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Analysis of Structural Design of Tracked Road Trains for Off-Road Container Transportation

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ABSTRACT

The article substantiates the relevance of comprehensive comparison of various versions of vehicles for off-road container transportation.

Following the need to identify a specific engineering solution for development of a tracked road train, it is proposed to use the analytic hierarchy process designed to solve problems associated with determining the priorities of the multicriteria hierarchical structure of the goal, as well as in the presence of heterogeneous criteria or dimensional and dimensionless indicators.

The comprehensive comparison of vehicles for off-road container transportation is based on the hierarchy of the mobility features, which is considered decisive for the choice of the priority variant of the structural design.

The objective of the work is to substantiate the choice of a priority engineering solution for structural design of tracked road trains for off-road container transportation based on a scientifically grounded hierarchy of the mobility features.

To attain the objective, a consistent solution of the following tasks is suggested as follows: development of requirements for vehicles and for a hierarchy of operational properties; analysis of existing structural design and layout solutions and justification of the choice of alternative solutions (specific designs of tracked road trains); conduct of a hierarchical synthesis of criteria based on the results of expert assessment; identification of the preliminary priority of alternative solutions; obtaining indicators of operational properties by methods of simulation mathematical modelling and/or full-scale mathematical modelling; choice of the priority engineering solution.

The article discusses the feasibility of using tracked road trains both for transportation of a single 45-foot container and for simultaneous transportation of two 20-foot containers with a total mass of 61 tonnes. The analysis of the existing versions of structural design of tracked road trains has shown that only a vehicle of SVG-701 «Yamal» series, developed in the 1980s and which is not currently manufactured, can provide such a payload capacity. Existing modern articulated tracked vehicles cannot provide transportation of such goods. Hence, the relevance of the task of determining the priority engineering solution referring to structural design and layout of tracked road trains at the present stage of development of technology.

Tracked single-hinged articulated semi-trailer road train and a double-hinged tracked road train are proposed as variants of structural design and layout versions of tracked road trains for off-road container transportation. Based on the analytic hierarchy process, opinions of experts and the hierarchy of operational properties, it was established that the engineering solution referring to double-hinged tracked road train should be prioritised. However, due to the small difference between the values of indicators used to select the options, it is necessary to conduct further studies to determine the values of the indicators of operational properties and to re-compare the options considering the results obtained.

Keywords: *tracked road train, technical characteristics, design and layout, analytic hierarchy process, priority engineering solution.*

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INTRODUCTION

Today, many countries actively explore areas that have been previously less accessible and that have not got a developed road network, or hard-surface roads. Rational choice of vehicles that meet series of criteria linked to climatic and economic operation conditions is among core elements, necessary for development of optimal transportation and logistics patterns. The on-going containerisation of freight haulage, along with its growing efficacy through reduced transhipment costs and better safety of goods, highlights relevance of finding engineering solutions that will ensure delivery of freight containers to such areas. The case that should be particularly studied refers to geographical zones where wheeled vehicles could not be operated, i. e., areas of the Far North. The above conditions prove the need for optimal structural design and layout of relevant vehicles (V).

There are various methods to carry out a comprehensive comparison of various options. There are well-known methods based on the use of generalised estimates referring to various properties, they are discussed in detail in [1; 2]. However, such methods are rather complicated for practical application since they consider a relatively small set of property meters, contain a large number of subjective assessment coefficients, and most of them are poorly applicable at the stage of research work.

At present, comprehensive comparison of effectiveness of various vehicles widely applies the analytic hierarchy process (AHP), developed by T. Saaty to solve problems associated with the need to determine the priorities within the multi-criteria hierarchical structure of the goal [3; 4]. The main advantage of the method is the ability to simultaneously consider various heterogeneous criteria, which can have not only dimensional and dimensionless property indicators but be subject also to a quantitative and qualitative assessment. There are known works in the field of comprehensive comparison of various vehicles, based on AHP, which confirm the effectiveness of the method [5–11].

The *objective* of the study is to justify the choice of priority engineering solution for designing tracked road trains for off-road container transportation based om the scientifically substantiated hierarchy of mobility features.

RESULTS

Analytic Hierarchy Process

Let us consider the application of the analytic hierarchy process for comparing various variants of structural and layout design of vehicles for off-road container transportation. Since the use of wheeled vehicles, as a rule, requires roads or prepared terrain, this type of vehicle is excluded from consideration.

Based on the developed hierarchy of operational features [12], we will conduct comparative assessment of alternative solutions referring to vehicles for off-road container transportation with analytic hierarchy process, assuming that mobility is the key criterion for choosing structural design and layout.

The analytic hierarchy process for determining the significance of the criteria for the hierarchy of operational features of vehicle mobility for off-road container transportation can be presented in the form of the following sequential steps [3; 4]:

1. Development of a hierarchy of operational features of vehicle mobility for off-road container transportation.
2. Development of matrices of paired comparisons for each level of criteria.
3. Obtaining expert judgments for each matrix of paired comparisons.
4. Identification of local priorities of criteria and alternatives.
5. Determination of matrix consistency.
6. Synthesis of priorities.
7. Determination the consistency of the hierarchy.

Analysis of Structural Design and Layout Solutions for Vehicles Intended for Off-Road Container Transportation

The article [13] has stated that a radical increase in the vehicle's cross-country ability for off-road container transportation can be achieved only by using articulated multi-body tracked vehicles or tracked road trains. Let us consider the existing and possible design and layout solutions for tracked road trains intended for container transportation, considering their classification [13–16].

Work on creation of experimental samples of tracked road trains for transportation of heavy indivisible cargo in Russia was carried out at NII-21 Research Institute. As a result, in 1964, a prototype model of DGM-1 tracked all-terrain vehicle with a payload capacity of 16 tonnes was

Pic. 1. DGM-1 articulated tracked all-terrain vehicle[1].

Pic. 2. Self-propelled launcher «object 825» (layout).
(The historical and engineering museum of Kirov plant JSC, 2001. Photo: bastion-karpenko.narod.ru[2]).

created (Pic. 1)[1], the design followed a semitrailer scheme. During road tests, the advantages of tracked road trains were determined as compared to single tracked vehicles when driving in the Far North in terms of cross-country ability, payload and cargo capacity.

Another known design and layout solution for a tracked chassis was obtained in 1970 following a series of research and development projects carried out by KB-3 design bureau of Leningrad Kirov plant and resulted in development of prototypes of a self-propelled tracked launcher, made according to the rail wagon scheme: «object 825 Sp2» and «object 825 Sp3», which are two tracked vehicles with independent control and connected through articulated rotary supports with a carriage frame with a carrying capacity of 60 tons. The structural and layout solution did not receive its development due to high requirements for vibration stress to the transported cargo, which at that time could not be met using the chassis of existing tracked vehicles. The external view of the model «object 825» based on two tanks[2] is shown in Pic. 2.

Another tracked road train was developed by SKB Gazstroymashina Design Bureau. It is BT361A-01 Tyumen articulated tracked all-terrain vehicle, developed in the late 1970s. The tracked all-terrain vehicle is made according to a trailed multi-hinge scheme: it had two tracked bogies pivotally connected to the transport platform; the bogies in turn were connected to each other using an articulation unit. The all-terrain vehicle was equipped with YaMZ-240BM diesel engine and had a mechanical driveline of the wheels of tracked bogies. The curvilinear movement of the all-terrain vehicle was carried out by controlling hydraulic cylinders in the articulation unit. To prevent the occurrence of longitudinal angular vibrations, shock absorbers were installed in pivot assemblies connecting the transport platform to the tracked bogies. The

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[1] Stepanov, A. Articulated all-terrain tracked and wheeled vehicles. *Technika i vooruzheniya,* 2003, Iss. 12, pp. 34–38. [Electronic resource]: Portal WikiReading. Section: Military. https://military.wikireading.ru/56023. Last accessed 21.09.2021.

[2] Internet portal of the Arms of Russia information agency. [Electronic resource]: https://www.arms-expo.ru/articles/armed-forces/rvsn-nerealizovannyy-proekt-pgrk-tselina-2-s-raketoy-rt-23uttkh-15zh62/. Last accessed 21.09.2021.

Pic. 3. Articulated tracked all-terrain vehicle BT361A-01 Tyumen[3].

Table 1

Technical features of Tyumen BT361A-01[1, 3]

Parameter	Value*
Engine power, kW	220
Average pressure of the engine on the ground, kg/cm^2	0,33
Curb weight, t	46
Payload capacity, t	36
Maximum speed, km/h	15
Ground clearance, mm	600
Overall dimensions (L x W x H), mm	15560 x 3740 x 3760
Track width, mm	1200
Transport platform dimensions (L x W), mm	8000 x 3500
Climbing angle, degree	16
Minimum turning radius, m	17
The depth of the ford to be overcome, m	1,5

* See, e.g., [Electronic resource]: https://dic.academic.ru/dic.nsf/ruwiki/617530. Last accessed 21.09.2021.

external view of the all-terrain vehicle BT361A-01 Tyumen[3] is shown in Pic. 3, and its technical characteristics are given in Table 1.

In the late 1980s, Yamal SVG-701 tracked all-terrain vehicle with a payload capacity of up to 70 tonnes was developed in collaboration with the Canadian Foremost Industries[4]. The all-terrain vehicle was built according to a double-hinged four-tracked scheme: two independent crawler tracks are interconnected by means of two hinges with a loading platform on which the cabin and the engine compartment were located. The external view of Yamal SVG-701 all-terrain vehicle[3] is shown in Pic. 4, and its technical features are given in Table 2.

Another design of tracked road trains refers to four-tracked all-terrain vehicles, made according to a double-hinge bolster-tractor scheme, with two tracked bogies, rotary supports of which have a mechanical connection between each other, which ensures coordination of the angles of rotation of tracked bogies in the horizontal plane when turning the all-terrain vehicle, while tracked bogies could independently «swing» in the longitudinal plane of the bogie. In 1973, NAMI [Central research institute for road vehicles and engines] developed the first prototype called NAMI-0157 with a carrying capacity of 8 tons, made according to this scheme. Subsequently, in the 1980s, UralAZ launched serial production of Ural-5920 all-terrain vehicle[5, 6, 7], its external view is shown in Pic. 5. Technical characteristics

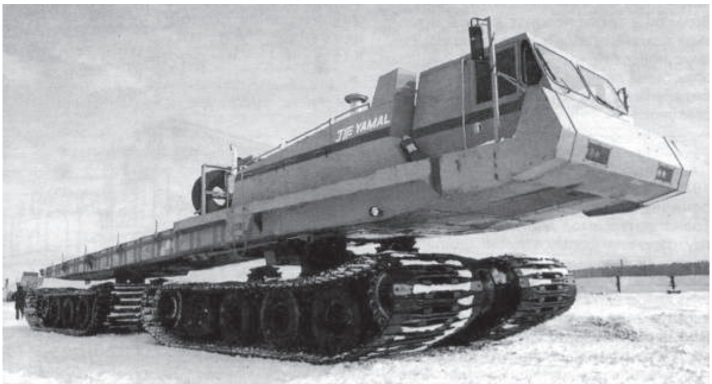
[3] Slavin, O. Yamal all-terrain vehicle: a swamp monster [*Vezdekhod Yamal: bolotny monstr*]. «5 wheel» car web portal. [Electronic resource]: https://5koleso.ru/articles/obzory/vezdehod-yamal-bolotnyy-monstr/. Last accessed 21.09.2021.

[4] Porter, D. From the Archives, The Foremost Yamal | Foremost Blog. Foremost Industries Website. [Electronic resource]: https://www.foremost.ca/archives-foremost-yamal/. Last accessed 21.09.2021.

[5] Automotive website Wroom.ru. [Electronic resource]: https://wroom.ru/cars/ural/5920. Last accessed 21.09.2021.

[6] Automotive website All-auto.ru. [Electronic resource]: https://all-auto.org/858-ural-5920.html. Lsst accessed 21.09.2021.

[7] Samoilenko, V. Ural-5920: the vehicle that does need roads [*Ural-5920 – mashina, kotoraya ne nuzhdaetsya v dorogakh*]. FB Internet site. 08.11.2016. [Electronic resource]: https://fb.ru/article/275695/ural——mashina-kotoraya-ne-nujdaetsya-v-dorogah. Last accessed 21.09.2021.



Pic. 4. Yamal SVG-701 tracked all-terrain vehicle.

Table 2

Technical features of Yamal SVG-701[3]

Parameter	Value
Engine power, kW	525
Average pressure of the engine on the ground, kg/cm^2	0,39
Curb weight, t	97,5
Payload capacity, t	70
Maximum speed, km/h	15
Ground clearance, mm	520
Overall dimensions (L x W x H), mm	20560 x 4700 x 4500
Track width, mm	1850
Transport platform length, mm	12000
Climbing angle, degree	30
Minimum turning radius, m	22
The depth of the ford to be overcome, m	2,6

Table 3

Technical features of the Ural-5920 all-terrain vehicle

Parameter	Value
Engine power, kW	154
Average pressure of the engine on the ground, kg/cm^2	0,22
Curb weight, t	14,5
Carrying capacity, t	8
Maximum speed, km/h	30
Overall dimensions (L x W x H), mm	9900 x 300 x 3700
Track width, mm	970
Transport platform dimensions (L x W), mm	5740 x 2317
Climbing angle, degree	30
Minimum turning radius, m	14
The depth of the ford to be overcome, m	1,8

of Ural-5920 all-terrain vehicle are given in Table 3.

Among the foreign experimental samples of tracked road trains, we note the prototype of Midgetman mobile ground-based strategic missile system, developed jointly by Martin Marietta and Caterpillar in the United States at the end of the 1980s, based on a trailer design. The total mass of the tracked road train was 108 tonnes[8, 9] (Pic. 6).

There are structural and layout solutions referring to four-tracked all-terrain vehicles, made according to a saddle single-hinge scheme, most famous among which are the Nodwell tracked all-terrain vehicles: Nodwell RN200 with a payload capacity of 12 tonnes and Nodwell RN400 with a payload capacity of 18 tonnes. Then, Foremost Industries launched series of four-tracked all-terrain vehicles made with centre pivot articulated steering: Foremost Chieftain-D with payload capacity of 13,6 tonnes and Foremost Husky-8 with payload capacity of 36 tonnes, which are still manufactured. The external view of Foremost Husky-8 all-terrain vehicle[10] is shown in Pic. 7, and the technical features are described in Table 4.

In addition, among four-tracked all-terrain vehicles manufactured by Foremost, we will single out the following models: Foremost Chieftain-R with a payload capacity of 13,6 tonnes and Foremost Chieftain-C with a payload capacity of 15 tonnes, made according to a trailed articulated scheme. They have hydraulic actuator on the articulation point to steer the vehicle.

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[8] Secret Projects Forum. [Electronic resource]: https://www.secretprojects.co.uk/threads/midgetman-sicbm-mobile-launchers.1076/. Last accessed 21.09.2021.

[9] ICBM Hard Mobile Launcher. [Electronic resource]: https://weaponsandwarfare.com/2019/06/05/icbm-hard-mobile-launcher/. Last accessed 21.09.2021.

[10] Foremost Industries website. [Electronic resource]: https://www.foremost.ca/foremost-mobile-equipment/tracked-vehicles/husky-8/. Last accessed 21.09.2021.

Pic. 5. Ural-5920 eracked all-terrain vehicle.

Pic. 6. Mobile soil missile system Midgetman[9].

Table 4

Technical features of Foremost Husky-810

Parameter	Value
Engine power, kW	328
Average pressure of the propeller on the ground, kg/cm²	0,32
Curb weight, t	42,9
Carrying capacity, t	36,3
Maximum speed, km/h	14,5
Ground clearance, mm	533
Overall dimensions (L x W x H), mm	14757 x 3632 x 3810
Track width, mm	1430
Transport platform dimensions (L x W), mm	10465 x 2743
Climbing angle, degree	31
Minimum turning radius, m	14
The depth of the ford to be overcome, m	1,43

Tracked road trains produced today in the Russian Federation comprise dual-body tracked all-terrain vehicles of Vityaz series with various payload capacity, made according to a trailed scheme, the curvilinear movement of which is provided by a kinematic method, by creating a folding moment in the swing-coupling device located between the sections.

Two-section tracked DT-30-1 or DT-30MN tractors can be used for off-road container transportation, as a base model if additionally equipped with a loading platform. The external view and overall dimensions of tracked trucks[11] are shown in Pics. 8 and 9, and their technical features are described in Table 5.

Let us present the main technical features of existing tracked road trains graphically showing the form of their dependences on payload capacity of the vehicle (Pic. 10).

Analysing technical features as a function of payload capacity, the following conclusions can be drawn:

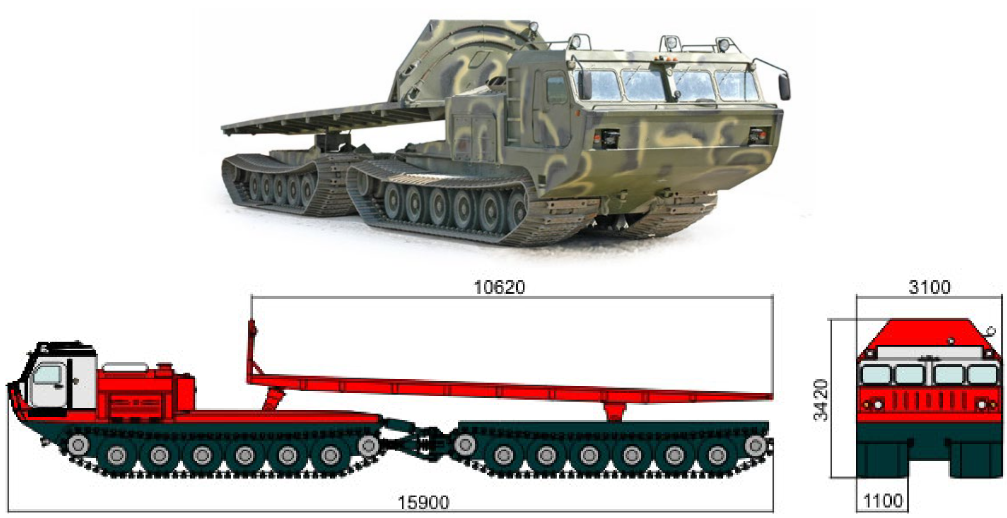
• With an increase in the payload capacity of tracked road trains, the minimum turning radius and the average pressure on the ground increase, while the payload capacity's rate is on average 0,8 and mainly depends on the adopted design and layout solutions.

• Average ground pressure of the considered tracked all-terrain vehicles is in the range from 0,2 to 0,4 kg/cm².

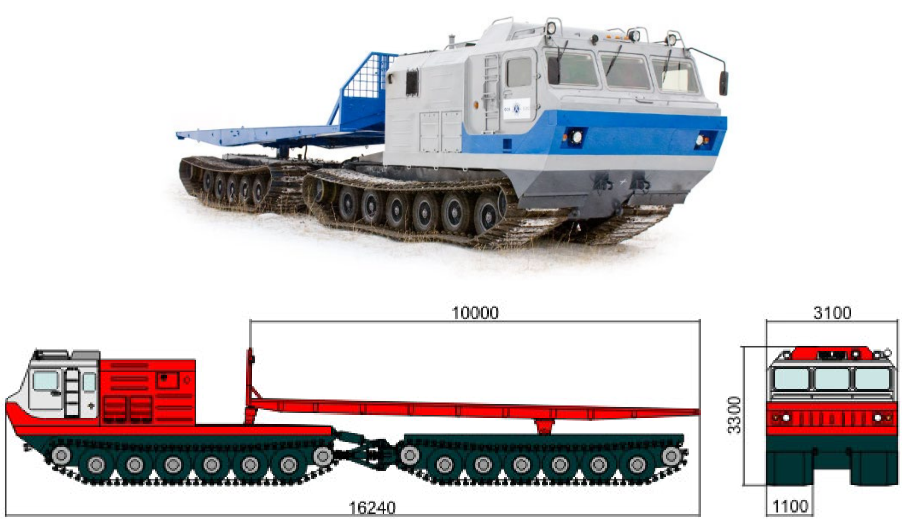
• Maximum speed is determined by the power of the engine and, depending on payload capacity and the adopted design and layout solutions, varies from 15 km/h to 37 km/h.

[11] Vityaz: a machine-building company located in the city of Ishimbay. [Electronic resource]: http://www.bolotohod.ru/. Last accessed 21.09.2021.

Pic. 7. Foremost Husky-8 tracked all-terrain vehicle[10].



Pic. 8. DT-30-1 articulated tracked ATV and its overall dimensions[11].

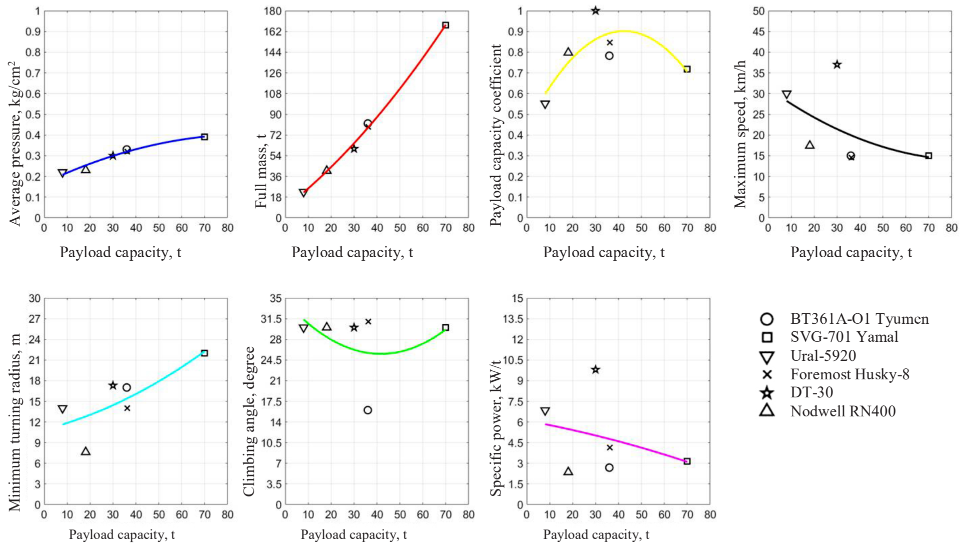


Pic. 9. DT-30MN articulated tracked ATV and its overall dimensions[11].

Table 5

Technical features of tracked DT-30-1 and DT-30MN ATVs[11]

Parameter	DT-30-1	DT-30MN
Engine power, kW	522	588
Average pressure of the propeller on the ground, kg/cm^2	0,3	0,3
Curb weight, t	29	30
Carrying capacity, t	30	30
Maximum speed, km/h	37	37
Ground clearance, mm	350	350
Overall dimensions (L x W x H), mm	15900 x 3100 x 3420	16240 x 3100 x 3300
Track width, mm	1100	1100
Loading platform length, mm	10620	10000
Climbing angle, degree	30	30
Minimum turning radius, m	17,3	17,3
The depth of the ford to be overcome, m	1,8	1,8



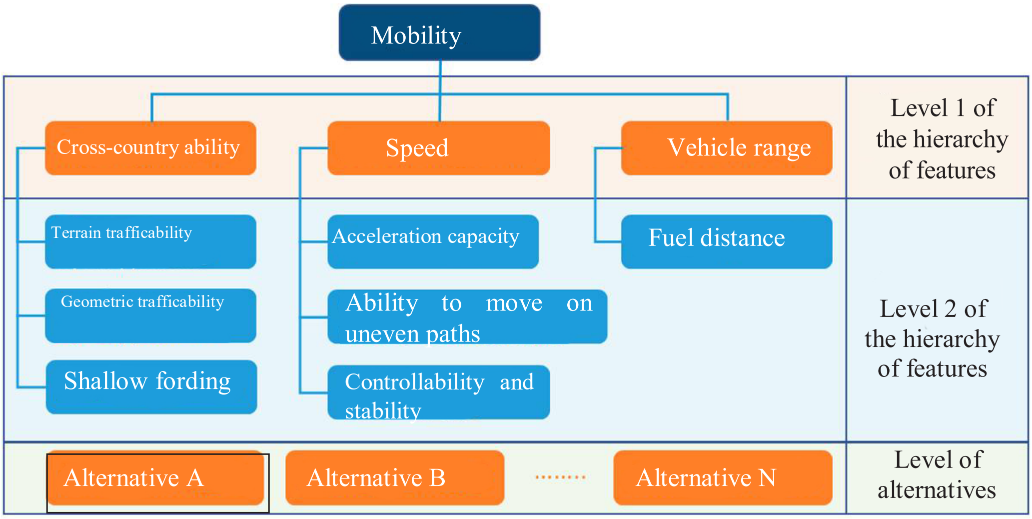
Pic. 10. Technical features of existing tracked road trains (compiled by the authors).

• The angle of the overcome climb for all considered tracked all-terrain vehicles takes on an almost constant value of at least 30 degrees.

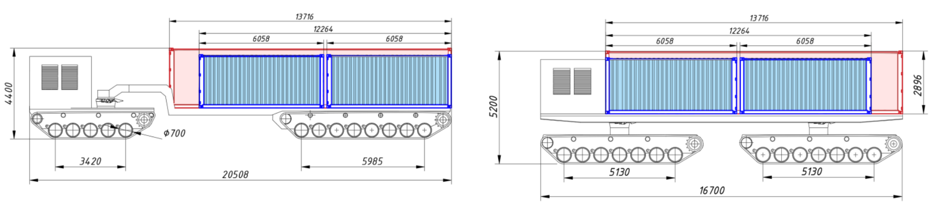
Solution to the Problem of Selecting Optimal Variant

When using tracked road trains for container transportation, it is economically expedient to transport containers using a single universal vehicle, which allows transporting a single 45-foot container or transporting two 20-foot containers. Thus, the vehicle's payload capacity is determined by the total gross weight of two 20-foot containers (61 t), and the overall dimensions of the loading platform should correspond to the dimensions of a 45-foot container. Of the described tracked all-terrain vehicles, only Yamal SVG-701 all-terrain vehicle, which is currently not produced, can provide such a payload capacity. The payload capacity of modern articulated tracked DT-30-1 and DT-30MN ATVs is 30 tonnes, thus the overall dimensions of the loading platform and their payload capacity allow transporting only a single 20-foot container. The considered foreign samples of tracked road trains also cannot provide the required payload capacity or are a defence object. Hence, the relevance of the task to determine a priority engineering solution for tracked road trains intended for container transportation and allowing transportation of one 45-foot container and of two 20-foot containers.

To solve the problem of determining the preferred version of the technical characteristics of a vehicle for off-road container transportation, we will use AHP. To build the hierarchy of



Pic. 11. Hierarchy of operational features of vehicles for container transportation (compiled by the authors).



Alternative «A» *Alternative «B»*

Pic. 12. Alternative versions of tracked vehicles for container transportation (compiled by the authors).

Table 6

Matrix of paired comparisons of criteria of the first level of the hierarchy (compiled by the authors)

Mobility	Cross-country ability	Speed	Vehicle range
Cross-country ability (K1)	1	5	3
Speed (K2)	1/5	1	1/3
Vehicle range (K3)	1/3	3	1

mobility (Pic. 11) [12], in accordance with AHP, we will compile tables of matrices of paired comparisons of criteria and alternative solutions using expert assessments made by the authors.

As compared alternatives, we will consider unmanned tracked road trains: a single-joint semi-trailer tracked road train (alternative «A») and a double-joint tracked road train (alternative «B»), the technical characteristics of which are considered and substantiated in [13]. The external view of the alternative versions of the considered tracked vehicles is shown in Pic. 12.

After expert assessment for the first upper level of the hierarchy, the matrix of paired comparisons will have the form shown in Table 6.

Also, matrices of pairwise comparisons according to criteria of the second level of the hierarchy are compiled and local priorities are determined. Matrices of paired comparisons for the criteria of the second level of the hierarchy are presented in Tables 7 and 8.

The local priorities of the fuel distance criterion (K3.1) will correspond to the local priorities of vehicle range criterion of the first level of the hierarchy.

For each matrix of paired comparisons of criteria, local priorities are determined, and then for the criteria of the lower level, global priorities are determined (Table 9), considering the local priorities of the criteria of the higher level of the hierarchy of properties.

Table 7

Matrix of paired comparisons as per cross-country ability criterion (compiled by the authors)

Cross-country ability	Terrain trafficability	Geometric trafficability	Shallow fording
Terrain (off-road) trafficability (K1.1)	1	3	3
Geometric trafficability (K1.2)	1/3	1	1
Shallow fording (K1.3)	1/3	1	1

Table 8

Matrix of paired comparisons of speed criterion (compiled by the authors)

Speed	Acceleration capacity (responsiveness)	Ability to move on uneven paths	Controllability and stability
Acceleration capacity (K2.1)	1	5	1/7
Ability to move on uneven paths (K2.2)	1/5	1	1/9
Controllability and stability (K2.3)	7	9	1

Table 9

Global priorities of the criteria of the lower level of the hierarchy (compiled by the authors)

Criterion	Priority
Terrain trafficability (K1.1)	0,382
Geometric trafficability (K1.2)	0,1275
Shallow fording (K1.3)	0,1275
Acceleration capacity (K2.1)	0,015
Ability to move on uneven paths (K2.2)	0,045
Controllability and stability (K2.3)	0,045
Fuel distance (K3.1)	0,258

Analysing the resulting vector of global priorities for the criteria of the lower level of the hierarchy, we can conclude that the priority criteria are the following (in the order of decrease in importance): terrain trafficability, fuel distance, geometric trafficability and shallow fording. The listed criteria to a greater extent affect the choice of a specific design of the vehicle in comparison with the others: acceleration capacity, controllability and stability and the ability to move on uneven paths. The defining criterion is terrain trafficability, which has a maximum priority of 0,382.

Similarly, for the considered vehicle's alternatives, considering expert judgment (qualitative assessment), a matrix of paired comparisons of alternatives was obtained and a vector of local priorities for each matrix was determined (Table 10).

To assess the adequacy of the results obtained, it is necessary to assess the consistency of the matrices of paired comparisons, which reflect subjective judgments, since the components included in them, as a rule, differ from the agreed values. A measure of the degree of deviation from consistency is the consistency index (Ic) [4], which is determined by the following expression:

$$Ic = \frac{\lambda_{max} - n}{n-1},$$

where λ_{max} – maximum eigenvalue of the considered pairwise comparison matrix, and n – dimension of the pairwise comparison matrix.

The consistency index is compared with a statistical random value called a random index (RI), which is obtained after processing a large number of matrices of different dimensions [3; 4]. Deviation from consistency is considered acceptable when the ratio of Ic to RI is less than 10 %. For the considered matrices of pairwise comparisons, the ratio of Ic to RI does not exceed 2,5 %, thus, the opinions of experts are considered consistent.

Further, based on the obtained global priorities of the criteria and local priorities of the alternatives, a hierarchical synthesis is carried out, as a result of which the global vector of the preference of the alternatives is determined, the results are shown in Table 11.

Thus, analysing the results obtained based on expert judgment, it can be established that the priority engineering solution is a saddle double-jointed tracked road train, however, given the insignificant difference in the values of the global priority vector, further research is needed to determine the values of feature indicators and to reassess it, considering the results obtained. Obviously, comparative assessment of the effectiveness of design of tracked road trains for newly developed vehicles is not possible without

Table 10

Matrices of pairwise comparisons of alternatives and the vector of their local priorities (compiled by the authors)

			Priority vector				Priority vector
K1.1	A	B		K2.1	A	B	
A	1	1	0,5	A	1	1	0,5
B	1	1	0,5	B	1	1	0,5
K1.2	A	B		K2.2	A	B	
A	1	1/3	0,25	A	1	1	0,5
B	3	1	0,75	B	1	1	0,5
K1.3	A	B		K2.3	A	B	
A	1	1/5	0,17	A	1	5	0,83
B	5	1	0,83	B	1/5	1	0,17
K3.1	A	B					
A	1	1	0,5				
B	1	1	0,5				

mathematical simulation of work processes using a computer [17; 18]. Also, to solve the presented problem, a complex of full-scale mathematical modelling can be effectively used, which makes it possible to simulate movement of vehicles along statistically specified routes under the control of a «driver-operator» who is at a computer in «real time».

Thus, comparison of various design and layout options for tracked road trains for off-road container transportation consists of the following stages:

• Development of a hierarchy of operational features further divided into criteria tiers.

• Identification of alternatives based on the analysis of structural and layout designs.

• Expert assessment of alternative options using the analytic hierarchy process; selection of alternatives.

• Determination of indicators of features for the selected alternative options by methods of mathematical simulation (full-scale mathematical modelling).

• Choice of the priority engineering solution, considering the results obtained during simulation of mathematical modelling (full-scale mathematical modelling).

CONCLUSIONS

Following the analysis of design and layout of existing tracked road trains, dependencies were found that reflect the change in the main technical characteristics associated with the required payload capacity of the vehicle. Of the presented tracked all-terrain vehicles, only Yamal SVG-701 all-terrain vehicle, which is not currently manufactured, can provide such a payload capacity. Existing tracked all-terrain vehicles cannot provide the required carrying capacity, therefore, based on the analysis results, requirements were developed for technical characteristics of vehicles intended for transportation of one 45-foot container or two 20-foot containers. Based on the hierarchy of operational features of unmanned tracked road trains intended for off-road container transportation, and the opinions of experts, it was established through the analysis of hierarchies that the priority engineering solution is a saddle double-jointed tracked road train, but due to the insignificant difference in the values of assessed global priorities for tracked road trains, further studies are required to determine the values of indicators of features using mathematical modelling of the working processes of tracked road trains and its re-evaluation, considering the results obtained.

Table 11

Global priorities of alternatives (compiled by the authors)

Alternative	Priority
«A»	0,44
«B»	0,56

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