for calculating formation plans with fixed train layouts, and for determining train layouts. The works [7; 8] developed scientific and methodological foundations for assessing the effectiveness of organising rapid passenger railway transportation in long-distance traffic.

However, the methods based on reliable forecasting and planning can hardly be used for irregular transportation. Modern methods for planning passenger transportation by rail need to be optimised and redeveloped for possible use in planning irregular railway passenger transportation [9].

One of the least developed issues to date remains the assessment of the effectiveness of organising irregular passenger transportation regarding implementing unified schemes for long-distance passenger trains. The use of unified schemes of long-distance passenger trains for various routes will allow them to be integrated into a single rotation scheme within each group, as well as to unify the processing passenger trains at the points of their formation and at origin stations. The study [10] pointed to an increase in the operating efficiency of passenger companies by reducing the number of passenger trains in circulation, which can be achieved by unifying their schemes. This approach will make it possible to reduce the required number of passenger trains, free up tracks where trains are assembled or stay, and distribute the types of services provided along the route by train type. The possibility of unifying passenger train layouts can be considered using clustering algorithms.

The *objective* of the study was to develop approaches to revealing optimal train composition when implementing unified layouts of long-range passenger trains involved in irregular passenger transportation.

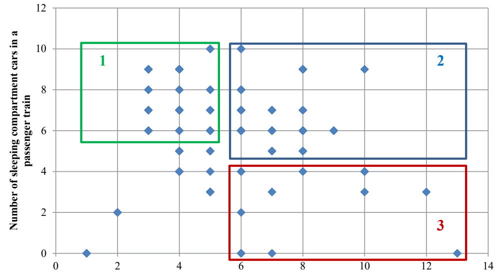
RESULTS

It is extremely difficult to visually show the dependence of the number of different types of cars in a passenger train relative to each other, therefore, as an example, let's consider the dependence of the number of compartment sleeping cars in a train on the number of sleeping cars without compartments but with reserved couchettes, these types of cars making up the bulk of the total number of passenger cars in a train.

When considering the North-Eastern railway segment of railway network in [11], a number of patterns were identified in the structure of passenger traffic, and the necessary measures were identified to change the composition of long-distance passenger trains on the chosen route.

To improve the efficiency of long-distance passenger transportation, it is also necessary to evaluate the impact of unification of train sets on development of additional passenger traffic when organising irregular railway transportation.

To determine the number and composition of passenger trains on a given route, it is necessary to obtain the following initial data:



Pic. 1. Dependence of the number of sleeping compartment cars in a layout of a train on the number of sleeping cars without compartments.

Table 1

Fragment of a sample of the number of remaining free seats in trains per destination points

№ of a direct train	**Number of days of circulation per month**	Number of seats		Number of cars in a trains				Required number of seats		Total excess/ shortage of seats	
		Compartment sleeping cars	Sleeping cars without compartments	De Luxe sleeping car	Compartment sleeping cars	Sleeping cars without compartments	Sitting cars	Compartment sleeping cars	Sleeping cars without compartments	Compartment sleeping cars	Sleeping cars without compartments
Origin-destination route fragment A1											
42	4	453	324	1	10	5	0	454	819	302	**-20**
376	4	302	475	0	7	6	1				
Origin-destination route fragment A2											
312		456	1204	0	6	7	0	173	445	1579	2946
310	15	1296	2187	0	8	9	0				
…											
Origin-destination route fragment A5											
no	4	0	0					42	57	**-42**	**-57**
…											
Origin-destination route fragment A7											
no	4	0	0					75	144	**-75**	**-144**

- «Monthly origin-destination pattern of passenger flows during the month of maximum traffic.

- Number of free seats in regular passenger trains.

- Composition of regular passenger trains.

- Infrastructure constraints (section transit capacity, length of passenger platforms, etc.)» [12], determined using the methodology[1].

The number of free seats in trains per their destination is shown in Table 1. To assess the possibility of organising transportation of passengers without increasing the number of trains and number of cars in them, we assume that there is a certain number of free seats. Based on the results of calculations, «origin-destination passenger flows A1 (K) and A2 can be organised through the use of free seats» [11].

In previous studies [13, 14], the «laws of distribution of technical and technological parameters of irregular railway passenger transportation» were assessed, based on this assessment the composition of trains of the direction under consideration was determined. The distribution of cars in a train can be expressed by the dependence of the number of sleeping compartment cars and sleeping cars without compartments, shown in Pic. 1.

The shown distribution should be divided into four clusters, which are further referred to as classes:

- «First» with a large number of sleeping compartment cars.

- «Second», which includes most common train layouts with approximately the same number of sleeping cars with and without compartments.

- «Third» with a larger number of sleeping cars without compartments.

- «Fourth» with a large number of cars for seating (not shown in Pic. 1).

To solve the clustering problem, we consider the K-means method preferable, since when comparing the advantages and disadvantages of the considered methods, the disadvantages of the K-means method are levelled out by the method of its application.

Table 2 presents the results of calculating unified layouts of passenger trains for four classes.

Based on the analysis, unified layouts of long-distance passenger trains were obtained for organisation of irregular transportation on the North-Eastern segment of railway network [11], and all the passenger trains under consideration were linked to unified layouts (see Table 3).

Data from the analysis and calculations of the results obtained showed that the first class of unified layouts includes most branded passenger trains, the second and third – rapid and long-distance trains, and the fourth –

[1] Methodology for determining the throughput and carrying capacity of public railway transport infrastructure. Approved by order of the Ministry of Transport of Russia dated July 18, 2018, No. 266. [Electronic resource]: https://docs.cntd.ru/document/542629643?ysclid=lq2gcsb059594241. Last accessed 24.07.2023.

Table 2

Unified layouts of passenger trains

Class	De luxe sleeping car	Sleeping compartment car	Sleeping car without compartments	Sitting car	Sum
«first»	1	10	3	0	14
«second»	0	8	7	0	16
«third»	0	4	7	1	12

Table 3

Fragment of a sample of passenger trains

№ of a train	Existing train layout				Capacity	Class of a unified layout
	De luxe sleeping	Sleeping compartment car	Sleeping car without compartments	Sitting car		
№ 89/90	0	8	11	1	954	2
№ 309/310	0	8	9	0	774	2
№ 311/312	0	8	6	0	612	1
№ 375/376	0	7	6	1	648	2
№ 565/566	0	4	11	0	738	3
№ 593/594	0	1	10	0	576	3

daytime passenger trains, i. e., the train layouts by train type are approximately similar to each other. To reduce the number of types of passenger trains, it is proposed to move to only one classification according to the classes of unified layouts, then the class of the train will determine not only its layout, but also its type.

Within the framework of unified layouts, it may be necessary to increase the number of cars in passenger trains No. 309/310, 311/312, 375/376 by a total of three «sleeping compartment» cars and three «sleeping cars without compartments». When using unified train layouts for these passenger trains, there will be an excess of de-luxe sleeping cars and sleeping compartment class cars and a shortage of sitting class cars (Table 4).

The network-wide model for regular passenger transportation requires adjustments for individual directions for irregular passenger transportation due to the shortage of sleeping

Table 4

Composition of passenger trains when their layouts are unified

№ of a train	Number of cars in a train by classes											
	De-luxe sleeping cars			Sleeping compartment cars			Sleeping cars without compartments			Sitting cars		
	act.	unif.	+/-	act.	unif.	+/-	act.	unif.	+/-	act.	unif.	+/-
309/310	0	0	0	7	8	1	6	7	1	0	0	0
311/312	0	1	1	8	10	2	6	3	-3	0	0	0
375/376	0	0	0	6	8	2	6	7	1	1	0	-1
Total			1			5			-1			-1

Table 5

Changes in composition of trains when unifying layouts

№ of a train	Number of cars in a train by classes											
	De-luxe sleeping			2-class sleeping compartment			3-class open sleeping			Sitting		
	act.	unif.	+/-	act.	unif.	+/-	act.	unif.	+/-	act.	unif.	+/-
309/310	0	0	0	7	8	1	6	7	1	0	0	0
311/312	0	0	0	8	8	0	6	7	1	0	0	0
375/376	0	0	0	6	8	2	6	7	1	1	0	-1
Total			0			3			3			-1

compartment cars and sleeping cars without compartments.

Considering the proposed economic distribution model, train 311/312 should be assigned a unified «second» class scheme, then the change in the composition of passenger trains will take the form shown in Table 5.

BRIEF CONCLUSIONS

Despite the increase in the number of cars in trains for individual passenger trains, when using unified schemes throughout the entire railway network, downtime at stations where trains are assembled or awaiting to return to origin point could be reduced more significantly compared with the route service is organised with equal number of trains going respectively to and from origin-destination points on the route.

The number of passenger trains in circulation should be used as the main indicator of the effectiveness of implementation of the methodology for unifying passenger train layouts, this indicator finally determines the need for a car fleet.

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