JUSTIFICATION OF WEIGHT NORMS FOR HEAVY HAUL TRANSPORTATION

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ABSTRACT

The article substantiates the weight standards for heavy trains, evaluates the technology of their formation, taking into account the existing factors and conditions. In particular, it is taken into account that in heavy traffic, locomotives with a large number of sections are used, the speed and travel time for all cargo trains should be the same, and the weight standards should be chosen so as to ensure the minimum cost of mastering the specified traffic volumes.

The promising importance of heavy weight trains requires development of technologically substantiated weight standards for those trains, so that those standards should comply with harmonized standards for ordinary trains. So the article offers description of main factors that should be taken into consideration while substantiating weight standards for heavy trains. The authors quote examples of possible variants of weight standards, methods of calculation of mean weights, structure of freight costs for different weight standards for both ordinary and heavy trains.

<u>Keywords:</u> railway, heavy trains, weight norms, linear loads, weight standard, distribution of actual train weights, distribution of trains' lengths.

Background. *From 2003 to the present, JSC Russian Railways has been consistently working to increase the average weight of a train. To a large extent, this is facilitated by organization of movement of heavy trains weighing 6000 tons or more [1]. The «General scheme for development of railways in the Russian Federation for the period up to 2020» defines the landfill and the main directions of movement of heavy trains in which coal, oil, petroleum products, mineral and chemical fertilizers are transported. While proceeding with formation of heavy trains with wagons with an axle load of 25 tons, it is possible to form trains weighing 8000–9000 tons or more. Taking into account the importance and prospects of heavy traffic, it is necessary to evaluate the technology of formation of such trains and, above all, to establish technologically sound weight standards. The following factors must be considered:*

1. For heavy traffic, locomotives with a larger number of sections are used than for ordinary (non-heavy) trains.

2. The speed, and, consequently, travel time on the hauls for all freight trains must be the same, in order to exclude necessity to develop individual threads of the schedule.

3. Weights for ordinary and heavy trains should be coordinated and selected in such a way as to ensure the same travel time on the section hauls.

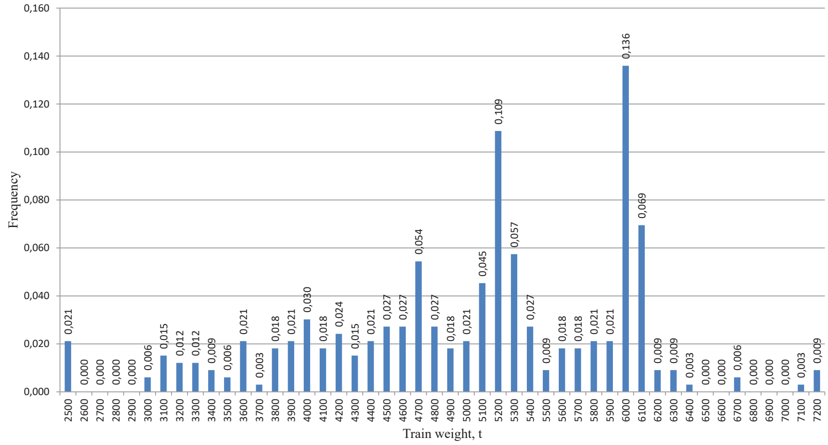
4. Weight norms for ordinary and heavy trains should be economically justified, ensuring a minimum of transportation costs for development of specified traffic volumes.

Objective. *The objective of the authors is to consider train weight norms aspects in relation to organization of heavy traffic.*

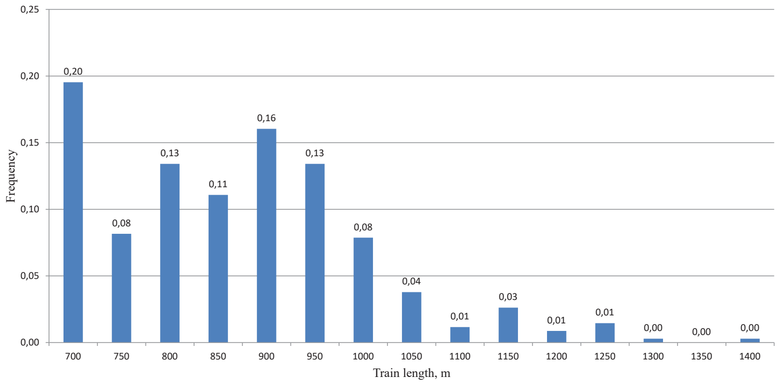
Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, mathematical methods, graph construction, specific railway and engineering tools.*

Results. *Pic.1 shows distribution of actual train weights gross for the section Likhaya – Bataysk in the even direction of motion. Weight norms are as follows: standardized – 3700 tons, for heavyweight – 6000 tons. In this distribution, 25 % of trains have a weight in the range of 3400–4600 tons, which is typical of ordinary trains, and 55 % of trains are heavy and the actual weights are in the range of 5200–6700 tons. All this indicates that it is impossible to form trains in strict accordance with given weight norms. The reasons for this are associated with the fact that, firstly, trains are formed along the length of a station's receiving-departure tracks, and, secondly, it is necessary to use free threads of the schedule, sending trains with underutilization of weight norms.*

Pic. 2 shows distribution of actual train lengths for the same section. Of the total number of trains, 28 %



Pic. 1. Histogram of distribution of train weights.



Pic. 2. Histogram of distribution of train lengths.

are formed with underutilization of the useful length of station tracks (57 conditional wagons) and 72 % of trains are long. The combined distribution of actual weights and lengths of trains (Pic. 3) suggests that 54 % of ordinary trains are formed with underutilization of both the useful length of stations' receiving-departure tracks and the weight norm. For heavy trains, 39 % have a weight less than the established weight norm (6000 tons) due to restrictions on the length of station tracks.

Thus, in general, the following conclusions can be drawn from the above analysis:

1. For a given weight norm, it is impossible to form trains strictly in accordance with weight standards, both for ordinary trains and for heavy trains, which is why there is a scatter of train weights.

2. For heavy and at the same time long trains, it is necessary to provide without-overriding pass on the section and a specialized thread of the schedule. It is also necessary for these trains to take into account the duration of accumulation of wagons to form a given train.

3. Justification of weight norms for ordinary and heavy trains should be carried out jointly, for example, if ordinary trains have a weight norm of 3000 tons and this weight norm is implemented by two-section locomotives traction, then for heavy trains there can be weights of 6000 tons or less, subject to driving such trains by locomotives with four sections. This need is due to the fact that speed and, consequently, travel times of ordinary and heavy trains in the schedule should be the same. In this case, departure of both ordinary and heavy trains is possible on any freight train schedule.

The sequence of calculations for the joint choice of weight norms for ordinary and heavy trains can consist of the following stages:

1. Collection of statistical material on the weights and lengths of trains in given sections of the direction in which the organization of movement of heavy trains is planned.

2. Depending on the power of the traction locomotives, variants of interconnected weight standards for ordinary and heavy trains are compiled.

3. For each option, the average weight of the train, volume of traffic, travel speed and travel time on the hauls are calculated.

4. Evaluation of each option is carried out using the reduced annual transportation costs, which are calculated for both ordinary and heavy trains.

Variants of interconnected weight norms, based on the condition that double traction is used for heavy trains and the critical train weight for regular trains is 4000 tons, can be as presented in Table 1.

Of course, for heavy trains it is possible to set a weight norm below those indicated in Table 1. For example, with a weight norm of 4000 tons for ordinary trains, it is possible to vary the weight norm for heavy trains from 6000 tons to 8000 tons. However, in this case, the double traction capacity for heavy trains will be underutilized, which cannot be considered appropriate.

When calculating the average weight of a train in each variant of the weight norms, a histogram of distribution of train loads is used, which is obtained on the basis of a statistical sample of weights and lengths of freight trains. Train load per unit length is calculated as the ratio of the average weight of the train to its length. Pic. 4 shows the histograms of distribution of train loads per unit length for Likhaya – Bataysk section in the odd direction of movement for ordinary and heavy trains. When calculating the average weight of a train, the formula proposed by professor K. K. Tikhonov is used [2]:

$$Q_{gr}^{*}=\frac{P^{*}(l_{st}-a)}{\sum_{i=1}^{k}\alpha_i+\frac{1}{P_t}\sum_{i=k+1}^{n}\alpha_i P_i},$$

where P^* – average value of a train load per unit length, t/m;

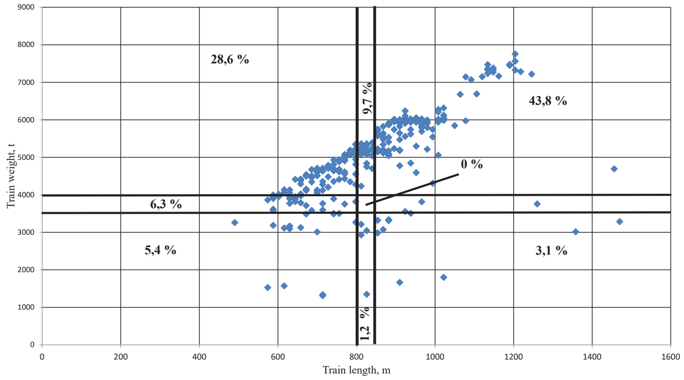
l_{st} – standard length of station's receiving-departure tracks, m;

α_i – frequency of the i-th digit of the histogram of distribution of trains loads per unit length;

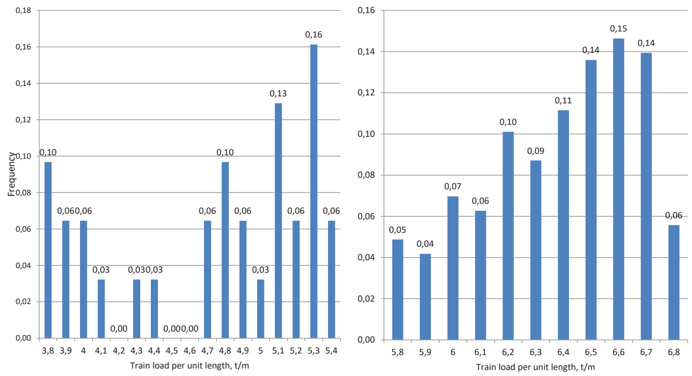
Table 1

Possible options of weight norms

Weight norms for ordinary trains, t	Weight norms for heavy trains, t
3000	6000
3100	6200
3200	6400
3300	6600
3400	6800
3500	7000
3600	7200
3700	7400
3800	7600
3900	7800
4000	8000

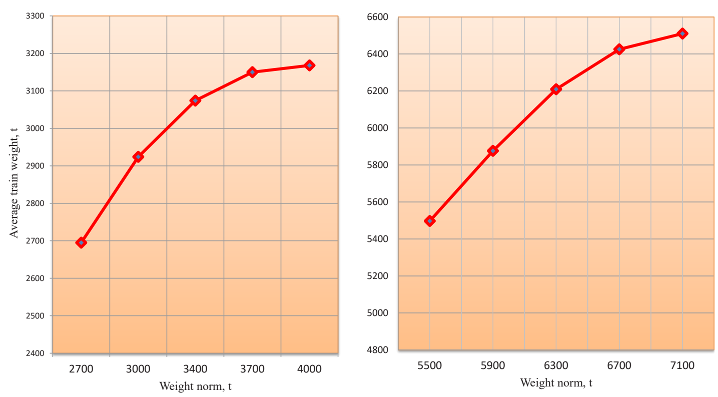


Pic. 3. Diagram of joint distribution of weights and lengths of trains.



Ordinary trains *Heavy trains*

Pic. 4. Histograms of distribution of loads per unit length.



Ordinary trains *Heavy trains*

Pic. 5. Dependence of the average weight of the train on the weight norm.

P_i – average value of a train load per unit length in the i-th digit of the histogram, t/m;

P_t – train load per unit length, corresponding to the weight norm, t/m;

k – number of the histogram digit, the right border of which coincides with P_t;

n – total number of the histogram digits.

Pic. 5 shows the dependence of the average weight of a train on the weight norm for ordinary and heavy trains. In turn, through the average weight of the train, it is possible to calculate the daily average movement of freight trains.

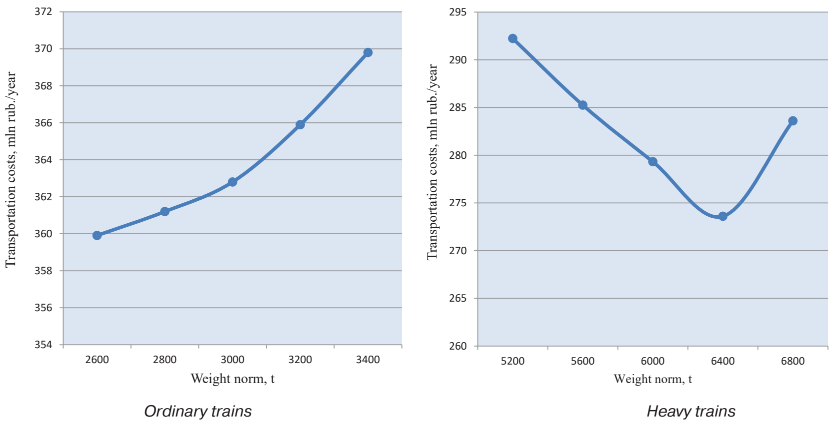
For ordinary trains:

$$N_{fr}^{ord} = \frac{A_{ord}}{Q_{gr}^{ord}}.$$

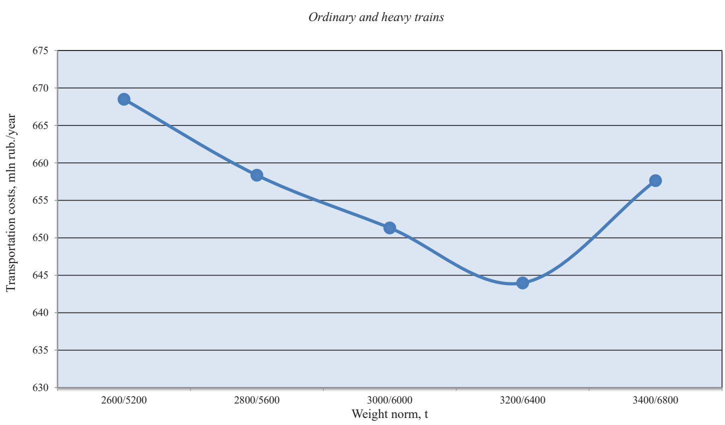
For heavy trains:

$$N_{fr}^{heav} = \frac{A_{heav}}{Q_{gr}^{heav}}.$$

In these formulas A_{ord} and A_{heav} – daily volumes of tons gross, transported in ordinary and heavy trains; Q_{gr}^{ord} and Q_{gr}^{heav} – accordingly average weight of an ordinary and a heavy train.



Pic. 6. Annual transportation costs.



Pic. 7. Total annual transportation costs.

The principles outlined above allow calculating for given weight norms:

- *average weight of ordinary and heavy trains;*
- *average daily movement of ordinary and heavy trains;*
- *travel speed corresponding to the weight norm of ordinary trains.*

Comparison of options for weight norms are implemented through the annual reduced transportation costs:

$$E\left(Q_n^{ord};Q_n^{heav}\right)=E_{trans}\left(Q_n^{ord}\right)+E_{trans}\left(Q_n^{heav}\right)+$$

$$+E_{acc}\left(Q_n^{ord}\right)+E_{acc}\left(Q_n^{heav}\right)+E_{res}\left(Q_n^{ord};Q_n^{heav}\right),$$

where $E_{trans}\left(Q_n^{ord}\right);E_{trans}\left(Q_n^{heav}\right)$ *are annual costs regarding a route direction associated with movement of ordinary and heavy trains;*

$E_{acc}\left(Q_n^{ord}\right);E_{acc}\left(Q_n^{heav}\right)$ *– annual costs for accumulation of ordinary and heavy trains;*

$E_{res}\left(Q_n^{ord};Q_n^{heav}\right)$ *– annual costs for reserve mileage of locomotives and brigades.*

Conclusion. *Pic. 6 shows the calculation results for choosing the optimal weight norms for ordinary and heavy trains. It is characteristic that the annual costs for ordinary trains with increasing weight norms increase, and for heavy trains they have an optimum. Total annual costs in Pic. 7 determine the optimal weight norms for ordinary and heavy trains, which amount to 3200 tons for ordinary trains and 6400 tons for heavy trains.*

REFERENCES

1. Pekhterev, F. S. Prospective areas of heavy weight trains traffic [*Perspektivnye poligony obrashcheniya tyazhelovesnyh poezdov*]. *Zheleznodorozhniy transport*, 2014, Iss. 9, pp. 7–10.

2. Tikhonov, K. K. Foundations for choice of optimal weight of freight trains [*Teoreticheskie osnovy vybora optimal'nyh vesovyh norm gruzovyh poezdov*]. Moscow, Transport publ., 1970, 200 p.

3. Baturin, A. P. Average Weight Calculation of a Freight Train. *World of Transport and Transportation*, Vol.12, 2014, Iss. 3, pp. 6–13.

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