PAPER • OPEN ACCESS

Information technologies in the assessment of timber road train – log trucks

To cite this article: S V Budalin *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **709** 022064

View the article online for updates and enhancements.

Information technologies in the assessment of timber road train – log trucks

S V Budalin[1], S V Lyakhov[1.2.3.]* and S V Nikulin[1]

[1]The Ural State Forestry Unvirsity, Siberian tract, 37, Ekaterinburg, Russia
[2] The Ural federal university, Mira street, 19, Ekaterinburg, Russia
[3] The Ural State Agrarian University, Karl Liebknecht street, 42, Ekaterinburg, Russia

* sergeilyakhov@mail.ru

Abstract. In work the estimation and a choice of log trucks for the certain technology of export of assortments on technical and economic criteria is considered. The considered algorithm includes the formation of requirements for cars -sortiment trucks from the road transport organizations, the choice of cars present in the market, the calculation of their economic efficiency, the definition of integrated quality indicators and the final choice of the car brand. As a result, the most efficient sorting vehicle is chosen for the selected timber transportation segment and the fleet of the trucking organization is formed, depending on the volume of transportation. The offered technique can be used at formation of a cargo vehicle fleet of any enterprise, its updating, and also at the organization of transportations with a view of fastening of concrete cars behind certain routes

1. Introduction

One of the most time-consuming and expensive processes in the timber industry is the transport of timber by road. In this process, up to half of the employees of enterprises are employed, and the transport component in the cost of production reaches 45-48%. The market is full of many models of similar log trucks of domestic and foreign production. Before the auto transport organizations (ATO) of the timber industry complex, there is often a problem of choosing the type of rolling stock (RS), since the decision to purchase a differently-used RS without proper justification is often ineffective.

The current methods for assessing the efficiency of the selection of forest vehicles, as a rule, do not take into account simultaneously a set of significant technical and exploitation indicators (TEIs) under specific conditions for the removal of timber. The choice of RS in the formation of the ATO park requires a reliable and reliable technique for the technical and economic evaluation of log truck. As the analysis shows, known methods do not allow to evaluate objectively the purchased timber automobile, which makes their application ineffective in practice.

Recently there has been a deconcentration of the development of cutting areas [1], which leads to an increase in the transport[1]ation distance of timber. The average distance of removal for the last 20 years has increased by 1.5 times, while the volumes of timber transportation in the assortments grow directly to consumers and to lower warehouses. Reducing transportation costs by increasing the efficiency of timber transportation by road trains is an actual task. It raises the importance of the problem of a

reasonable choice and rational performance indicators for log road trains for the removal of timber in whips and assortments and its effective organization.

The problem is aggravated by the fact that the organization and planning of the transport process for the removal of timber is based on the normative speeds of movement without taking into account the energy assessment and subsequent rapid correction of performance indicators. This complicates the task of increasing the efficiency of forestry vehicles, the choice of rational operating parameters of road trains and determining the TEI of their work. A significant impact on the efficiency of timber removal is provided by the ability of logging companies to purchase a diverse range of logging trailers, including those equipped with loading mechanisms, depending on logging technology.

2. Assessment of technical and operational indicators of log truck

We will evaluate and select the forest vehicles for the following typical conditions of the timber industry complex: the type of cargo - assortments; length of assortments - 2,5 - 3,5 m; the length of the gondola with cargo is 150 km; the average value of the utilization factor is 1.0; the average value of the mileage utilization factor is 0.5; natural and climatic conditions - temperate continental climate, low-wooded terrain; the days of operation of the substation in the year are 125; time in the attire - 10 h. Automobile-sortiment trucks, designed for this type of transportation, must be highly mobile, equipped with hydromanipulators and work as tractors with trailers with a carrying capacity of more than 17 tons. Other requirements for rolling stock (RS) by road transport organizations (ATO) at the acquisition stage of cars, as a rule, are not significant.

For comparison, we choose alternative car brands that meet the above requirements in their technical parameters: URAL-63685, IVECO AMT-633920, MAZ-6303A8, KRAZ-6233M6. The choice of cars for operation in these conditions is carried out according to the developed algorithm [2, 3]. In the first stage, after choosing alternative cars, an estimation of their economic efficiency is made. The estimation of economic efficiency is made for the service life of the timber cars, which is accepted Tc = 8 years.

To assess the economic efficiency, first of all, the annual productivity of forest vehicles is determined by years during the service life. Discounted cash flows (DCFs) are calculated for the life of vehicles. Then, based on the results obtained, the net present value (NPV) of each vehicle brand is determined [2, 3].

Indicators of economic efficiency of cars for 8 years of operation are given in Table 1

Table 1. Indicators of economic efficiency of the estimated log trucks.

№	Indicators	URAL-63685
1	NPVon increasing at r = 25%, rubles	345004,3
2	NPVon increasing at r = 18%, rubles	402182,3
3	Return On Investment	1,26
4	Internal payback ratio,%	27,5
5	Term of recoupment, years	4,5

As the results of calculations show, the maximum NPV value at r = 18% is the car IVECO AMT-633920 (DDP = 693188.5 rub.), NPV of other cars is also positive, and according to the algorithm it is necessary to assess the technical and operational quality indicators of all compared log trucks (table 2).

Table 2. Carrying capacity of a forest vehicle and a road train.

Car model	Car load capacity, q, t	Carrying capacity of a road train, q, t
IVECO AMT - 633920	21,9	47,5
MAZ - 6303A8	17,0	40,3
URAL - 63685	20,0	40,0
KRAZ - 6233M6	18,5	33,3

At the next stage, the technical performance of the presented cars is evaluated by the criterion of the integral coefficient. A significant part of the cost of the fixed assets of the ATO is the RS, which is characterized by a number of characteristics (price, load capacity, fuel consumption, etc.) and used for specific cargoes. Ultimately, the choice of a type of RS for transportation will determine the costs not only for its acquisition, but also for operation, and, consequently, this will affect the profit and profitability of the enterprise.

In the organization of transportation by motor vehicles, the choice of such a substation is essential, the use of which would ensure the maximum efficiency of transport. In specific conditions of transportation, the choice of type of RS is affected by the properties of timber, the way of carrying out loading and unloading operations, road conditions, etc. [3].

In practice, when choosing the type of RS, in addition to economic criteria, it is necessary to take into account a significant number of different technical requirements and limitations. Several heterogeneous criteria can be compared and a generalized indicator can be derived. Let's select the most important technical and operational indicators of the main log trucks for a typical ATO and reduce them to Table 3.

The considered indicators can have different influence (weight) at formation of the general criterion for a choice of RS. You can take into account the degree of influence of various indicators by their ranking. For this purpose, column "rank" is entered in Table 3, and the indicators are ranked from 1 to 12 places [4]. The larger the range of indicators will be used, the more sensitive will be the influence of the ranking. The most optimal is the number of indicators, and, consequently, the rankings of the order of 10. Out of 100 indicators, the 100th place occupies no place at all in determining the value of the generalized criterion.

Table 3. Technical and operational indicators of log trucks with the rear location of the manipulator.

№ rang	Parameter name	Car model			
		URAL - 63685	IVECO AMT - 633920	MAZ - 6303A8	KRAZ - 6233M6
1	Total weight of the road-train, kg	53500	60900	52000	46800
2	Wheel formula	6x4	6x6	6x4	6x6
3	Declared resource before overhaul, thousand km	400	750	450	350
4	Curb weight, kg	13500	13440	11700	13500
5	Ratio of the curb weight of the vehicle to the mass of the load	0,675	0,611	0,676	0,730
6	Basic rate of fuel consumption, l / 100km	32	27	26	40
7	Estimated rate of fuel consumption by road train, l / 100 km	82	84	80	96
8	The price of the car, thousand rubles.	2670	5740	2230	2385
9	Periodicity of maintenance, km	10000	15000	8000	6000
10	Labor intensity of servicing, person per hour	3,4	3,6	3,4	4,1
11	Rated engine power, kW (hp)	293(400)	309(420)	294 (400)	243(330)
12	Maximum climbability,%	27	35	25	33

All the twelve of considered indicators have non-comparable absolute units of measurement, therefore their absolute values must be presented in relative form by the ranking method (Table 4). For each indicator, choose the best of all the options and take it as one. The remaining values are represented by the reduced quantities, taking into account the rank exponent in the normalizing functionE.F.Titov, which will show the degree of deterioration in the value of this indicator compared to the best [5]. The resulting value will be the value of the total coefficient, which can be taken as the integral quality index. The highest value of the total coefficient corresponds to the best variant of the selected car.

Table 4. The resulted factors of log trucks.

№ rang	Parameter name	Car model			
		URAL-63685	IVECO AMT-633920	MAZ-6303A8	KPA3-6233M6
1	2	3	4	5	6
1	Total mass of the road train	0,88	1,00	0,85	0,77
2	Wheel formula	0,67	1,00	0,67	1,00
3	Declared life before major repairs	0,43	0,87	0,54	0,32
4	The equipped weight of the car	0,66	0,67	0,71	0,66
5	Ratio of the curb weight of the vehicle to the mass of the load	0,500	0,559	0,500	0,450
6	Basic rate of fuel consumption	0,333	0,416	0,430	0,200
7	Estimated fuel consumption rate of the road train	0,322	0,314	0,330	0,265
8	Price of the car	0,201	0,143	0,250	0,233
9	Periodicity of maintenance	0,125	0,188	0,100	0,075
10	Labor intensity of service	0,140	0,132	0,140	0,111
11	Rated motor power	0,098	0,104	0,099	0,082
12	Maximum climbability	0,059	0,077	0,055	0,072
13	Total factor	4,42	5,18	4,68	4,24

For the sake of clarity of the results obtained, radars of technical and operational indicators (quality radars) of each brand of a forest vehicle are built (Figure 1, 2). We choose the most significant first eight indicators: 1-total mass of the road train; 2-wheel formula; 3-declared resource before major repairs; 4-curb weight of the car; 5-ratio of the curb weight of the car to the mass of the goods carried; 6-base rate of fuel consumption; 7-computed rate of fuel consumption of the road train; 8-car price.

Figure 1. Radars of vehicle quality indicators URAL - 63685 and IVECO AMT – 633920.

Figure 2. Radars for vehicle quality indicators MAZ-6303A8 and KRAZ-6233M6.

The sum of the coefficients of the IVECO AMT-633920 car is greater than the sum of the coefficients of all others, therefore, the IVECO AMT-633920 log truck has the best technical performance of the four cars under consideration and is most suitable for the ATU of the Sverdlovsk region.

To perform the comparative characteristics of cars, a computer program is developed among themselves.

The program helps to select a rolling stock with rather low operating costs rather quickly and easily when exporting timber. To do this, it is sufficient to select the rolling stock from the base of the calculation program or to create a new one by determining its main technical parameters and storing it in the database. The program is developed on the "C #" platform for working in Microsoft Windows [6, 7].

3. Evaluation of timber harvesting efficiency

The analysis of the results of calculation of the main and complex indicators of the efficiency of timber transportation by road trains is carried out with the help of the proposed diagrams (Figure 3). On the rays are laid out segments that are equal to the values of the trailer-standard trains, in which all indicators of the efficiency of timber transportation by road trains are equal to one. The main indicators of the efficiency of timber transportation by road trains are represented by radius vectors whose lengths are equal to the corresponding numerical value of the indicators. The numbers at the

ends of the vectors are equal to the corresponding number of the evaluated enterprise. A small polygon is constructed at the ends of segments equal to 0.5 [8].
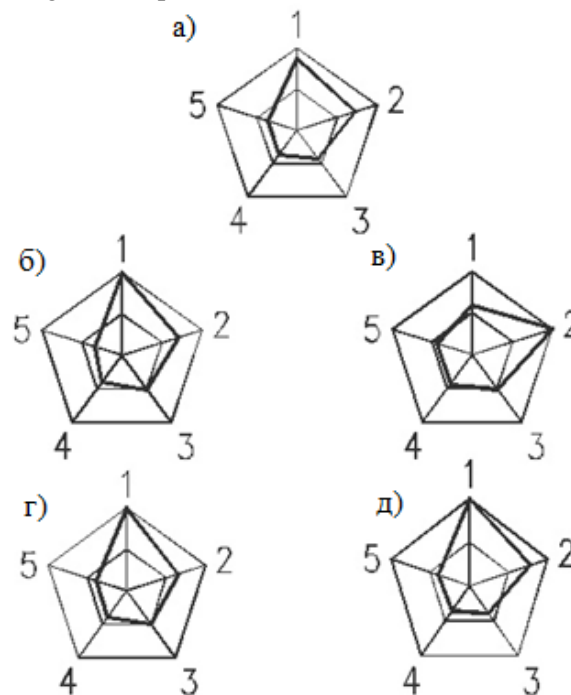

Figure 3. Diagrams of the complex and resulted main indicators of the efficiency of timber transportation by road trains: $a–K_i$, $б– \Theta\alpha_в$, $в –\Theta\gamma$, $г –\Theta\beta$, $д–\Theta V_э$; 1 - IVECO-633910, 2 - IVECO-633920, 3 - Ural-5557, 4 - Ural-444403, 5 - Ural-43204

Analysis of calculations by models of road trains makes it possible to reveal some regularities. The area of the polygons constructed at the ends of the radius vectors (Figure 5), in this case, reflects the efficiency of the timber removal by the given model of the logging road train on the enterprise. When assessing the efficiency of removal by model of road trains, all the average values of the indicators are above the average. The emission factor is the most important ($\Theta\gamma = 0.717$), while the mileage utilization index is much lower ($\Theta V_э = 0.541$). On the average, the value of the complex indicator of the efficiency of removal according to models of logging road trains $K_i = 0.552$.

The lower value of the efficiency level for the complex indicator by models indicates, apparently, its greater dependence on the design parameters of the road trains: the curb weight ma, the cargo capacity γ, the body capacity $v_к$.

Comparison of the data also shows that, regardless of the choice of basic indicators, the ranking of road trains by the integrated efficiency index within the enterprise, as well as by a particular brand, remains practically unchanged - only the values of integrated and basic performance indicators change. A conclusion is also confirmed about the high values of one of the main indicators - operational speed in general, which on certain routes for certain models of logging road trains is smaller than the values of the output coefficients, the use of cargo capacity and mileage.

Ural-43204 has the lowest cargo capacity (as well as payload capacity) among the group under consideration (nominal cargo capacity $V_н = 21$ m³), the value of the complex indicator is 0.359, while for the IVECO 633929 ($V_н = 60$ m³) it is 0.589; for the road train Ural-444403 ($V_н = 23$ m³) - 0.417; for the road train Ural-5557 ($V_н = 23$ m³) - 0.484. The IVECO ATT-633910 ($V_н = 55$ m³) is the first in the ranking of road trains based on a generalized efficiency of removal of 0.914.

IVECO logging road-trains are more load-carrying and have a higher efficiency level of haulage by a generalized efficiency measure than Ural road trains. This phenomenon can be caused by many

reasons, which affect differently the various indicators. IVECO-633920, which has the highest load capacity from the group under consideration, ranks second among the five among the models of logging lorry convoys. In order to achieve a greater value of the complex indicator of the effectiveness of the removal, this model should have either greater absolute values of the main indicators of the efficiency of the removal (all but the utilization factor of cargo capacity) or with the same values of the main indicators to have greater productivity.

Thus, the values of the obtained values of the considered indicators are primarily explained by their multi-causal nature, and therefore, the final choice of priority directions for increasing the efficiency of timber removal by the park of logging road trains should be carried out using the methods of probability theory and mathematical statistics [1].

4. Selection of priority directions for increasing the efficiency of timber removal

In order to select the priority areas for increasing the efficiency of timber transportation by the fleet of road trains in the enterprise, it is necessary to investigate the dependence of the complex indicator on the levels of the main performance indicators.

The researches of Y M Radkevich have shown that these dependences for forest machines can be described with a linear equation of the form

$$Ki = a\Theta P_{ij} + b \tag{1}$$

where a and b - coefficients;
ΘP_{ij} - i-th indicator of the j-th car or road train

Dependencies of this kind were obtained by J M Radkevich for cleaning combines; Yu E Voronov - for drilling rigs; G I Solodomi and V A Aleksandrov - for mobile support mechanisms [1], V.V. Przhezhetskiy and R S Shamsutdinov - for excavators. A similar approach can be extended to logging road trains. The coefficients of the linear regression equation were determined using the least-squares application of Microsoft Excel [9]. The resulting coefficients a and b, as well as the correlation coefficient r and the Fisher-Snedekor F-criterion are shown in Table 5.

The critical value of the F-criterion with a confidence level of 95% is 1.5711. The values of the correlation coefficients, as well as the comparison of the calculated value of the F-criterion with its critical value, indicate a rather close correlation between the values of the complex indicator and the efficacy levels for the main indicators.

Table 5. Coefficients of linear regression, correlation, and Fisher-Snedekor equations.

Indicators the equations	The resulted basic TEI efficiency of removal			
	$\Theta\alpha_\text{в}$	$\Theta\gamma$	$\Theta\beta$	ΘV_e
α	1,187	0,521	1,055	1,226
b	-0,105	0,429	-0,090	-0,136
r	0,975	0,604	0,651	-0,714
F-criterion	1,3161	1,5711	1,5019	1,4608

Obviously, the greater the angle of inclination of the correlation line to the abscissa axis, the stronger the dependence of the complex efficiency index on each of the main ones, and therefore, to achieve the greatest effect, the main efforts should be directed toward the improvement of these indicators. This angle is determined mainly by the value of the coefficient b of the linear regression equation.

Using dependencies of the efficiency level on a complex indicator from the efficiency levels for the main indicators, it is possible to locate the main indicators of the efficiency of timber transportation by road trains in terms of their effect on the complex indicator:
1) exponent of output factor $\Theta\alpha_{_в}$;
2) service speed indicator ΘV_e;
3) indicator of the mileage utilization factor $\Theta\beta$;
4) index of utilization factor $\Theta\gamma$.
Thus, in order to increase the level of efficiency in the complex indicator, it is first of all necessary to develop measures aimed at increasing the output ratio and operating speed.

4.1. Analysis of timber transportation routes
The analysis of the routes for the movement of logging lorry trains was carried out taking into account the largest volume of removal in a certain direction and a certain type of rolling stock. The magnitude of the slopes of the road is taken into account with a step of 1 km.
The use of truck trains in different directions is determined depending on the harvesting technology in the cutting area and the availability of loading and unloading equipment at the plot and rolling stock. When the manipulator is installed on the road train, the downtime at the site is reduced, which in turn allows to increase the operational speed - the most significant basic indicator by the degree of influence on the complex [1, 10].

4.2. The program for calculating the integrated indicator of timber harvesting efficiency
To calculate the specific energy costs of timber removal, a program was developed that takes into account the main technical parameters and special conditions for operating a timber log truck, as well as the weighted average deviation on a particular route. The program helps to quickly and easily pick up the rolling stock with the least expenditure of energy for the removal of timber. To do this, it is sufficient to select the rolling stock from the base of the calculation program or to create a new one by defining its main technical parameters and saving it in the database. The program is developed on the "C #" platform for working in Microsoft Windows [1, 11].
In addition, it is possible to analyze the condition of the fleet of vehicles involved in the export of timber. The analysis allows to assess the level of efficiency of timber transportation by road trains and to determine the most significant indicators and the degree of their impact on its levels. Calculations showed that the most influential parameter is the operating speed of the road train. One of the options for increasing it is the use of manipulators on logging road trains, which reduces the downtime in the cutting area.

5. Conclusion
Existing methods of assessing the efficiency of timber trucks, as a rule, do not simultaneously take into account a complex of significant TEI under specific operating conditions, and therefore there is currently no comprehensive evaluation of the operation of logging road trains. It is such an assessment for road trains of different models at each enterprise that would make it possible to significantly improve the TEI and ensure their scientifically based planning. The organizational measures proposed on the basis of the integrated assessment should lead to an increase in the TEI of the efficiency of timber transportation by road and, consequently, to the improvement of the efficiency of the production processes of the timber industry.

References
[1]   Lyakhov S V. *Increasing the efficiency of timber transportation by the fleet of road trains based on the planning of technical and operational indicators*: dis. ... cand. tech. sciences. Ekaterinburg, 2012, p 164.

[2]   Nekrasov D N, Budalin S V and Astaf'eva O M. *Algorithm for the selection of logging road trains with the definition of an integral quality factor*, Electronic Journal: Contemporary problems of science and education, **№ 12**, 2012.

[3]   Nuretdinov D I. *The method of choosing the type of rolling stock for a trucking enterprise according to technical and economic criteria*: dis. ... cand. tech. sciences. Naberezhnye Chelny, 2004. p 172.

[4]   Abalonin S M. *Competitiveness of transport services: training. Allowance,* Moscow: IKTs Akademkniga, 2004. p 172.

[5]   Budalin S V and Nekrasov D N. *Choice of logging road trains on technical and operational indicators*, Journal of Scientific Works of the USFEU: Forests of Russia and economy in them, 2012, **№1-2 (42-43)**. pp 70-72.

[6]   Nekrasov D N, Lyakhov S V and Budalin S V. *Algorithm for the selection of timber rolling stock for the fleet of timber industry enterprises*, Forests of Russia and the household in them, 2012. **№1-2 (42-43)**. pp 67-70.

[7]   Astafieva O M, Budalin S V and Nikulin S V. *Evaluation of forest vehicles for the conditions of the Sverdlovsk region*, Modern problems of science and education. URL: http://www.science-education.ru. 2014. **№ 5**.

[8]   Budalin S V and Lyakhov S V. *Analysis of qualitative indicators of operation of logging road trains*, Natural and technical sciences. 2011. **№ 2 (52)**, pp 481-485.

[9]   Gmurman V E. *Theory of Probability and Mathematical Statistics*; Moscow: Higher School, 1997. p 497.

[10]   Budalin S V. *Evaluation of the efficiency of logging road trains at the stages of selection and operation: training. Allowance*, USFEU, Ekaterinburg, 2015. - 215 with. 5.95 MB.

[11]   Lyakhov S V. *Determination of specific energy inputs for the removal of forest raw materials and technical and operational indicators of logging road trains*, Natural and technical sciences. 2012. **№ 1**. pp 78-81.