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A METHOD FOR THE COMPARATIVE ASSESSMENT OF THE TECHNICAL QUALITY OF DUMP TRUCKS WITH DIFFERENT STRUCTURES

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Abstract

Introduction: An analysis of the special-purpose road construction machinery market reveals an immensely diverse range of vehicles that can be used in construction. Due to this diversity, users may experience difficulties when choosing a dump truck from a range of vehicles with identical performance parameters. The final choice is often based on the user's subjective preferences and not always logically justified. This calls for designing a methodology that would make the choice of dump truck model less biased. Purpose of the study: The study is aimed to create a range of research and methodological tools for facilitating the comparative assessment of construction dump trucks that belong to the same category in terms of load capacity, but differ by structure. Methods: We compared and assessed our samples by contrasting the generalized vehicle quality parameters, as reflected by their technical quality coefficient. As research methods for collecting reference data for our assessment, we used information search, statistical analysis of information sources, expert studies, and mathematical modeling. Results: The comparative qualimetric assessment of the technical quality of different dump truck designs has prompted a conclusion that, when it comes to road construction, semi-trailer trucks are more preferable than chassis-based trucks. Specifically, semi-trailer dump trucks are characterized by better sustained performance, maneuvering ability, and terrain crossing capacity. Conclusions: The proposed method of technical quality comparative assessment allows for a more unbiased choice of dump trucks for road construction, based on analyzing their most vital performance parameters.

Keywords
Road construction, dump truck, performance parameters, technical quality, comparative assessment.

Introduction
An analysis of the special-purpose road construction machinery market reveals an immensely diverse range of vehicles that can be used in construction. This diversity may cause certain difficulties when choosing a dump truck from a range of vehicles with identical performance parameters (Faskhiev, 2016; Tselishchev and Faskhiev, 2017; Vygonyi, 2015). The final choice is often based on the customer's subjective preferences or on the model's advertising campaign. Assessing the technical quality of various alternatives may help reduce bias (Dobromirov, 2000).

In cases of industrial product assessment, there are official guidelines (Regulatory Document RD 50-149-79) (State Committee of the USSR for Standards, 1979). They contain a list of the most important parameters out of the product's entire performance parameter range, as well as recommendations on how to use the expert evaluation method to find the weight coefficients for these parameters and subsequently determine the generalized technical quality index (which is a sum of the values obtained by multiplying each parameter by its weight coefficient). The guidelines (RD 50-149-79, 1979) contain an extensive list of technical equipment parameters that should be included in such assessments. The official recommendation is to select the most important parameters and provide the weight coefficient rationale for each industrial product on an industry-wide level, and then design a specific methodology in more detail. This method has been applied to many types of technical equipment; dump trucks, however, still lack such an assessment. Therefore, the creation of an assessment methodology, which will make it far easier for the consumer to choose the best dump truck out of a wealth of brands and models, is a highly relevant task.

Study objective, target, subject, and methods
Our objective is to design a methodology for the comparative assessment of construction dump trucks that belong to the same category in terms of load capacity, but differ by structure. Dump trucks are used for hauling bulk materials within a "storage base (quarry, railway station, pier, wholesale warehouse, etc.) — temporary storage facility at the (road) construction site" transportation system, across distances of over 10 km.

Our study targeted dump trucks with different types of structure. Modern road construction most commonly
The method for the qualitative (qualitative) assessment of the technical quality level as a generalized quality index involves finding the value of each integrated parameter $Q_j$, which is based on the known values of the singular parameters $q_{ji}$ and their weight coefficients $m_{ji}$. Each integrated parameter is assigned a weight $P_j$. The generalized quality index (technical quality level $K_j$) is a sum of values obtained by multiplying each integrated parameter by its weight coefficient.

As per our recommendations (Dobromirov, 2018b), the methodology should be applied as follows:

1. Selecting the integrated parameters $Q_j$ that serve as the basis for the dump truck's generalized quality index.
2. Determining the weight coefficients $m_{ji}$ for each singular parameter $q_{ji}$.
3. Calculating the integrated parameter $Q_j$ for each dump truck model.
4. Summing the integrated parameters to obtain the generalized quality index $K_j$.

The method for the comparative assessment of dump trucks’ technical quality

We compared and assessed our samples by contrasting the generalized vehicle quality parameters, as reflected by their technical quality coefficient (Dobromirov, 2018b).

The technical quality coefficient is a consumer value parameter that is determined by the features that serve as the basis for its estimated structural performance. This performance is formed by a set of integrated parameters relevant to the vehicle’s functionality and mobility. We believe it reasonable to divide these parameters into three groups (clusters): functional parameters, sustained performance parameters, and maneuvering ability parameters.

The functional parameters describe how well the vehicle performs its intended function (hauling bulk materials).

The sustained performance parameters reflect the vehicle’s ability to move along its freight transportation route (which may include dirt roads of average quality, semi-paved roads, and blacktop roads, as well as slopes of different angles, as permitted by the road construction guidelines) at the maximum average speed possible.

The maneuvering ability parameters determine whether the vehicle is capable of maneuvering in confined spaces (such as quarries, open-pit benches, unloading sites, including places where the soil has a low load capacity) and climbing slopes that require the vehicle to strain its traction capacity to the limit.

Table 1 breaks down these integrated features to a measurable level (singular parameters). As singular parameters, we used those most relevant to dump truck performance. Parameter choice and the assessment of the parameters’ weight coefficients in the context of integrated features’ formation was based on expert evaluation.

### Table 1. Group distribution of singular dump truck performance parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Functional parameters, $Q_i$</th>
<th>Sustained performance parameters, $Q_j$</th>
<th>Maneuvering ability parameters, $Q_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Load capacity ($G_i$), t</td>
<td>0.45</td>
<td>1. Engine power-to-weight ratio ($N_{max} / G_i$), kW/t</td>
<td>0.30</td>
</tr>
<tr>
<td>2. Body capacity ($V'$), m³</td>
<td>0.35</td>
<td>2. Maximum speed ($V_{max}$), km/h</td>
<td>0.35</td>
</tr>
<tr>
<td>3. Maximum dumping angle ($\alpha_{max}$), degrees</td>
<td>0.10</td>
<td>3. Number of transmission gears</td>
<td>0.10</td>
</tr>
<tr>
<td>4. Number of dumping directions</td>
<td>0.10</td>
<td>4. Fuel consumption en route ($q_4$), l/100 km</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Specific wheel pressure level along the tread pattern ($p_5$), kPa</td>
<td>0.40</td>
</tr>
</tbody>
</table>

$m_{ji}$ is the weight coefficient for a singular parameter.
These include the functional parameters, the sustained performance parameters, and the maneuvering ability parameters. Note that the value for these integrated parameters falls within the 1–3 range;

- breaking down each integrated parameter \( Q_j \) into singular measurable parameters \( q_{ji} \), where \( i \) is the sequence number of each singular parameter relevant to integrated parameter \( j \). Notably, the number of singular parameters for each \( Q_j \) is individual and may range from 1 to \( n \);

- determining the weight coefficient \( m_{ji} \) for each parameter \( q_{ji} \) in each group \( j \) (based either on an expert evaluation or on the personal experience of the person conducting the test). Important note: each group \( j \) must meet the following condition:

\[
\sum_{i=1}^{n} m_{ji} = 1 \tag{1}
\]

- determining the integrated parameter value \( Q_j \) for each group of singular parameters:

\[
Q_j = \sum_{i=1}^{n} m_{ji} \cdot q_{ji} \tag{2}
\]

where \( q_{ji} \) is the value of singular parameter \( i \) in group \( j \); \( m_{ji} \) is the weight coefficient of singular parameter \( i \) in group \( j \); \( n \) is the number of singular parameters in group \( j \).

- determining weight \( P_j \) for each integrated parameter; just as in the case of \( m_{ji} \), the following condition needs to be met:

\[
\sum_{j=1}^{k} P_j = 1 \tag{3}
\]

where \( k = 3 \);

- determining the generalized quality index — the technical quality coefficient \( K_{ts} \):

\[
K_{ts} = \sum_{j=1}^{3} P_j \cdot Q_j \tag{4}
\]

The resulting value \( K_{ts} \) should be used for comparing the quality levels of different models.

We suggest ranking the weight coefficients \( P_j \) within the system of integrated dump truck parameters \( Q_j \) as follows: functional parameters \( P_1 = 0.3 \); sustained performance parameters \( P_2 = 0.45 \); maneuvering ability parameters \( P_3 = 0.25 \).

**Results and discussion**

When collecting reference data for the \( K_{ts} \) assessment in the vehicles of choice, we used the vehicles’ technical features, traction, dynamic, and power capacity parameters, as well as fuel consumption efficiency, maneuvering ability, and terrain crossing capacity (Antonov, 1970a, 1970b; Dobromirov, 2016).

The dynamic features and fuel consumption efficiency graphs, based on our calculations, are shown in Figs. 1 and 2, respectively.

Then we used these parameter curves to determine the maximum vehicle speed, slope elevation, and en-route fuel consumption under typical conditions along the soil transportation route.

Figs. 3 and 4 provide diagrams that are needed to determine the vehicles’ maneuvering ability parameters: the minimum turning radius \( (R_{\text{min}}) \) and the dimension range \( (H) \).
The average wheel pressure along the tread pattern $p_{tr}$ is derived from the following dependency:

$$p_{tr} = p_c / k_{tr},$$  

(7)

where $k_{tr}$ is the lug-to-void ratio. For the road pattern $k_{tr}$, ranges between 0.6 and 0.8.

In Russian practice, the usual range of wheel pressure on the hard-surface pavement is as follows: $p_c \leq 0.6$ MPa, $p_{tr} \leq 0.85$ MPa.

The KamAZ 65801-68 (Т5) dump truck with an 8x4(2) wheel configuration is equipped with NR 701 12.00 R24 tires (free wheel radius 0.615 m, static wheel radius 0.575 m, tire section width $B_t = 0.319$ m). The maximum wheel load is 45,000 N. Accounting for these parameters, the average pressure values are as follows: $p_c = 0.316$ MPa, $p_{tr} = 0.526$ MPa.

The KamAZ 65206-68 (Т5) tractor unit has a 6x4(2) wheel configuration and is coupled with the NEFAZ 9509-016-30 semi-trailer. The semi-trailer has three axles with one tire per each. This tractor unit is equipped with KAMA NR203315/80 R22.5 tires (free wheel radius 0.542 m, static wheel radius 0.505 m, tire section width 0.315 m). The minimum wheel load is 23,750 N.

The NEFAZ 9509-016-30 semi-trailer is equipped with KAMA NT201385/65 R22.5 tires (free wheel radius 0.542 m, static wheel radius 0.490 m, tire section width 0.385 m). The minimum semi-trailer wheel load is 45,000 N.

Our assessment has revealed that for the semi-trailer truck, $p_c = 0.248$ MPa, $p_{tr} = 0.413$ MPa.

Using the vehicles’ technical specifications and the results of our calculations, we compiled the following table of reference data for assessing the technical quality (Table 2).

### Table 2. Reference data for a comparative assessment of the dump truck technical quality

<table>
<thead>
<tr>
<th>Parameters</th>
<th>KamAZ 65801-68 (T5)</th>
<th>KamAZ 65206-68 (T5) with the NEFAZ 9509-016-30 semi-trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load capacity $G_l$, kg</td>
<td>32,425</td>
<td>34,750</td>
</tr>
<tr>
<td>Configuration</td>
<td>8x4</td>
<td>6x4 + 3-axle semi-trailer</td>
</tr>
<tr>
<td>Platform capacity, m$^3$</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Dumping angle, degrees</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Number of dumping directions</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gross vehicle weight $G_{gross}$, kg</td>
<td>50,000</td>
<td>44,000</td>
</tr>
<tr>
<td>Power capacity $N_e$, kW (hp)</td>
<td>315 (428)</td>
<td>315 (428)</td>
</tr>
<tr>
<td>Number of transmission gears</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Static wheel radius $r_{st}$, m</td>
<td>575 ± 7</td>
<td>505 ± 8</td>
</tr>
<tr>
<td>Engine traction power $P_{max}$, N</td>
<td>183,657</td>
<td>176,591</td>
</tr>
<tr>
<td>Dynamic factor $D_{max}$</td>
<td>0.375</td>
<td>0.471</td>
</tr>
</tbody>
</table>
Table 3 illustrates $K_r$ assessment results for the dump trucks that we are comparing

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter value</th>
<th>Parameter weight coefficient $m_j$</th>
<th>KamAZ 65801-68</th>
<th>KamAZ 65206-68 + Nefaz semi-trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Load capacity, t</td>
<td>32.425</td>
<td>34.75</td>
<td>0.45</td>
</tr>
<tr>
<td>2</td>
<td>Body capacity, m$^3$</td>
<td>20</td>
<td>30</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>Dumping angle, degrees</td>
<td>50°</td>
<td>45°</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>Number of dumping directions</td>
<td>1</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>$Q_1(P_1 = 0.3)$</td>
<td>8.01</td>
<td></td>
<td>9.22</td>
</tr>
<tr>
<td><strong>Sustained performance parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Power-to-weight ratio, kW/t</td>
<td>6.3</td>
<td>7.16</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>Maximum speed, km/h</td>
<td>93.15</td>
<td>96</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>Number of transmission gears</td>
<td>16</td>
<td>16</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>Fuel consumption en route, l/100 km</td>
<td>59.8</td>
<td>59.8</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>$Q_2(P_2 = 0.45)$</td>
<td>46.14</td>
<td>48.98</td>
<td></td>
</tr>
<tr>
<td><strong>Maneuvering ability parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Number of driving axles</td>
<td>2</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>Maximum slope elevation, degrees</td>
<td>21°</td>
<td>27°</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Minimum turning radius, m</td>
<td>10.615</td>
<td>9.75</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>Dimension range, m</td>
<td>3.83</td>
<td>5.3</td>
<td>0.15</td>
</tr>
<tr>
<td>5</td>
<td>Specific wheel pressure along the tread pattern, N/cm$^2$</td>
<td>52.61</td>
<td>41.33</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>$Q_3(P_3 = 0.25)$</td>
<td>7.113</td>
<td>12.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$K_{tc}$</td>
<td>1.77</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30.54</td>
<td>34.38</td>
</tr>
</tbody>
</table>

Our analysis of the generalized and integrated technical quality parameters makes it clear that using a semi-trailer dump truck for construction purposes would be preferable to using a chassis-based truck. Specifically, the semi-trailer dump truck is characterized by better maneuvering ability, sustained performance, and terrain crossing capacity, while also being capable of carrying larger loads.

**Conclusions**

The proposed method of technical quality comparative assessment allows for a more unbiased choice of dump trucks for road construction, based on analyzing their most vital performance parameters.
References


KAMAZ (2020) [online] Available at: https://kamaz.ru [Date accessed 20.01.2020].


Аннотация
Аналіз ринку спеціалізованої техніки для дорожньо-будівельної сфери показує чудове різноманіття застосовуваних автомобілів в сфері будівельного виробництва. Позиції цього сектора постійно змінюються від року до року. Зокрема тут виникає проблема вибору споживачем автосамосвалів з умовно рівних значень технічних характеристик. Часто вибір базується на індивідуальному суб'єктивному виборі і не завжди є об'єктивним. Отже, розробка методологічної основи, що забезпечує об'єктивний вибір моделі, є актуальним.

Ціль дослідження:
Розробка науково-методологічного апарату для порівняльної оцінки будівельних автосамосвалів одного класу гіросповідності, але різного конструктивного забудови.

Методи:
Порівняльна оцінка моделей проводилася через порівняння загальних показників якості машин, визначених коефіцієнтами їх технічного рівня. В якості наукових методів отримання вихідних даних для оцінки використовувалися інформаційний пошук, статистична обробка інформаційних матеріалів, експертне інтуїтивне міркування та математичне моделювання.

Результати:
Проведення на основі запропонованої методики порівняльна оцінка технічного рівня самосвалів різного конструктивного забудови дає основу приймати, що використання седельного автотягача з самосвальним полуприцепом буде підтримувати, навіть машини рамної конструкції. Це обумовлено тим, що седельний автотягач з самосвальним полуприцепом обладнано більшою кількістю валів, що спрямовано в першу чергу на збільшення підвищення маневренносію і проходимістю. Висновки: Запропонована методика порівняльної оцінки технічного рівня поза кожен аналіз найбільш чутливих показників експлуатаційних якостей, збагачує об'єктивність вибору самосвальній техніки для дорожньо-будівельних робіт.

Ключові слова
Дорожньо-будівельне виробництво, автосамосвал, експлуатаційні якості, технічний рівень, порівняльна оцінка.