HADMÉRNÖK

IX. Évfolyam 1. szám - 2014. március

Gávay György Viktor - Gyarmati József
gavay.gyorgy@uni-nke.hu - gyarmati.jozsef@uni-nke.hu

PRESENTATION OF OFF-ROAD VEHICLES, SELECTION AND ANALYSIS

Abstract

The process of purchase long and time consuming. The planned in-service time of the military devices is between 15-25 years and in this time their field of operation can also change. A capability analysis that measures the suitability for the widened scope of duties (for example disaster management tasks) is also possible with the usage of decision making support methods applicable in case of research and development. The MCDM processes provide opportunity for the comparison of existing devices with respect to task implementation.

A haditechnikai eszközök rendszeresítése hosszú, és időigényes feladat. Az eszközök tervezett üzemeltetési ideje 15-25 év között van és ez idő alatt az alkalmazási területük is megváltozhat. Döntéstámogató módszerek alkalmazásával lehetővé válik olyan vizsgálat, amely a változó feladatkörökre, például a katasztrófavédelmi feladatokra való alkalmasságot méri fel. Az MCDM[1] eljárásokkal lehetőség nyílhat a meglévő eszközök összehasonlítására a feladat végrehajtás szempontjából is.

Keywords: *military equipment, disaster, cross-country vehicles, applicability, SMART method ~ haditechnikai eszköz, katasztrófahelyzet, terepjáró gépkocsi, alkalmazhatóság, SMART eljárás*

[1] MCDM (Multi Criteria Decison Making) To solve the multi-criteria decision problems developed, the approach adopted by law [3].

FOREWORD

Disaster recovery is part of the tasks of the Hungarian Defence Forces. The available assets significantly affect the effectiveness of the organization. Selecting the vehicles for a task is an operative decision process and it has to be made on the basis of decision theory. A method that eases the selection process is needed. The MCDM methods are good for selecting cars [1] or the military devices [2]. The overall effectiveness of the devices correlated to each other can be seen with the correct usage of these methods.

This publication only deals with the comparison of the military off-road vehicles. The usage of off-road vehicles in the disaster recovery have been examined from different points of view. The analysis lacks the defensive criteria that are important for military usage, but instead it is based on criteria like ergonomics, number of transportable persons and mobility, which has been defined taking into consideration the VSE method.

THE METHOD OF THE ANALYSIS

The comparison is based on one of the simple processes of the MCDM the SMART (Simple Multi-Attribute Rating Technique) [4] method, which is introduced[2] according to the [5] item of the bibliography. The process has been modified by the authors several times, which made it interesting and usable also for the military-technical field and it has the following mathematical model: (1) [5]:

(1)

	A_1	A_2	$\cdots$	A_n	
C_1	$u(a_{11})$	$u(a_{12})$	$\cdots$	$u(a_{1n})$	w_1
C_2	$u(a_{21})$	$u(a_{22})$	$\cdots$	$u(a_{2n})$	w_2
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	
C_m	$u(a_{m1})$	$u(a_{m2})$	$\cdots$	$u(a_{mn})$	w_m
	y_1	y_2	$\cdots$	y_n	

$$y_j = \sum_{i=1}^{n} w_i u_j(a_{ij})\ u_{(x)} \in [0;100]\ \ a \in R$$

where:

- C_i - the i^{th} criterion,
- A_j - the j^{th} alternative,
- a_{ij} - the value of j^{th} alternative according to i^{th} criterion,
- u_i - the i^{th} criterion utility function,
- w_i - the weight number indicating the importance of the i^{th} criterion.

According to the summary of the model the y_i value in the (1) model is the weighted average as per weight numbers of the alternatives' usefulness per criterion.

[2] VSE (Vehicle Slop Elavation) that describes the ability to conquer macro obstacles [9].

The amount of usefulness of the alternatives as per a criterion can be visually demonstrated by plotting the utility functions in a frame of reference indicating the minimum and maximum usefulness. The process consists of eight steps:

a) the identification of the decision maker,
b) the identification of the alternatives,
c) the definition of the criteria (criteria that can be numerically valued and that plays an effective role from the mission implementation point of view when using a device should be chosen),
d) definition of the criteria's utility functions (it is useful to define linear functions, which are good for illustrating the difference between the usefulness of the devices),
e) selection of the weight numbers (the priority of the criteria compared to each other can be defined experientially),
f) the calculation of the alternatives' values.

The devices and the criteria get listed in a decision matrix. The results define the overal effectiveness of the devices. The results can also be compared on the basis of economic criteria. Since no suitable data is available, no such analysis has been carried out.

The identification of the decision maker (a)

In this case the decision maker is the assigned commander. The best alternative is chosen by the decision maker.

Examined vehicle types as possible alternatives (b)

In this case the alternatives are made up of the off-road vehicle types accepted for use at the Hungarian Defence Forces:

- Uaz 469 B
- Opel Fontera
- Mercedes G270
- Mercedes G280

All four are off-road vehicles. All of them have approach angles, departure angles and ground clearance that have been configured according to the requirements of the off-road usage. The vehicles have either permanent or part-time 4WD. The technical data can be found in table

	Uaz 469 B	**Opel Frontera**	**Mercedes G 270**	**Mercedes G 280**
engine performance: P (kW)	53	85	115	135
engine torque: M (Nm)	170	260	400	410
weight: m (kg)	1600	1920	2540	2540
total weight (kg)	2300	2600	3500	3500
specific performance (kW/t)	22	32,8	32,8	38,7
number of passengers	7	5	5	5

1. table. Technical data [6] [7] [8]

Criteria and utility functions (c,d)

The introduction of the criteria should not always be separated from the definition of the utility functions belonging to them. In case of separation the logic of the criteria's selection would become harder to trace. The chosen criteria:

- ergonomics (it defines the pressure affecting the driver),
- passenger transport capacity (in case of disaster management tasks how many people can be transported with one vehicle),
- tactical mobility (capability to to move in difficult terrain),
- reliability (the result of task execution depends on the reliability of the vehicle).

Ergonomics: The extent of pressure affecting the driver is significantly important from his point of view. Working in a constantly disturbing, uncomfortable environment can lead to concentration problems. This can have a tragic outcome in case of emergency. In case of any unexpected situations or accidental driving mistakes the fast reaction of the driver can be the key to the successful task execution. It should also be taken into consideration that the tiring conditions also affect the performance of the executive force.

The usefulness of the vehicle can be defined with scoring. In this case "0" usefulness occurs when the instrument does not have any conditions belonging to the given criterion. The vehicle having the worst features, but possessing the condition can gain 1 point at the measurement, while the vehicle with the best features can gain 3 points.

When designing the Uaz 469 B, ergonomics was not considered important, so it clearly lags behind the level of modern vehicles. The Mercedes G 270 and 280 are on the same level, while the Opel Frontera is closest to a modern car in terms of comfort. In respect of ergonomics the amount of generated vibration affecting the driver is determinant. The amount of this can be defined with numbers by the "K" ride comfort indicator in the VDI 2057 standard. Since this data is not available, a definition that makes it possible to differentiate between given alternatives needs to be worked out. Our knowledge resulting from the usage of the types is not measurable data, it cannot be used. Such measurable or definable statements, features and data are needed which can be expressed with numbers and be used to determine the usefulness. The chosen sub-criteria:

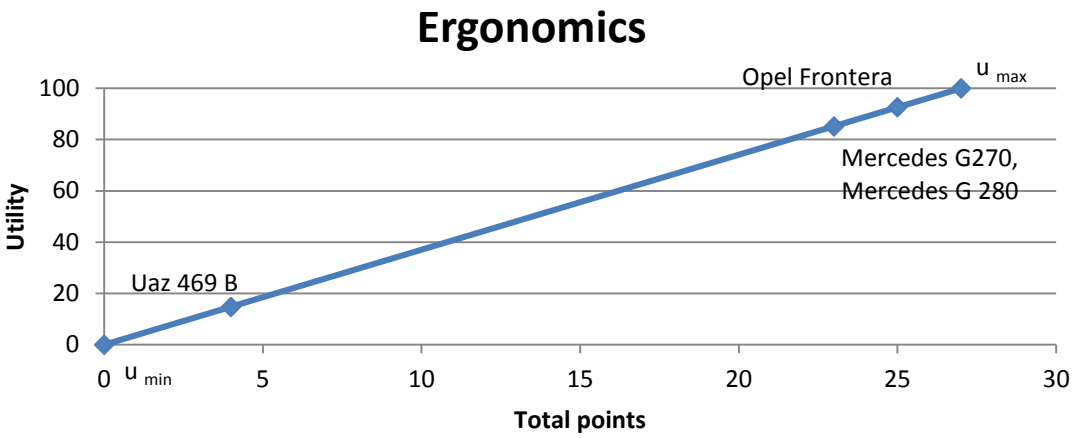
- driver's seat (adjustable height, adjustable back, arm-rest, headrest),
- the possibility to simply open the back door,
- the possibility to adjust the steering wheel,
- the existence of parking heater,
- the existence of air-conditioning[3]

The quality of the driver's seat consists of more criteria, on the basis of which the order can be set up with simple scoring (table 2).

	Uaz 469 B	**Opel Frontera**	**Mercedes G270**	**Mercedes G280**
adjustable seat	0	3	3	3
seat flexibility	1	3	3	3
adjustable back rest	1	3	3	3
headboard	0	3	3	3
seat side supports	1	3	2	2
adjustable steering	0	3	2	2
stationary heating	1	1	3	3
air conditioning	0	3	3	3
automatic turn signal	0	3	3	3
total points	4	25	23	23

2. table. Criteria of seat configuration

[3] Beside convenience criteria the air-conditioning system also has significance in terms of security. It can dehumidify the windshield in case of hazy, rainy weather conditions.

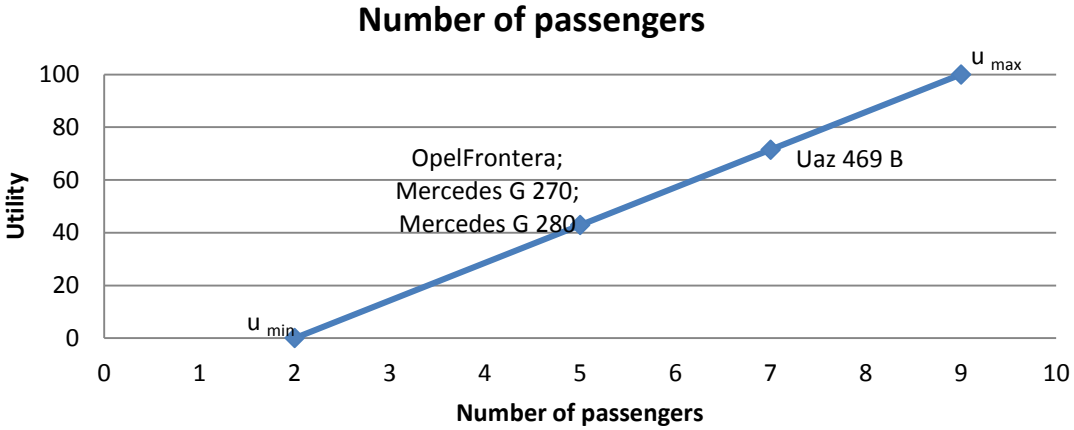


1. figure. Ergonomics

The utility function of the ergonomic criterion:

$$u(x) = \frac{100}{27}x$$

Passenger transport capacity: The seating capacity enabling passenger transportation essentially defines the degree of vehicle usability in case of task execution. When such vehicles are used in populated, disaster struck areas, the possibility of unforeseen disaster management tasks (such as people rescue) always needs to be taken into consideration. This question needs to be highlighted when determining the weight number and applying the comparison method. The least useful and the most useful parameters also need to be defined, which would be 2 and 9 in this case. 2 persons means of course 1 personnel and 1 transportable passenger, 9 is the number of maximum transportable people including the driver in case of vehicles that can be driven with category "B" driver's license. The usefulness of the alternatives with respect to the passenger transport capacity is displayed by figure 2.



2. figure. Number of passengers

The utility function of the passenger transport capacity criterion:

$$u(x) = \frac{100}{7}(x-2)$$

Tactical mobility: The vehicle mobility can be described with several well-definable parameters. The mobility can be measured with the help of speed, acceleration, ability to overcome obstacles, portability on the battlefield, manoeuvre capability and performance. The

disaster recovery activities clearly differ from the operational field activities in the fact that the defence capabilities of the vehicles play a less important role.

The required technical data is displayed in table 1. There are many factors that highly influence the mobility from the marching performance point of view and the most important is a specific performance (the amount of engine power per ton correlated to the weight of the vehicle) considering our examination.

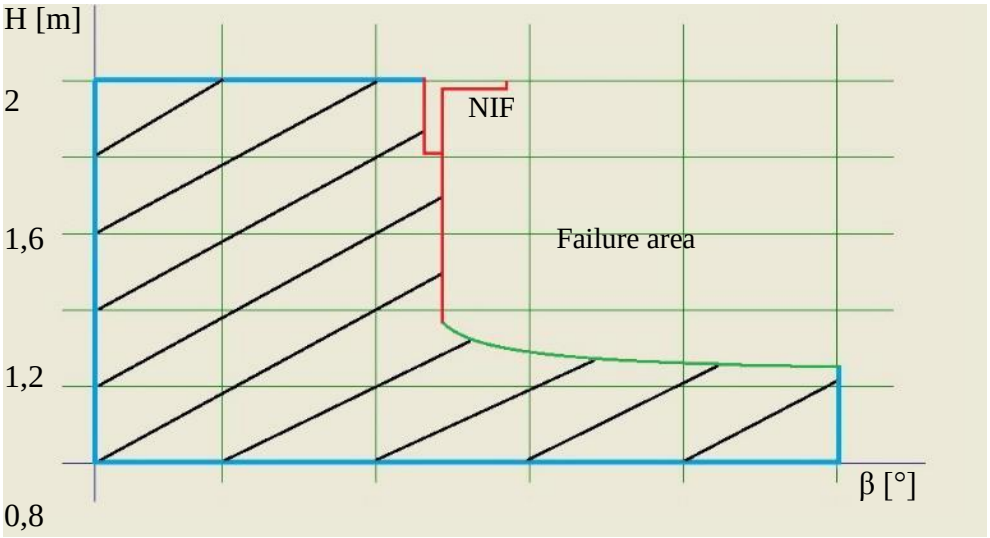
The most beneficial of these for us is the specific performance that reflects the ascending conquering capability.

The off-road capability of the vehicle is one of the most important requirements of military usage [9]. The VSE diagrams should be used for this purpose, for this process best illustrates the ability to overcome macro obstacles (graph 1). The obstacles that can be overcome by the vehicle are shown with the ruled field below the diagram. This means that neither the front nor the back console suffers any collision and the ground clearance is enough for the bottom of the vehicle to avoid the obstacles. The OMN (Obstacles Mobility Number) value can be determined by integral calculus on the basis of the given interval defined by the VSE chart [10]. The larger this value is, the better the ability is to overcome macro obstacles.

The diagram can be divided into two parts:

- NIF (Nose In Failure): the obctacle height that can be overcome with the front and back consoles is shown with the red lines,
- HUF (Hang Up Failure): the green coloured border-curve of the vehicle bottom collision.

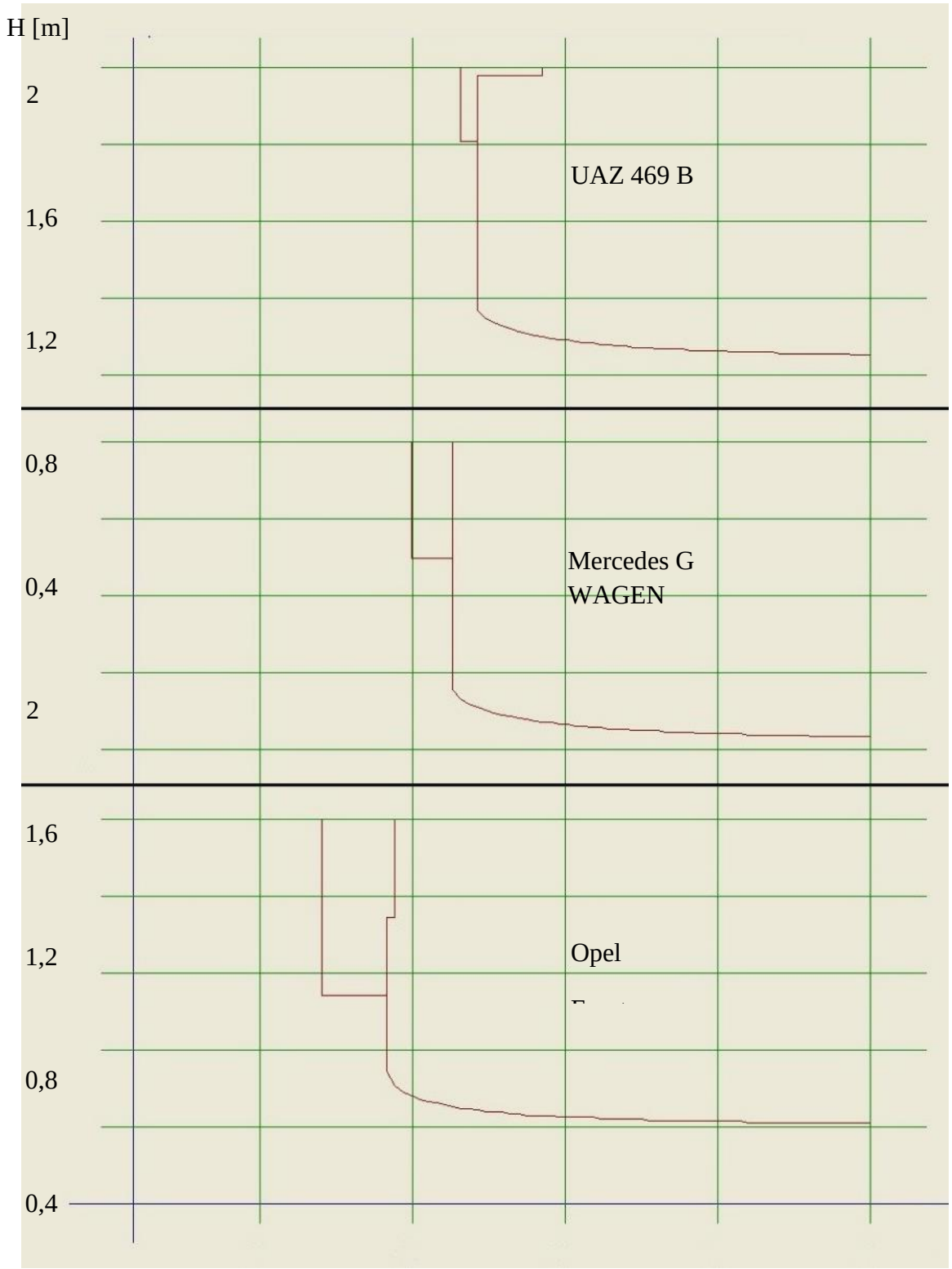
The H_{max} height is 2 metres, the angle of the obstacle's profile facing the vehicle's direction is 90° .



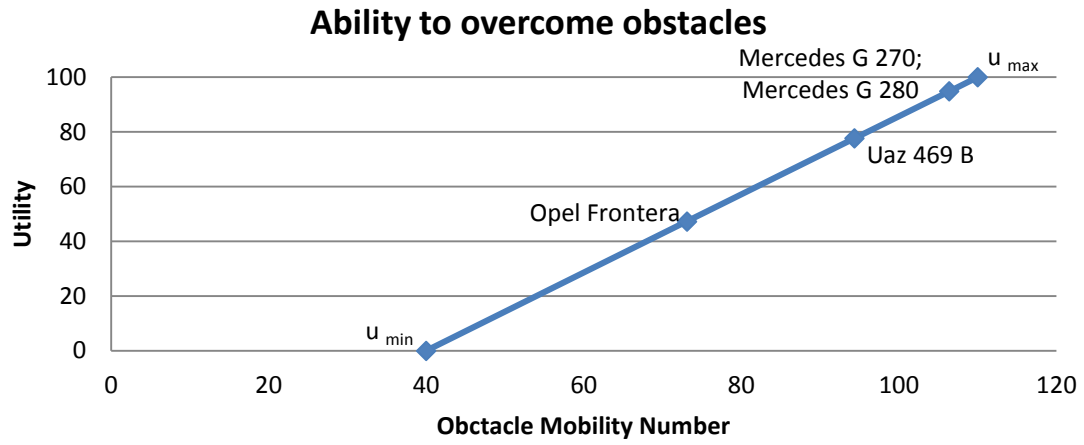
3. figure. Illustration the VSE curve

The VSE diagrams (figure 3) show the capability to overcome obstacles of the examined vehicle and also illustrate the difference between the compared vehicles.

The diagram of the Uaz 469 B and the Mercedes G 270 differ in the field of the NIF a little bit. The Opel Frontera's HUF curve that starts at a smaller angle value clearly indicates the possibility of getting stuck (graph 2). The program VSE for Windows 4.0 that edited the curves of the HUF and NIF functions was used to calculate the OMN numbers [11]. Defining the usefulness needs the minimum and maximum utility parameters. It is practical to set the OMN value of an average car as the minimum utility value, which is 40 in this case. The maximum value is that of the Unimog, which is 110 here.



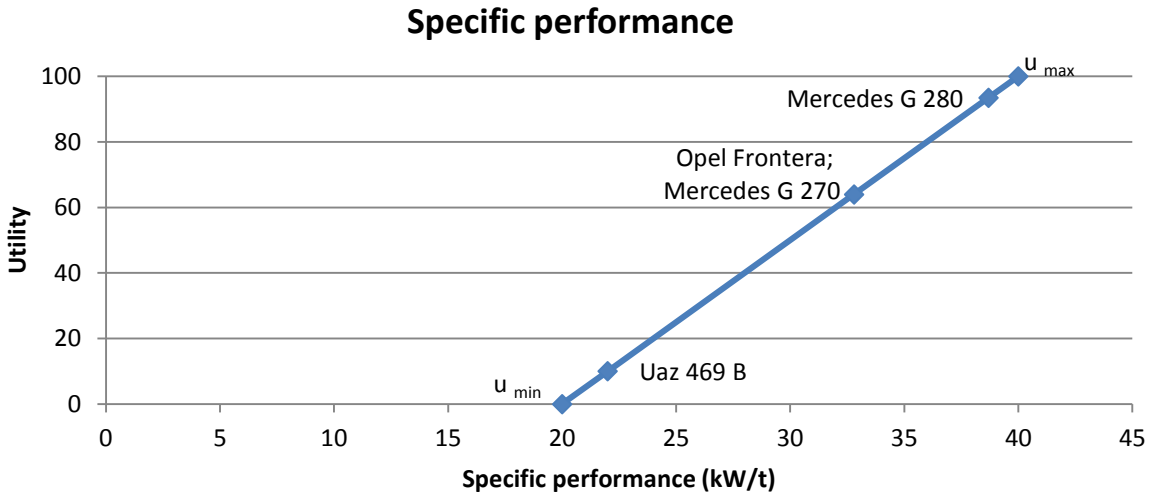
4. figure. Longitudinal VSE diagram of UAZ 469 B, Opel Frontera and of Mercedes G Wagen (short-wheelbase version)



5. figure. Ability to overcome obstacles

The utility function of the capability to overcome obstacles:

$$u(x) = \frac{10}{7}(x - 40)$$



6. figure. **Specific performance**

The utility function of the specific performance:

$$u(x) = \frac{10}{4}(x - 20)$$

The two main criteria of tactical mobility are marked as the two separate criteria of the SMART process. Determining a common score is possible but this is the simpler way.

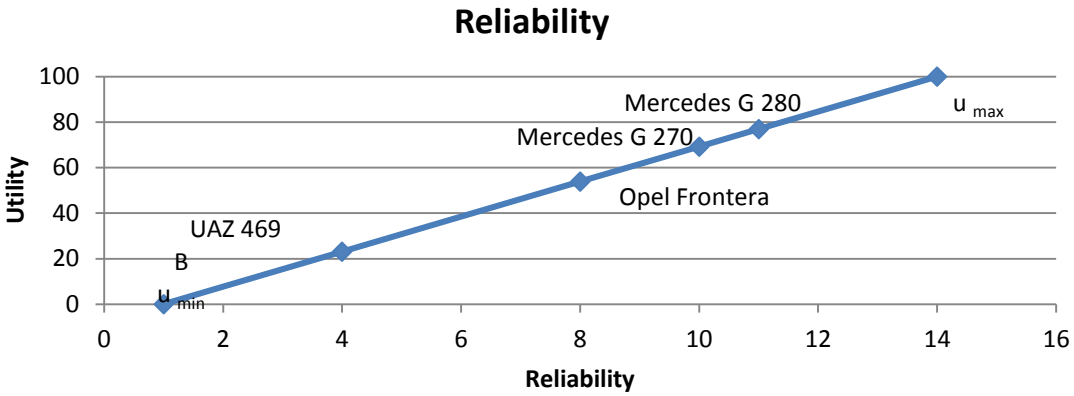
Reliability: When examining the usefulness, the question of reliability also needs to be taken into consideration. The age of the instruments affects the failure inclination. In this case the sensitivity of a modern diesel engine can bear a risk for the operational circumstances, just like an ignition problem in case of an older vehicle. In case of modern instruments such electronic or contact failures can occur that result in the engine commanding system restraining the engine's performance. If the endurance of the engine parts or the emission value of the exhaust fumes gets endangered, it is possible to go on with emergency operation even with limited engine performance.

In case of frequently and much used vehicles the preparedness of the operating personnel is the key that helps to restore the combat-readiness within a short time when making smaller reparations.

There is no precise data available for the measurement of reliability, so such features need to be defined that make it possible to compare the examined vehicles based on this criterion. Although no precise definition is possible regarding the field of reliability in this case, it would be a mistake to ignore this criterion. If the vehicle does not have the conditions required for the criterion it receives 0 points. The newest vehicle receives 10 points, the oldest gets 1 point.

	Uaz 469 B	Opel Frontera	Mercedes G 270	Mercedes G 280
engine oil pressure gauge	1	0	0	0
engine temperature gauge	1	1	1	1
engine oil temperature gauge	1	0	0	0
emergency mode	0	0	1	1
age	1	7	8	9
total points	4	8	10	11

3. table. Reliability affecting factors



7. figure. Reliability

The utility function of reliability criterion:

$$u(x) = \frac{100}{13}(x - 1)$$

Definition of the weight numbers (e)

Defining the weight number has a determinant significance regarding the result of the comparison. In case we would like to define the usefulness on the operational field it is practical to evaluate the experiences of the operating staff with the help of a survey. Although the questionnaires count as experimental results, they are still not of the same value as the exactly measurable reality. This data needs to be based on the original primary data collection.

The table 4 contains the chosen weight numbers which have been defined on the basis of estimation.

Definition of the values (f)

criteria	Uaz 469 B	Opel Fronrea	Mercedes G 270	Mercedes G 280	utility function	w. n.[4]
ergonomics	14,81	92,59	85,18	85,18	$u(x) = \frac{100}{27}x$	1
number of passengers	71,43	42,86	42,86	42,86	$u(x) = \frac{100}{7}(x-2)$	4
VSE	94,86	47,28	77,66	77,66	$f(x) = \frac{10}{7}(x-40)$	3
specific performance	10	64	64	93,5	$u(x) = 5(x-20)$	2
reliability	23,07	53,84	69,92	76,92	$u(x) = \frac{100}{13}(x-1)$	3
result	674,2	695,39	827,36	907,39		

4. table. Determining of the score

The weight numbers that are the result of the process can be found in the lower row of the table 4. The oldest vehicle has the least usefulness based on the chosen criteria and the evaluation method.

SUMMARY

The topic of the publication is the application of a decision theory. The presentation is possible through a theoretical example without the precise definition of the weight numbers. The alternatives' usefulness can be defined based on the listed criteria. This examination is an attempt to make a list of the usefulness of the off-road vehicles. The criteria were chosen entirely on the basis of real demands. Diagram illustrations clearly show the difference between the alternatives in case of all criteria. The question of the weight numbers is a critical point that can only be made entirely official with a much bigger research work. The last step of the SMART process would be the sensitivity test which has not been executed in this case. It is essential to create questionnaires that would make it possible to define precise weight numbers with the help of the information gained from the operating staff.

References:

[1] C. Burgha - Structuring and Weighting Criteria in Multi Criteria Decision Making (MCDM) http://www.researchgate.net/publication/251780347_Structuring_and_Weighting_Criteria_in_Multi_Criteria_Decision_Making_%28MCDM%29 (letöltve: 2014.01.21)

[2] Gyarmati József – Döntési modell kialakítása közbeszerzési eljárás során, Hadmérnök II. Évfolyam 3. szám - 2007. szeptember pp. 36-52

[3] Dr. Gyarmati József - Haditechnikai eszközök összehasonlítása közbeszerzési eljárás során Hadmérnök, I. évfolyam 2. szám 2006.

[4] Temesi József - A döntéselmélet alapjai Aula kiadó, Budapest 2002 ISBN 9639345644

[5] Dr. Gyarmati József – SMART, a többszempontú döntési probléma egy egyszerű megoldása, Hadmérnök III. Évfolyam 2. szám - 2008. június pp. 78-87

[6] Az UAZ 469B típusú terepjáró személygépkocsi anyagismereti és igénybevételi szakutasítása GJMŰ/126

[4] weight number

[7] Oktatási Segédlet a Magyar Honvédség gépjárművezetői állománya részére (MBG 270 CDI gépjármű típus ismeret szaktanfolyam)

[8] http://katalogus.hasznaltauto.hu/opel/frontera_2.2_dti_limited_aut.-2018770 (2103.04.24)

[9] Vartman György - Járművek akadályleküzdő képességének összehasonlítása a VSE módszer alkalmazásával, http://portal.zmne.hu/download/konyvtar/digitgy/nek/2003_2/14_vartman.pdf (2013.04.23)

[10] Dr. Laib Lajos - Terepen mozgó járművek Szaktudás Kiadó Ház 2002 Budapest ISBN 9639422010

[11] VSE for Windows 4.0 szoftver használati utasítás