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Evaluation of Military Logistics Vehicles in Public Procurement

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Abstract:

The current geopolitical situation in the Europe is forcing some countries to modernize the equipment and armaments of their armies and to prepare for response to potential threats. It is difficult to assess the advantageousness and quality of military logistics vehicles to be purchased when there are different perceptions of the functionality of the product among future users, and in particular when the quality assessment tools are not perfect and the available and statutory quality assessment tools are hardly used in tendering procedures. This article presents the methodology for the evaluation of military logistics vehicles in public procurement. The proposed methodology allows comparing military logistics vehicles on the basis of economic and technical criteria and assessing the needs of different users.

Keywords:

evaluation criteria, military logistics vehicles, public procurement

1 Introduction

Public procurement conducted by public authorities is aimed at purchasing goods, services or works from the supplier selected through tendering procedure. The procurement procedure is inherently complex and requires the knowledge of both legal framework and of the object to be purchased, in order to avoid legal disputes and to acquire the right service, goods or work. Procurement of military equipment requires a very careful preparation of procurement documents, as it is a long-term and costly procurement. Specifications must therefore be drawn up with the utmost care and by

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specialists who are well versed in the field, and the tendering procedures themselves must be legally sound and carried out in compliance with the law which provides for and defines the specificities of the procurement of such equipment [1] so that the acquisition of military equipment is not disrupted by legal disputes. It should be noted that procurement takes into account many factors that are sometimes very difficult to reconcile, and the result is not necessarily of the highest quality. The purchase must not only be of good quality, but must also be acquired as required by law, using allocated funds in a rational way. The price of the purchase is of great importance as it is the dominant evaluation criterion in public procurement. Although the law also provides for quality assessment tools in public procurement procedures, they are not yet widely used. This is probably due to doubts about whether quality can be objectively assessed. However, Garvin argues that quality is an objectively measurable value that indicates the conformity of parameters of an object with predefined requirements that meet the needs of the user [1]. However, when there is more than one user and their expectations of the quality and functionality of the object may differ, the quality criterion becomes a particular challenge for public procurement. In addition, the evaluation of the purchase still needs to measure the quality-price ratio properly, in order not to violate the principles, requirements and objectives laid down by laws.

One of the main reasons for writing this paper is corruption in public administration as discussed in the publication [2] which presents ways to eliminate corruption in public administration in the construction industry in China. Another source for writing this paper is a study [3] that was conducted to determine the factors influencing tendering in public institutions in Kenya. This study is aimed at assessing various factors affecting the implementation of open tendering in order to improve its utilization and performance. The study focused on the ways how various public institutions chose different procurement processes over open tendering. The data collection tool was a self-administered questionnaire with the support of research assistants. The data collected were analyzed using descriptive statistics and inferential statistics, namely Pearson Product Moment Correlation and T-test and they were presented by the use of tables. The studies [3] and [4] show that strict public procurement procedures are needed as well as adequate staff training to improve practices in procurement and to create efficiency in the tendering process. The extensive study [5], which deals with large-scale IT implementation, initiates the interactive development of the system and the adaptation of the system to the specific needs of the organization after the tender process. In the tender process, the contracting authority defines the usability requirements, evaluation procedures and selection criteria. Whereas IT vendors strive to create and design solutions that best meet these requirements. The above usability analysis shows the contracting authority how the requirements should be incorporated into the design to ensure the usability of the selected system.

According to [6] , tendering is usually used by governments and companies to purchase goods or services from manufacturing companies or service providers. According to this article, e-tendering is the most commonly used method of public procurement and therefore there are various security implications. This paper explores how smart contracts (based on the Ethereum blockchain) can be used to design a distributed e-tendering system. The main objective [6] is to establish a fair, transparent and open tender process.

As a first step before acquiring a military logistics vehicle, contracting authorities need to prepare the operational requirements documents in accordance with the descriptions of procedure for the preparation, coordination and approval of the operational requirements documents [8]. Operational requirements are specified in the Operational Requirements Document (ORD), on the basis of which more detailed technical requirements – technical specifications – are developed. According to the Description of Procedure, the ORDs are usually prepared in three stages. In the first stage, the content and the type of military logistics vehicle are identified, the justification for the need to acquire the vehicle is stated and the most appropriate military logistics vehicle is specified. The second stage sets out the minimum parameters that reveal the capabilities and characteristics of the offered military equipment. Finally, at the last stage, the essential functional requirements are identified, which, if not met, render the offered vehicle unusable. The assessment and justification of implementation of the operational requirements is carried out in the light of market analysis. This reflects the range of choices for a given vehicle, indicative prices, etc. Possible options that are used for similar tasks in the North Atlantic Treaty Organization (NATO) or in the European Union MS are presented. Thus, to some extent, the aim to ensure quality starts at the very early stages of purchase process.

According to national public procurement laws, a technical specification is a document describing the characteristics of the goods, services or works to be purchased. Technical specifications drawn up are an integral part of procurement documents. The Supplier and their proposed product must comply with the qualification and technical requirements set out in the procurement documents and any other conditions imposed by the contracting authority. In order to ensure that the tendering procedure is fair and organized on equal terms and conditions for all potential tenderers, technical specifications are drafted in accordance with the principles regulated by the Law on Public Procurement in the Field of Defence and Security (hereinafter – the LPP), namely: equal treatment, non-discrimination, transparency, mutual recognition and proportionality.

Mere compliance with the requirements of the technical specifications cannot determine the choice of a particular product in a tendering procedure. For this reason, the criteria for the evaluation of tenders are used. The selection of the evaluation criterion dictates the procedures for evaluating the suppliers' tenders – the criteria against which they will be compared, etc. The criterion used to compare and evaluate the tendered objects determines how well the expectations of the contracting authority will be met. The inclusion of quality criteria in the comparison increases the likelihood of obtaining a better quality product than that guaranteed by technical specifications.

The contracting authority evaluates tenders on the basis of the following criteria:

- the lowest purchase price,
- the most economically advantageous tender.

Thus, tenders in public procurement may be evaluated on the basis of one of the two criteria. The selected criterion and technical specifications are communicated to suppliers in procurement documents before the start of the tendering procedure.

The lowest purchase price criterion has a number of weaknesses as it does not assess the cost-effectiveness, socio-economic benefits and life-cycle costs of the object to be procured and is therefore not appropriate for more technically complex purchases. Looking only at the acquisition cost of tenders, there is a risk of buying the cheapest product, which will satisfy only minimum technical requirements (as defined in technical specifications) and will have higher operating costs than a more expensive product that might be purchased at a higher price. This can lead to a financially unjustified and loss-making decision.

When the evaluation criterion of economic advantageousness of the tender is chosen for military logistics vehicles to be procured, not only the price but also the life-cycle costs are taken into account. This criterion can also be used to assess the relevance of technical characteristics in relation to the needs of potential users. Therefore, depending on the quality of drafting of the evaluation methodology and the sub-criteria selected for quality assessment, the contracting authority will be able to acquire a product with a significantly better quality-price ratio by using this criterion in the context of public procurement procedure than it would acquire by relying solely on the lowest price criterion. If a product is purchased at the lowest price, without taking into account its life-cycle costs, it can hardly be considered the one of the main objectives of the LPP, namely to purchase a product through rational use of funds allocated to it, i.e. using the funds allocated for that purpose in a reasonable manner, has been met. It should be noted that the criteria for evaluating a tender for a public procurement in the field of defense and security are defined in the Guidelines for the evaluation of public procurement tenders by using the most economically advantageous tender or the lowest price criterion.

2 Criteria for Assessing Technical Characteristics of the Military Logistics Vehicles to Be Purchased

The indicators of the evaluation criteria for military logistics vehicles to be purchased should be divided into three main categories of criteria for the product to be purchased:

- the lowest purchase price military logistics vehicles,
- the lowest life cycle costs of the military logistics vehicles,
- and technical functionality of the military logistics vehicles, which can be divided into:
    - the mobility,
    - the ballistic protection,
    - the camouflage and other protection criteria,
    - the operating environment.

2.1 Criterion of the Lowest Purchase Price – C_P

The purchase price C_P is used to value certain assets, especially assets acquired. It means the price at which the property was acquired and the costs associated with its management (the purchase price is equal to the sum of the acquisition price and ancillary financial costs). The acquisition costs of related assets are not exhaustively defined and may be shown according to specific fixed assets, others may be for tangible fixed assets and intangible assets, others for inventories.

2.2 Criterion of the Lowest Life Cycle Costs – LCC

At present, almost every user evaluates, selects, and assesses products not only in terms of real utility value but also in terms of both the acquisition cost of the product, and mainly the cost of ownership. Various economic analyses are used to clearly illustrate and quantify the required expenditures. In recent years, the product life cycle cost analysis has been used. When deciding to buy a product, a number of factors is considered; they are related not only to costs but also to reliability. It must not be forgotten that the basic aim should be to achieve customer satisfaction. The product is required to ensure proper reliability and life cycle costs to be as low as possible (optimal – not necessarily the lowest cost). At the same time, the product must perform its function safely without undue impact on the environment and the operation. The purchase of a product is determined not only by the initial costs (acquisition), as is sometimes perceived but also by the expected ownership costs, which are operating costs and maintenance costs for the entire life of the product. Last but not least, the costs of the settlement (disposal) must not be neglected [9].

Life cycle cost analysis is the process of economic analysis to assess the total cost of acquisition, ownership and settlement (disposal) of a product. It can be used throughout the product life cycle, or in some parts, or in a combination of different life cycle stages. The basic goal of life cycle cost analysis is to provide input data for decisions made at any stage, or at all stages of the life cycle [9].

The general product requirements are:

- product readiness,
- minimal life cycle costs while ensuring product readiness and customer needs,
- safe operation without undue impact on the environment,
- easy maintainability over the lifetime [9].

Fig. 1 presents the incurred costs that may arise within the product life cycle. It can be seen from the above that the costs of LCC are most affected in the first stages of the life cycle. According to Fig. 1, this can be up to 50 %, which is not realistic in practice. On the contrary, during production and operation by the user, it can be only 5 %. The figure also shows that around 72 % are operating, maintenance and disposal costs, depending on the type of product.

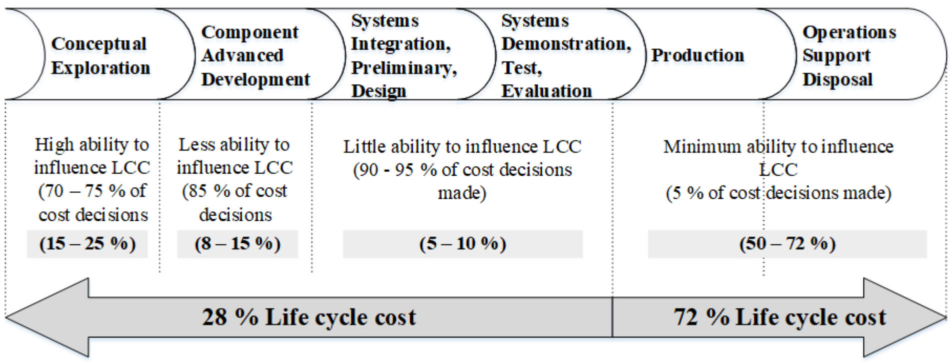

Fig. 1 Costs incurred and committed during the life cycle acquisition process [9]

In general, life-cycle costs are divided into the following five areas [10]:

- costs of concept period – CC, } purchase costs,
- costs of design and development period – CDD, } purchase costs,
- costs of manufacture and installation period – CMI, } purchase costs,
- costs of operating state and maintenance period – COM, ownership costs,
- costs of disposal period – CD, liquidation costs.

In general, the life cycle costs of *LCC* can be expressed by the following equations

$$LCC = C_{\mathrm{P}} + C_{\mathrm{OW}} + C_{\mathrm{D}} \tag{1}$$

where C_{P} – the military logistics vehicle purchase cost, C_{OW} – ownership costs for operating of the military logistics vehicle and C_{D} – the military logistics vehicle disposal cost.

We adjusted relation (1) for the calculation of life cycle costs to the following final form

$$\begin{aligned} LCC = {} & C_{\mathrm{P}} + \frac{c_{\mathrm{aF}}}{100} p_{\mathrm{F}} t_{\mathrm{l}} + \frac{c_{\mathrm{aOL}}}{100} p_{\mathrm{OL}} t_{\mathrm{l}} + \frac{t_{\mathrm{l}}}{\overline{d}_{\mathrm{aT}}} n_{\mathrm{T}} p_{\mathrm{T}} + \frac{t_{\mathrm{l}}}{\overline{d}_{\mathrm{aAB}}} n_{\mathrm{AB}} p_{\mathrm{AB}} + C_{\mathrm{SI}} t_{\mathrm{la}} + \\ & + \left(C_{\mathrm{E}} + C_{\mathrm{TC}}\right) \frac{y_{\mathrm{n}}}{t_{\mathrm{la}}} + \frac{t_{\mathrm{l}}}{MTBF} \left(\overline{c}_{\mathrm{m}} + \overline{c}_{\mathrm{p}} \overline{t}_{\mathrm{pc}}\right) + \frac{t_{\mathrm{l}}}{MTBM_{\mathrm{p}}} \left(C_{\mathrm{OMPM}} + \overline{c}_{\mathrm{p}} \overline{t}_{\mathrm{pm}}\right) + C_{\mathrm{D}} \end{aligned} \tag{2}$$

where $\overline{c}_{\mathrm{aF}}$ – the average fuel consumption [l/100 km], p_{F} – the fuel price [EUR/l], t_{l} – the service life of a military logistics vehicle [km], $\overline{c}_{aOL}$ – the average consumption of oil and lubricant [l/100 km], p_{OL} – the price of oil and lubricant [EUR/l], $\overline{d}_{\mathrm{aT}}$ – the average life of a tactical vehicle tyre [km], n_{t} – the number of tyres on the tactical vehicle [pc], p_{T} – the price of one piece of tyre [EUR], $\overline{d}_{\mathrm{aB}}$ – the average life of one accumulator battery [km], n_{AB} – the number of accumulator batteries in the military logistics vehicle [pc], p_{AB} – the price of an accumulator battery [EUR], C_{S1} – the price of mandatory annual insurance of a military logistics vehicle [EUR], t_{la} – the operating time of the military logistics vehicle until decommissioning [years], C_{E} – the costs related to the measurement of military logistics vehicle emissions [EUR], C_{TC} – the costs of mandatory technical inspection [EUR], y_{n} – the number of years of legal validity of emission measurement and technical condition for the given type of the military logistics vehicle [years], $MTBF$ – the mean time of operation between failures [km], $\overline{c}_{\mathrm{m}}$ – the average cost of material for repairing a failure [EUR], $\overline{c}_{\mathrm{p}}$ – the average hourly cost of labor and workshop equipment used for maintenance [EUR/hour], $\overline{t}_{\mathrm{pc}}$ – the mean time of labor-intensity for repairing a failure [hours], $MTBM_{\mathrm{p}}$ – the mean operating time between preventive maintenances [km], C_{MPM} – the costs of material used for preventive maintenance [EUR], $\overline{c}_{\mathrm{p}}$ – the average hourly cost of labor and workshop equipment used for maintenance [EUR/hour], $\overline{t}_{\mathrm{pm}}$ – the mean time of labour-intensity per one preventive maintenance [hour] [11]. $MTBF$, $\overline{c}_{\mathrm{m}}$, $\overline{c}_{\mathrm{p}}$, $\overline{c}_{\mathrm{m}}$, $\overline{c}_{\mathrm{p}}$, $\overline{t}_{\mathrm{pc}}$, $MTBM_{\mathrm{p}}$, C_{MPM}, $\overline{c}_{\mathrm{p}}$ and $\overline{t}_{\mathrm{pm}}$ will be supplied by the manufacturer or supplier of military logistics vehicle.

In this way, the cumulative costs for each passenger motor vehicle are calculated. Since the passenger motor vehicles may have a different service life t_{l} which is expressed in kilometers, it is recommended to convert this equation to specific costs which are related to one kilometer of use. The selected LCC_{S} life cycle specific costs can be expressed by the following equation [11]

$$LCC_{\mathrm{S}} = \frac{LCC}{t_{\mathrm{l}}} \tag{3}$$

2.3 Criterion of the Technical Functionality T

Mobility Criterion

The vehicle's mobility assessment is based on the six important components underpinning it, which are performance capability, terrain passability, maneuverability, overcoming of obstacles and evacuation functionality. Based on their data, conclusions can be drawn about the mobility and operational capability of specific vehicles in different circumstances.

a) Performance Capability of the Military Logistics Vehicles

The main mobility factors are engine power and vehicle weight. From these parameters, the engine power-to-weight ratio of the military logistics vehicle can be calculated.

$$PWR = \frac{P}{WT} \tag{4}$$

where *PWR* – engine power-to-weight ratio [W/kg], *P* – engine power [W] and *WT* – weight [kg].

The chassis must be designed so as to withstand the increased gross weight of the military logistics vehicle, while its engine must have enough power to prevent the vehicle from losing traction and mobility. As military equipment is usually purchased for a long term, this parameter is particularly important because the future development and improvement of the equipment will depend on the level of this parameter. The higher payload adds flexibility in upgrading the existing platform according to its operational nature or simply according to one's needs. Additional armor, equipment, and armament systems are just some elements that can be applied by upgrading the vehicle with the payload available for that. This can be expressed as a ratio of the payload to the vehicle-specific weight.

This parameter is basic, but in order to transfer the stated mass power of the engine, it is necessary to ensure the transmission of power to the wheels and subsequently to the diverse terrain.

b) Terrain Passability of Military Logistics Vehicles

It is necessary to calculate the performance indicator of the wheeled vehicle – ground pressure. However, there are other factors (traction, transmission type, etc.) of importance for the total performance capability of a military logistics vehicle. There are many methodologies for combining these factors and calculating the indicators of performance capability; however, over the years, only a few reliable methodologies have been established in the army according to which theoretical evaluations of vehicles are carried out and their expected passability is predicted. This article focuses on the analysis of the performance capability evaluation indicators – Vehicle Cone Index (*VCI*) and Mean Maximum Pressure (MMP) used by the Americans and the British. In addition to these vehicle performance capability indicators, other criteria should also be distinguished that describe the vehicle's adaptability to a given operating environment, and one of such other criteria being tyre chains. If they are included in the offered vehicle's delivery scope, it is a major advantage in winter. Data on the contact surface area of wheels and the Nominal Ground Pressure are also important. It is even better if the vehicle is equipped with a Central Tyre Inflation System.

The *VCI* indicator is derived through empirical calculations on the basis of readings from a penetrometer that measures strength and resistance of soil to penetration, permeability, deformation and the vehicle's components. A cone penetrometer is a tool for determining soil cone index. According to the American methodology, the Cone Index (CI) is nothing more than the expression of force required for pushing the penetrometer's cone-shaped tip into the ground [12]. It shows the resistance of the measured soil surface to compression and deformation – soil strength. Engineers have linked the expression of this indicator to the *VCI*.

Correlations found allow comparing the indices of interacting vehicles and soil surface. The comparison allows drawing conclusions about the capability of a given vehicle to travel over a given soil surface. To calculate the *VCI*, the vehicle's mobility index (MI) is determined using the following formula [12]:

$$MI = \left(\frac{KF \cdot SF}{FF \cdot GF} + RF - PF \right) \cdot VF \cdot TF \tag{5}$$

where *KF* – the contact pressure factor, *SF* – the vehicle weight factor, *GF* – the wheels protection factor, *RF* – the wheels load factor, *PF* – the clearance factor, *FF* – the tyres factor, *VF* – the engine factor, *TF* – the transmission factor. Eq. (5) shows that the mobility index for wheeled vehicles covers practically all indicators related to the passability of the vehicle. Each of the above listed factors is also calculated individually according to [12]. When the vehicle's mobility index is known, the cone index can also be obtained. The wheeled vehicles' *VCI* is calculated according to the following formulae:

$$VCI_1 = 11.48 + 0.2MI - \frac{39.2}{MI + 3.74} \tag{6}$$

$$VCI_{50} = 28.23 + 0.43MI - \frac{92.67}{MI + 3.67} \tag{7}$$

As a standard, the *VCI* is calculated for one pass – VCI_1 and for fifty passes – VCI_{50}. The higher the *VCI* value, the worse the vehicle's performance capability [12].

To find out the vehicle's ability to pass over a given terrain, its *VCI* just has to be compared with the Rating Cone Index (RCI) of soil. The cone index under assessment is the product of the aforementioned cone index and the deformation index [13]. The *VCI* allows not only to estimate the possibility of a single pass for a single vehicle, but also to predict the number of passes by the given vehicle on the same terrain.

Another important criterion is the Central Tyre Inflation system (CTI). The CTI allows adjusting the pressure of each tyre without leaving the driver's cab. Some CTI systems are automated, which means that they automatically adjust the optimum tyre pressure when travelling on terrain of varying hardness. The CTI system can increase the vehicle's performance capability by reducing the MMP and *VCI* by around 10 % [14]. In the event of minor tyre damage, the tyre does not flatten so quickly because of automatic pressure maintenance, which substantially prolongs the vehicle's travel on wheels with minor damages. Other technologies are also available to ensure continuity of the vehicle's travel with damaged tyres. In regions where punctures of tyres are likely, it is advisable to choose a vehicle with Run-Flat tyres. The vehicle can travel with such tyres even when they are completely deflated [16, [16].

c) Maneuverability of the Military Logistics Vehicles

Maneuverability is the capability of military logistics vehicles to quickly change speed and direction [17]. The following maneuverability parameters are relevant for the comparison of the offered military logistics vehicles: speed, acceleration time, turning radius, power-to-weight ratio.

There are three main indicators defining speed as maximum speed, maximum reverse speed, minimum speed. All these measures are relevant depending on the nature of the task or operation for which the particular military logistics vehicle will be used. Looking for a versatile vehicle that meets a wide range of tasks in the army requires the appropriate ratio between the following values.

The turning radius of the vehicle is significant in urban battles. Larger areas suitable for turning are not common in towns. For this reason, a smaller turning radius is required. The weight-to-power ratio is the indicator calculated dividing the vehicle's weight by its power. As modern military logistics vehicles tend to become heavier due to thicker armor and additional equipment, it is not surprising that this value is widely used to evaluate and compare the mobility of vehicles.

d) Overcoming Obstacles with Military Logistics Vehicles

According to the NATO standard STANAG 4357 [18], military logistics vehicles are tested by overcoming specific obstacles [18]. The obstacle clearance capability indicators used in the assessment of the vehicle's mobility are vertical obstacle, water obstacle, lateral angle of inclination, trench, uphill, and downhill clearance. Indicators of the capability to overcome the identified obstacles are probably the most commonly used to describe, evaluate or compare the mobility of specific vehicles for warfare. The factors influencing the overcoming of obstacles can be explained in terms of geometric parameters of the specific vehicle.

Some of the geometric parameters of the vehicle that directly affect the overcoming of these obstacles are clearance, front and rear protrusion, front and rear approach angles, longitudinal passability radius, maximum lift angle, maximum inclination angle, transverse passability angle [16].

The longitudinal passability angle is expressed as the maximum value in degrees, at which a vehicle can drive downhill to a flat spot without hitting the bottom. The value is dependent on the wheel base length. The vehicle's clearance is one of the main criteria for overcoming obstacles. This is a geometric parameter of the vehicle that becomes particularly relevant when driving on very rough terrain with many single obstacles which may be hit by the bottom of the vehicle. The clearance is a distance between the supporting surface and the lowest point of the vehicle's body. However, it should be emphasized that the size of this parameter alone does not determine the capability of the vehicle to overcome obstacles on the road. The correlation with other mobility parameters is necessary. Therefore, high clearance will be useless if the vehicle has a small axle track and rolls over on its side when moving transversely downhill or hits a steep hill with its too-long front end before starting to move uphill. The interaction between the clearance value and the vehicle's base and axle track is essential for all-terrain vehicles. The interaction of these three structural dimensions is one of the main factors determining the given vehicle's capability to overcome obstacles. Another important parameter for travelling across uneven terrain (uphill, downhill) is a transverse passage angle or lateral inclination angle. This parameter describes the uphill steepness that causes the military logistics vehicle to lose its static or dynamic balance. It depends on the military logistics vehicle's center of mass and axle track length. The capability of the vehicle to maintain static and dynamic balance depends on its design parameters, the center of gravity. Basically, the narrower it is and the higher the center of gravity, the greater is the risk of rollover – the lateral slope crossing angle is smaller.

Stability factor of a military logistics vehicle. According to the extensive statistical study of vehicle accidents by [19], the probability P_R of rollover versus non-rollover for a car involved in an accident is mostly determined by the static stability factor, and it can be given as

$$P_R = \frac{100}{1 + S_S^{6.9}} \tag{8}$$

where S_s – the static stability factor, which is calculated as follows

$$S_S = \frac{T}{2h} \tag{9}$$

where T – the track width, h – the center of mass.

Modern military logistics vehicles are adapted to overcome water obstacles (hereafter – wading), which is one of the important indicators taken into account when analyzing the vehicle's obstacle overcoming criteria. The wading depth to be overcome and whether water crossing requires prior preparation of the vehicle are of high importance. If the preparation is required, this must be taken into account. The time and resources required for the preparation and whether the need for the preparation will interfere with the tasks for which the vehicle is intended to be used should be considered.

e) Maximum Mileage of Military Logistics Vehicles

It is the number of kilometers driven per full tank. The criterion taken into account when assessing the vehicle's mobility is its maximum mileage. Mileage indicates the distance a vehicle can travel on a full fuel tank. This indicator is relevant depending on the intended use of the vehicle to be purchased. A higher mileage will always be an advantage during operations, but in the case of acquisition support vehicles (trucks) to be used only during exercises this indicator will not be relevant.

f) Evacuation of Military Logistics Vehicles

Evacuation is the last mobility criterion defining the ability to evacuate a vehicle and to control it during evacuation. As army vehicles are also used in missions, it is not possible to predict when a vehicle may have to be evacuated for mine explosion or other reasons. A vehicle that can be towed off-road without dismantling or modifying its structure always has an advantage over a vehicle that can only be towed on conventional roads and needs dismantling and modifying its structure, which is time consuming. The timing during an operation can be a decisive factor. The situations when a vehicle gets stuck and there is simply no one to pull it out are also frequent. This is where a winch can come in handy. With the winch mechanism, the vehicle can pull itself out of an unfavorable situation. It is important that the winch included in the vehicle has sufficient power.

Ballistic protection

Ballistic and mine protection criteria are regulated by the relevant NATO standard STANAG 4569 [20]. Ballistic protection is divided into six levels. Each level represents the armor resistance to the respective threat. The higher the level, the more threats the vehicle can withstand. A vehicle with protection level B6 can withstand an artillery shell exploding within a radius of 10 m, while a vehicle with protection level B1 can withstand only a shell of the same caliber exploding at a distance ten times greater. Often, a high level of protection implies much higher weight of the vehicle, which will substantially reduce the vehicle's mobility capabilities and growth potential.

Mine protection. There are four levels of mine protection. Each level, except the first (general), is further subdivided into two different levels. One of these levels marked with "b", represents the armor resistance to explosives under the bottom of the vehicle. The level marked with "a" indicates the vehicle's resistance to explosion of contact mines under its wheels or tracks.

Camouflage and Other Protection Criteria

Another important component of protection is camouflage. The less visible you are, the less likely you are to be targeted on battlefield. The dimensions and noise emission level are decisive in addressing the issue of inconspicuousness. A big target is a good target. The dimensions of military logistics vehicles should be as small as possible, depending on the tasks for which they will be purchased. The vehicle's body armor does not always compensate for extra centimeters of volume on the account of dimensions. For this reason, it is necessary to seek the best possible balance between the vehicle's dimensions and armor.

The three above discussed protection criteria relate not only to external threats but also to safety of the crew inside the vehicle body, such as an automated or manual internal fire extinguishing system, the reliability and functionality of seat belts. If the level of protection according to the NATO standard (STANAG 4569) is not sufficiently high, the following indicators are also relevant: the possibility to attach a net to detonate the cumulative charge before it reaches the body of the vehicle, the possibility to install active armor, the internal spall liner and laser warning system, which is particularly useful when hostile forces use laser-guided missiles [20]. Protection against radiological, nuclear, chemical and biological weapons is also of great importance.

Operating Environment

The assessment of the operating environment takes into account the suitability of the vehicle to operate in cold and hot climates, as well as on mountainous terrain. The climatic zones were regulated until 2001 by STANAG 2895. It is appropriate to judge the vehicle's operating environment from the minimum hot-cold climatic zones, because the climatic zone reflects not only the maximum or minimum possible temperature expression, but also other factors (humidity, dryness, dustiness, etc.) that may influence the operation of the vehicle's mechanisms. Challenging operating conditions typically include cold temperatures, deep snow cover, frequent snowstorms and snowdrifts. Other conditions in which vehicles' ability to function is assessed cover hot climate desert areas with poorly developed road networks, lack of forest plantations and water, increased air dustiness, high daily temperature variations; mountainous areas with thinned air and low atmospheric pressure; highly variable terrain; off-road and extent of deterioration of roads. High humidity of the region is also attributed to the challenging operating conditions for engines [21].

For cold and warm weather operations, it is important that the vehicle is fitted with appliances (heater, air conditioner) of sufficient power to maintain an optimum temperature in the cabin to keep the crew comfortable when needed. It is also important to consider the capacity of the engine heater and the minimum temperature at which the engine can be started without warming up.

Temperature variations can cause problems not only for the health of the crew but also for the functioning of the vehicle: in hot weather the service time of batteries is shorter; electronic equipment, such as electronic control unit, can get overheated and become unreliable or simply stop working; hot weather is also harmful to rubber [22]. As a consequence, the vehicle's tyres can become more prone to damage.

Requirements for electrical equipment of a vehicle. The evaluation of the electrical equipment covers three equipment characteristics – the generator power, the total power of all batteries and the nominal voltage.

The nominal voltage level determines the range of applications of electrical equipment. In the USA and many neighboring European countries, the armies have adopted 24 V nominal voltage for military equipment. The best performance is achieved by vehicles supporting several nominal voltages.

The power of the generator is a parameter that is becoming more and more relevant. As more electronic devices (monitors, radios, etc.) are used in modern vehicles, higher power generators are needed to produce the necessary amount of electricity to keep running all devices used by the crew. For this reason, higher power generators have been integrated into the vehicles.

For day or night-time tasks, it is important that the crew's equipment remains operational when the engine is off. This is where batteries come into play. In modern military logistics vehicles, it is common to have several main and auxiliary batteries to maintain the functionality of the vehicle when the engine is off.

3 Use of Multi-Criteria Analysis for Ranking Military Logistics Vehicles in Public Procurement

We recommend the use of multi-criteria analysis to determine the ranking in the selection procedure in each sub-category for the assessment of technical characteristics of motor vehicles. Metfessel allocation, Compensation method, Scoring method, Fuller method, PRIAM method, ORESTE, ELECTRE, PROMETHEE, AHP and Saaty method can be used for multi-criteria analysis [23]. This method compares the preferential relationships of the criteria pairs arranged in the Saaty table. However, unlike Fuller's method, in addition to the criteria preference itself, the size of this preference is also determined, i.e. not only if one variant is better than the other, but also how much better it is. In Saaty's method, the degree of criteria preference can be taken into account. Therefore, we propose to use Saaty's method for the evaluation of the selection of a military logistics vehicle, which seems to be the most appropriate.

The Saaty method is used to determine the weights of criteria v_i and v_j which is performed in two steps. First, the matrix of preference intensities S is determined. The elements of the matrix S, which we denote as *(i*-th row, *j*-th column), are obtained by finding the number of how many times the criterion K_i is more significant than the criterion K_j if it holds that K_i is more significant or as significant as K_j. This ratio of the significance of the two criteria, which is expressed by the elements s_{ij}, can also be interpreted as the ratio of their weights:

$$s_{ij} = \frac{v_i}{v_j} \quad i, j = 1, 2, 3, \ldots, m \tag{10}$$

Based on how many times the criterion K_i is more significant than K_j, the numbers from 1 to 9, the meaning of which is given in Tab. 1 [26-29] are assigned to the elements s_{ij} of the matrix of preference intensities S.

If K_j is more significant than K_i, the elements of s_{ij} are determined as follows:

$$s_{ij} = \frac{1}{s_{ji}} \tag{11}$$

If the criterion K_i is s_{ij}-times more significant than the criterion K_j, then the significance of the criterion K_i is $1/s_{ij}$-th of the significance of the criterion K_i. If relation (11) holds for all elements of the matrix S, then the matrix S is reciprocal.

Tab. 1 Language descriptors

Weight	Descriptor
1	The elements are equally important
2	The row element is very slightly more significant than the column element
3	The row element is slightly more significant than the column element
4	The row element is quite a bit more significant than the column element
5	The row element is far more significant than the column element
6	The row element is almost demonstratively more significant than the column element
7	The row element is demonstratively more significant than the column element
8	The row element is much more significant than the column element
9	The row element is totally more significant than the column element

The second step is to determine the weights based on the knowledge of the matrix *S*, for which several procedures can be used, such as determining the eigenvector corresponding to the maximum eigenvalue of the preference intensity matrix *S* or the least squares method that minimizes the expression [24]:

$$D=\sum_{i=j}^{m}\sum_{j=1}^{m}\left(s_{ij}-\frac{v_i}{v_j}\right)^2 \tag{12}$$

on the condition

$$\sum_{i=1}^{m} v_i = 1 \tag{13}$$

To calculate the weights of the criteria using the Saaty method, a procedure working with the geometric mean will be applied to the matrix *S* [24]:

$$S=\begin{pmatrix} 1 & s_{12} & \cdots & s_{1j} \\ s_{21} & 1 & \cdots & s_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ s_{i1} & s_{i2} & \cdots & 1 \end{pmatrix} \tag{14}$$

To determine the weights, Saaty proposed several methods by which the weights v_j can be estimated. The most commonly used procedure is to calculate the weights as the normalized geometric mean of the rows of the Saaty matrix (the logarithmic least squares method). The values of b_i are calculated as the geometric mean of the rows of the Saaty matrix [24]

$$b_i=\sqrt[n]{\prod_{j=1}^{n} s_{ij}} \tag{15}$$

The weights are then calculated by normalizing the b_i

$$v_i = \frac{b_i}{\sum_{i=1}^{n} b_i} \qquad (16)$$

Saaty's method can be used not only to determine the preference between criteria, but also between variants.

The matrix is square of order $n \times n$ and expresses an estimate of the proportions of the weights of the i-th and j-th criteria. There are always values of one on the diagonal of the Saaty matrix (each criterion is equivalent to itself). The degree of consistency is measured, for example, by the consistency index, which Saaty defined as [24]:

$$C_{\mathrm{I}} = \frac{\lambda_{\max} - n}{n-1} \qquad (17)$$

where $\lambda_{\max}$ is the largest eigenvalue of the Saaty matrix and n is the number of criteria.

To check the validity of the table, the consistency ratio C_{R} must be calculated according to (18). To calculate the C_{R}, the variable consistency index C_{I} according to (17), the random index R_{I} and the largest eigenvalue of the matrix ($\lambda_{\max}$) must also be calculated. The value of R_{I} is freely available in the tables.

$$C_{\mathrm{R}} = \frac{C_{\mathrm{I}}}{R_{\mathrm{I}}} \qquad (18)$$

To evaluate the criteria, a single table is created with rows and columns listing all the criteria. The weights of the criteria are then assigned within the pairwise comparison according to which criterion is preferred. Then the geometric means b_i and the resulting weights v_i are calculated according to (15) and (16) respectively.

As many tables as there are criteria are prepared for partial evaluation of alternatives. All criteria will be listed in the rows and columns in the tables. Each table will compare how the variant meets the characteristics of each criterion. Accordingly, weights are assigned to individual preferences in a pairwise comparison. Then the geometric mean b_i and the resulting weight v_i are calculated. Finally, the C_{R} validation according to (18) of all created tables will be verified.

4 Proposal of a Methodology for Evaluating the Selection of a Military Logistics Vehicle in a Tender

The Law on Public Procurement requires contracting authorities to conclude a purchase contract so that the goods they need are purchased reasonably using the allocated funds. The reasonable use of the allocated funds can be achieved when the price-to-quality ratio is optimal in purchasing with taxpayer money.

The final evaluation of the selection of a military logistics vehicle at its acquisition will proceed as follows:

- the Saaty weights are calculated for each vehicle using the criterion of the lowest purchase price (C_{P}),
- Saaty's weights are calculated for each vehicle using the lowest life cycle cost (V_{LCC}) criterion,
- the weights of the Saaty method are calculated for each vehicle using the criterion of the technical functionality (V_{T}) which will be supplied by the

manufacturer or supplier of military logistics vehicles. Next the weights of the individual subcategories can be calculated as:

- the mobility criterion – V_{TM}
  - the performance capability – V_{TMp} ,
  - the terrain passability – V_{TMt} ,
  - the manoeuverability – V_{TMm} ,
  - the overcoming obstacles – V_{TMo} ,
  - the maximum mileage – V_{TMmm} ,
  - the evacuation – V_{TMe} ,
- the ballistic protection – V_{TP} ,
- the camouflage and other protection criteria – V_{TC} ,
- the operation environment – V_{TO} .

The weights of the individual criteria for military logistics vehicles are calculated using the Saaty method, Eqs (10)-(18). Then the total weights are calculated V_{CP} , V_{LCC} and V_{T}.

Significance coefficients are set for individual criteria such as k_{CP} lowest purchase price, k_{LCC} lowest life cycle cost and k_{T} technical functionality, provided that the following

$$k_{\Sigma} = k_{\mathrm{C}_p} + k_{\mathrm{LCC}} + k_{\mathrm{T}} = 1 \quad (19)$$

Individual total weights and vehicles are calculated according to the relationship

$$V_{\Sigma_i} = V_{\mathrm{C}_P} \cdot k_{\mathrm{C}_p} + V_{\mathrm{LCC}} \cdot k_{\mathrm{LCC}} + V_{\mathrm{T}} \cdot k_{\mathrm{T}} \quad (20)$$

From the calculated values V_{Σ_i} we find the maximum value that is most suitable within the selection of a military logistics vehicle when acquiring it within the tender.

5 Conclusions

Based on the analysis we conducted in the opening section of this paper, we found that there are not many articles that deal with the acquisition of equipment through public tenders. Most of the articles deal with tenders in construction, information technology and the selection of services such as public transport. Therefore, we have proposed a multi-criteria evaluation for the acquisition of military equipment that is subject to superior requirements, mainly in terms of technical aspects such as mobility parameters, ballistic protection, camouflage and other protection criteria, and operating environment. Parameters such as purchase price and life cycle costs are usually defined as standard in the tender process. In our proposal, all these parameters are incorporated and based on the resulting value we are able to determine the order of selection without being influenced by the human factor, as stated in the publications [2].

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