AUTHOR'S PRESENTATION FOR DOCTORAL (PHD) DISSERTATION

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Examination, Comparison and Evaluation of Armored Combat Vehicles with a focus on Mobility

author's presentation for doctoral (PhD) dissertation

B U D A P E S T

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Contents

1. DEFINITION OF THE SCIENTIFIC PROBLEM

The analysis of mobility and fighting capabilities of Armored Fighting Vehicles (AFV) shows that change is difficult and development lags behind firepower and protection. The Hungarian Army uses the GMP-95 mobility model which needs to be enhanced using research results in order to meet today's expectations. It is also advisable to replace simple score ranking with a more accurate Decision Theory.

2. OBJECTIVES OF THE RESEARCH

1. Analysis of the Hungarian Army Armored Fighting Vehicle Fleet in relation to the surrounding countries.
2. Analysis of the mobility expectations of armored combat vehicles linked to typical military tasks without in depth analysis.
3. Military and Technical Mobility Analysis in order to expand the GMP-95 model.
4. Creating a new system of Groups and Categories for Armored Fighting Vehicles would enable comparison of agility and certification testing.
5. Method selection and application for matching and qualifying of Armored Fighting Vehicles by mobility.
6. Elaboration of the selection methodology of Armored Fighting Vehicles.

3. HYPOTHESIS OF THE RESEARCH

1. By analysing the Hungarian Army's AFV fleet in relation to the surrounding countries it is possible to determin the direction of future development.
2. The fighting qualities, Firepower, Mobility and Defense of Armored Fighting Vehicles play a fundamental role in combat capability.
3. A Mobility Analysis Test Method could be developed to assist in choosing between Wheeled or Tracked suspension for typical military tasks.
4. Examination of the technical criteria defining Mobility shows that a new classification with details would detect which of the GMP-95 Mobility models should be improved.
5. A more accurate measurement and qualification is possible, shuch type of comparative methods have not yet been used to assess armored fighting vehicle mobility.

The new method could assit in modernizing existing Armored Fighting Vehicles, or to purchase new ones; domestic or foreign. What's more, it compares existing ones with new ones, allied or even other off-road equipment.

4. METHODS OF THE RESEARCH

I used the followings research methods in my dissertation:

- Using the method of literature research to the extent necessary for my research, I reviwed, evaluated and compared research results of mobility for Armored Fighting Vehicles. Furthermore, I studied tactical applications and grouping features, as well as advanced combat roles.
- Using the analysis-synthesis method I evaluated the technical solutions for Wheeled and Tracked AFV's. The background of its function revealed differences and similarities between the two kinds of suspension systems.
- I used mathematical methods and technical criteria for evaluating mobility.
- I used the AHP and the KESSELRING comparison methods to examine and rank the Mobility of the current and potentially future Hungarian Army's Combat Vehicle Systems.

5. SHORT SUMMARY OF THE COMPLETED EXAMINATION BY CHAPTERS

In the **first chapter** I gave an overview of the Hungarian Army Armored Fighting Vehicle fleet's situation, and its expedient directions in the field of Mobility taking into account of NATO policies, and the Hungarian Army objectives. I introduced the Hungarian Army's Armored Fighting Vehicles status and the difficulties for future model selection of wheeled and tracked combat vehicles.

In the **second chapter** I reviewed Tracked and Wheeled AF Vehicles and their tactical characteristics in modern warfare. I studied agility separately from other fighting qualities, emphasizing its importance. I also analized the relationship of firepower and mobility.

In the **third chapter** I presented the concepts of tactical, operational and strategic mobility as the war activities different Mobility levels. I also examined the characteristics of each level for

all three war activities mentioned. I pointed out possibilities for improvement. I showed the physical background of progressing through a terrain by the analyses of general and spontaneous self-propelled movements. I analyzed the designs of the wheeled and tracked AFVs emphasizing their identical and different design features. I also determined which characteristics play the most important roles in the increase of mobility. I offered graphical solutions to obtain the limits of applications of wheeled and track-based platforms. Based on technical and military considerations I systemized the main features of terrain mobility of the wheeled and tracked AFVs. New important factors were found and these were incorporated into the GMP-95 mobility model criteria system. This makes it possible now to apply the Modern Decision-Theory Model in order to achieve more accurate evaluation of vehicles which leads to more reliable comparisons than was previously possible.

I based the **fourth chapter** on the fact, that military combat vehicle's - as complex systems - defining properties can be examined independently as complex subsystems in a complex multi-criteria decision-making environment. I made an overview of the potential modern decision-making methods for cross-country Armored Fighting Vehicle's comparisons. I chose two decision-making methods for comparison of Armored Fighting Vehicles.

In the **fifth chapter** I set up the database comparison by supplementing the GMP-95 model's criteria system. I filled this database with new parameters for selected wheeled and tracked AFVs. I arrived at today's modern armored combat vehicle classification, matching and ranking using methods that have not yet been used to compare AFVs by mobility. With my methodology I proved that the mobility of AFVs is quantifiable and evaluation is possible. I also verified that my new methodology works.

The new methodology I developed provides a more accurate classification, therefore it is possible to compare my results to the Hungarian Army's (revised) method.
My process enhances the GMP-95 model - thus improving the accuracy of the ratings with the following points:

- determining the suitable suspension system for the mission, chooses (determins) the Armored Fighting Vehicle type and variety;
- quick calculation of traction force, using the simplified formula;
- developing such specific values becomes more detailed while examining mobility;

- sort mobility vehicles for each qualifying data according to the criteria described;
- by using complex multi-criteria decision-making methods a more accurate classification and ranking of vehicles is possible and in addition provides wiser decision making on the topic of mobility.

6. CONCLUSIONS

1. I found that the Hungarian Army's former developments did not affect the Armored Fighting Vehicle fleet, the Hungarian Army is still waiting to aguire the new Armored Fighting Vehicles. Before this purchase decision, answers to such questions as the types of the vehicles, proportion of wheeled-tracked vehicles, that is to say what kind of functions are needed, wheeled or tracked Armored Fighting Vehicles.

2. During the examining of the role of Armored Fighting Vehicles in combat, I concluded that next to the heavy (basic) tanks with high tactical Mobility come into view a lighter - thus more air transportable - wheeled and tracked Armored Fighting Vehicles.
   I found that the only possible way to close the nowadays again opening scissor's of military firepower-mobility, is by increasing the air transportability, and developing the air transportable Armored Fighting Vehicles.
   By studying Armored Fighting Vehicles I also ascertained that from the three fighting qualities (firepower-mobility-defense) the mobility is the most difficult to improve upon. Therefore, it's deeper examination snatching from it's " environment " is justifiable.

3. I determined those characteristics which play a dominant role in increasing mobility by the levels of mobility.
   I found that the application limits of wheeled-, and tracked mounted platforms is definable by the context of total weight and terrain mobility, taking into consideration the combat role and climate conditions.
   The test methods for Armored Fighting Vehicles mobility helped me arrive to the conclusion that the GMP -95 model is supplemented with additional technical and military aspects of structural solutions, which also characterized their behavior.

4. I determined that Mobility is such a complex fighting quality that it should be evaluated using a more precise measuring method of complex multi criteria systems.
   Instead of using a simple table ranking, the multi-criteria measurement method is more advanced and offers a better comparison to make decisions. I found that, it should be used more methods to extract convincing results.

7. NEW SCIENTIFIC RESULTS

1. Thesis

By examining the Firepower and Mobility Fighting qualities of tanks, I discovered that today the only effective way to close the gap between forces firepower-mobility is to creating better conditions for air mobility and increasing it.

My conclusion is that air transportability became a key element of combat vehicles, and thereby the mobility of troops in modern conditions.

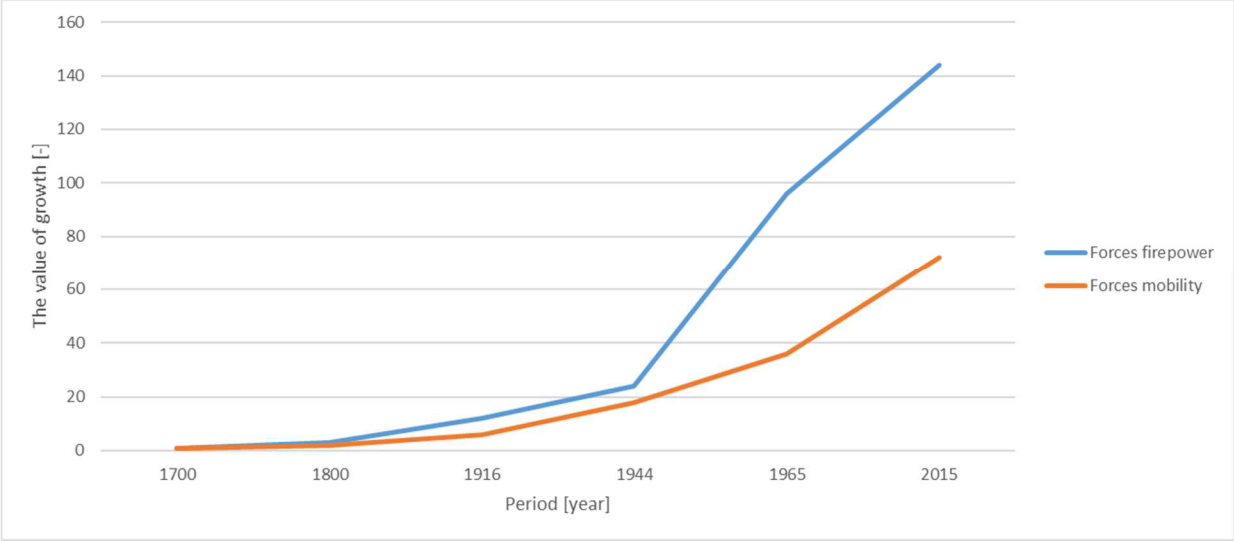

Fig. 1. The movement of the firepower-mobility scissor from the XVIII. century to today (Miklós Kovácsházy)

The "scissors" moving between the firepower and mobility can be discover for Armored Fighting Vehicles such as tanks. The development of internal combustion engines to increasing the specific power has become increasingly more expensive and more complicated. The use of more "stronger" engines is physically and economically limited as the traction realization on the terrain and the accelerations because of the human tolerance, with which we have arrived at the border. The "land-based" mobility is cannot be significantly increasing. A tank cannon's fire power for todays has increased significantly thanks to for example the computer -controlled fire control system, the smooth-walled barrel launched missiles.

The only possible way to close the "scissor" of firepower and mobility is to move away from the ground and increase air transportability and develop air transportable Armored Fighting Vehicles.

The idea seems to be justifyable sighting a highly regarded doctoral thesis, which called for the awareness of the importance of air transportability, and the establishment of wheeled, independent, rapid air transport Brigades in the United States army (Stryker brigade).

2. Thesis

At the relation of the tactical, operational and strategic mobility levels characteristics play the most important role in increasing the mobility achieved at that given level.

I ordered to the military activities of Mobility levels to be the main factors of Armored Fighting Vehicle's mobility, made the relationship between the mobility's military and technical scientific interpretation.

The main factors of mobility **Table 1.**

Armoured Fighting Vehicles mobility - military aspects			
Military activities mobility level	***The mobility level's main features***		***The mobility level's enhancement possibilities***
Tactical mobility	soil carring strenght	ground pressure	gear, thread development
		traction power transmission	
	average speed	micro obstacle overcome ability, swinging	suspension system's refinement
		macro obstacle overcome ability, OMN	suitable suspension system and chassis construction
		water barrier overcome ability	increase speed and stability in water
	ported firepower delivering to the target		increase effect of firepower on the target
Operational mobility	range	mode of engine operation	introduction of "Single Fuel Concept"
		fuel consumption	power trail losses reduction
			increasing the engine efficiency
	fuel service		fuel air transporting
Strategic mobility	transportability to long distances on road, railroad, waterline and in the air		increasing the airborn Armored Fighting Vehicles proportion in the armed forces

(Miklós Kovácsházy)

As presented in Table 1. it is clear that the off-road capacity and the operational range can be only significantly increased with air transportation.

3. Thesis

I developed a graphic method to quicly identify whether wheeled or tracked suspension system is the best selection depending on the combat role.

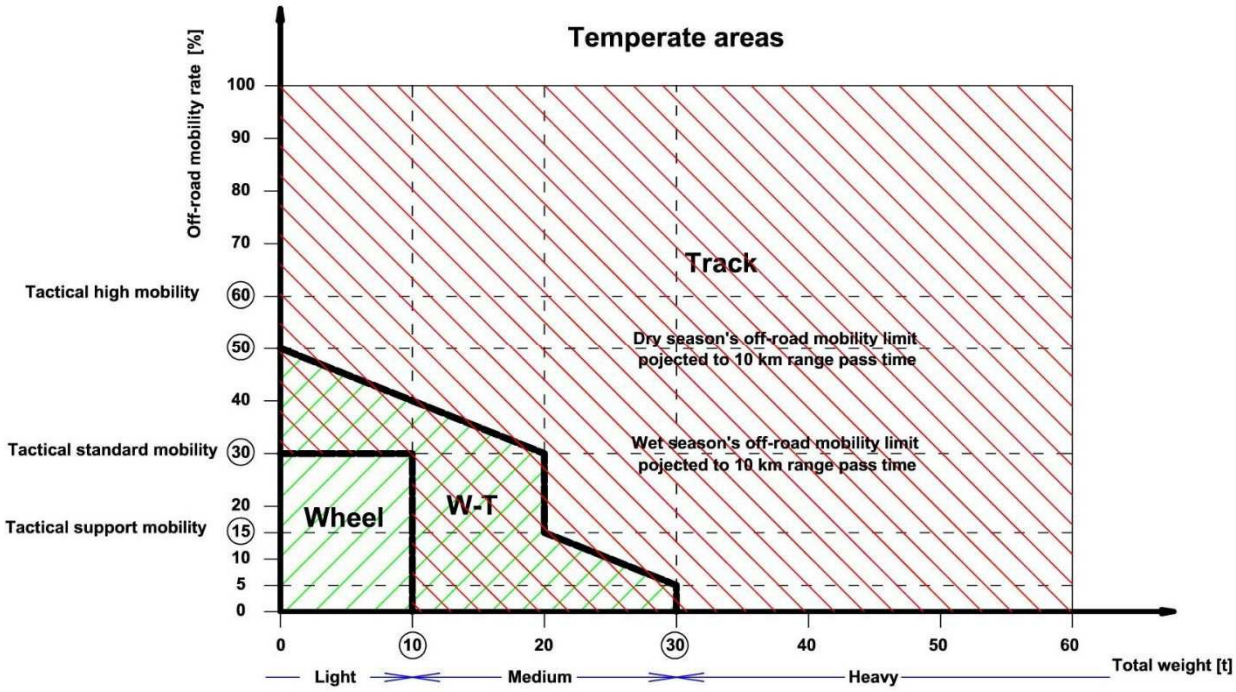

Fig. 2. Application limits of wheeled and tracked mounted platforms by context of total weigh, field mobility (Miklós Kovácsházy)

The diagram shown in Fig.2 offers a graphic solution to determine when to apply wheeled and when tracked AFVs. It is easy to interpret. Its axes are the total mass of the vehicles – horizontal – and the off-road mobility rate – vertical. The areas on the graph are the result of taking into consideration the mass categories, the roles of the vehicles and the climate. There are three mass categories (0-10 t, 10-30 t, and 30-60 t). The roles are given by three off-road mobility rate values 15% (support), 30% (standard), and 60% (high). The % value gives the portion of the time the AFV is moving on the terrain (i.e. off-road). Shortly it is called terrain movement. The area of wheeled-only AFV applications is limited from above by the time (%) required to complete the tactical task, as well as by the permitted ground pressure (VCI) determined by the number of wheels or tracks. The same area has the 10 t mass limit and usually 30% terrain movement limit. Most of the wheeled vehicles having 20 t as upper mass limit. For lower terrain movement operations (mobility rate about 5%) the upper mass limit reaches 30 t, e.g. for self-propelled artillery or transport vehicles. Above 30 tons total mass only tracked AFVs

can be used conveniently. For these the terrain movement is determined by the weather, 50% and 30% for dry and wet conditions respectively.

The limited scope of tracked devices, depending on climatic conditions starting field areas over 50% mobility rate in decline, taking into account the increase in the dry and the wet weather limiting factors.

The intermediate area of wheeled and tracked both devices can be used. In the same weight category to choose the right gear for the combat role requirements needs an individual decision.

4. Thesis

I improved the GMP-95 mobility model for off-road vehicles, and I developed a new system of evaluation criterial of the military, physical and technical aspects of the mobility.

Studying the mobility - to supplement the in use GMP-95 mobility model - I created the self-propelling, mobility determining factors and characteristics for Armored Fighting Vehicles summarized in the table no. 7. (in the dissertation) Based on that, the Armored Fighting Vehicles mobility examination can be divided into the technical aspects, as structural solutions, and the military aspects as well as the military activities (motility) Mobility levels. For both criteria, I enumerated the characteristics and behaviors that affect the increasing possibilities of mobility.

So, by their use, the selection's, and the evaluation's first step – surpassing the GMP-95 model - is the determination of the off-road mobility rate, and the proper mission fits suitable suspension system, the wheel, or track. As, the second step the extended examination criterial of GMP-95 motility model the decision-makers can evaluate, classified and compare the Armored Fighting Vehicles along the mobility.

5. Thesis

For the faster and easier examination of some features of Mobility I worked out:

• the internal combustion engines and gas turbines operating features graphic comparison figure;

• the simplified calculation formula of the traction power requirement.

On Fig no. 3. Comparable shown the internal combustion engines and gas turbines operating features perceptible the gas turbines better - preferable fit to the traction needs torque ramp. It's curves show the suitability of a large mass vehicle to tow.

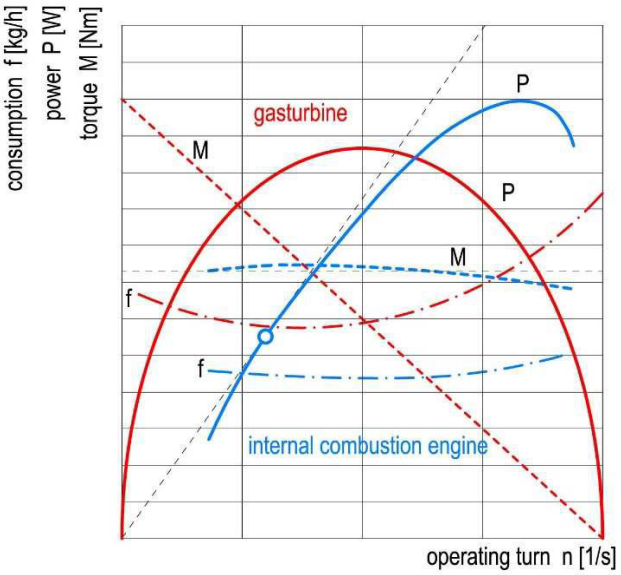

Fig. 3. The internal combustion engines and gas turbines operating features (Miklós Kovácsházy)

However, despite the attractive features it is not widespread because of it's design and mode of combat conditions requires due to a variety of driving speeds (often idle, slow travel, attack). The main reasons are the difficult controllability, high operating turn, the high temperature air emission, and the high fuel consumption.

At the usual off-road moving, the combat speeds are relatively low. Thus, the air resistance caused traction power requirement neglecting estimated well with the counteracting with the 10 % weight increasing extension of the rotary pieces of the vehicles power train:

Thus, the required traction power estimated by a good approximation:

$$P_{engine(estimated)} = \frac{1,1}{0,9 \cdot \eta_{power\ train}} \cdot G \cdot \cos\alpha \cdot (f_{rolling} + \mu_{sticking}) \cdot v \qquad [W] \qquad (1)$$

6. Thesis

I proved the utility of the new criteria system developed by me, by using multi-parameter systems suitable methods for comparing groups of Armored Fighting Vehicles along the mobility.

The new method – based to the GMP-95 model - for the Armored Fighting Vehicle's classification and comparability along the mobility usage's steps are the followings:

1. Decision makers, expectations and aims clarifying respected by the required combat role, type of suspension, species, and variety of Armored Fighting Vehicle determining;
2. Gathering the parameters of comparing Armored Fighting Vehicle;
3. Reference off-road routes designation, road sections, soil bearing capacity measurements;
4. In relation to the certain vehicles, calculation of the off-road traction power requirement taking into account the movement resistance;
5. By the traction diagram based on the results of the 4. point, determine the maximum combat speed on the reference off-road routes;
6. Determination of the macro obstacle overcome ability (OMN), and the crossing time - so speed - of the reference off-road routes;
7. At each reference off-road routes determination of the micro obstacle overcome ability's speed reducing effect of vibration, determine the average speed and average fuel consumption;
8. Set up specific values;
9. In relation to the certain vehicles, organize mobility qualifying datas by the presented criterial systems;
10. The rating and ranking of the Armored Fighting Vehicle supply by using the suitable complex multi-criteria decision-making methods.

On the basic of the comparable parameters filled database the suitable complex multi-criteria decision-making methods (in my case AHP and KESSELRING) can applied for today's modern armored combat vehicles classification, matching and ranking. The Armored Fighting Vehicle's complex evaluation, ranking can be done considering the decision-makers determined off-road usage requirements.

8. PRACTICAL USAGE OF THE SCIENTIFIC RESULTS

1. The whole dissertation, and each chapter independently can be used to support and training the professionals in the subject of the development of land armed forces.
2. I recommend the collected military science-, and technical knowledge and the improved mobility qualification methodology for the training, and further training of the civil, and military wheeled- and tracked off-road operator professionals, engineers.
3. I recommend the applicable parts of this work for the shaping of the new Hungarian designed and manufactured Armored Fighting Vehicles. The study may help to determine the future directions of the development.
4. I recommend the use of the presented comparison, ranking and rating process in the following areas for decision making, decision support and for other military science research:

- definition the fields of application of the wheeled-, and tracked Armored Fighting Vehicles,
- comparison of the Armored Fighting Vehicles in use with each other;
- comparison of the new requirements and the existing Armored Fighting Vehicles in use with each other;
- comparison of the allied army's and the existing own Armored Fighting Vehicles in use with each other;
- comparison of the potential opponent army's and the existing own Armored Fighting Vehicles in use with each other.

The application of this methodology is recommended to narrowing a large number of Armored Fighting Vehicle variety to 2-3 potential pieces, what follows their expedient practical comparison.

9. RECOMMENDATIONS FOR CONTINUATION OF THE RESEARCH

1. Further research is recommended to examine and evaluate the combat mobility with diagrams where the horizontal and vertical axes include the terrain properties (terrain profile, VCI, NoGoTerrain) and the vehicles' features (OMN, average speed, average fuel consumption) respectively. This would offer a graphical solution for the selection of Armored Fighting Vehicle by the properties of the terrain and by the capabilities of the vehicles.

2. Nowadays more and more attention is given to the role that air transportability plays in determining mobility. It is possible to develop the criteria-system for the mobility with respect of air transportability. It seems appropriate to develop it's rating values.

3. For further research it is recommended to create a rating system for the firepower with the corresponding database, similarly to the way it was done for mobility.

4. I recommend for further research to evaluate the complex qualification of the Armored Fighting Vehicles by the analysis of protection and firepower similar to the way I performed in connection with mobility (tactical qualities; military, physical, technical background; defining characteristics; criteria system; application of multi-criteria decision-making methods) in my study. The process would give a complete picture of the examined, evaluated and compared Armored Fighting Vehicles. Thus, by the comparisons, ranking on the field of firepower-protection-mobility fighting qualities one could get adequate images about the former, the existing, from the system subtrahend, the renewable, in the future system delivered, the future produced, as well as allied, what's more, other Armored Fighting Vehicles technical and tactical quality and relative qualities.

10.LIST OF PUBLICATOINS OF THE CANDIDATE

Articles published in periodicals in Hungarian language:

1. Kovácsházy Miklós: A lánctalp, mint a harckocsi egyik legfontosabb alkotója, Hadmérnök, IV. évfolyam 2. szám, 2009. június, 246–258, http://hadmernok.hu/2009_2_kovacshazy.pdf (Letöltés időpontja: 2010. január 08.)
2. Kovácsházy Miklós: A lánctalpas járószerkezet kialakítása, Hadmérnök, IV. évfolyam 3. szám, 2009. szeptember, 140–150, http://www.hadmernok.hu/2009_3_kovacshazy.pdf (Letöltés időpontja: 2010. január 08.)
3. Kovácsházy Miklós: A harckocsik ABV védelme, Hadmérnök, VII. évfolyam 2. szám, 2012. június, 150–159, http://hadmernok.hu/2012_2_kovacshazy1.pdf (Letöltés időpontja: 2012. november 05.)
4. Kovácsházy Miklós: A harckocsik önmentésének kérdései, Hadmérnök, VII. évfolyam 2. szám, 2012. június, 65–76, http://hadmernok.hu/2012_2_kovacshazy2.pdf (Letöltés időpontja: 2013. március 15.)
5. Kovácsházy Miklós: A Csepel 300 katonai tehergépkocsi ismertetése I. rész, Haditechnika, XLVI. évfolyam 3. szám, 2012/3, 16–20.
6. Kovácsházy Miklós: A Csepel 300 katonai tehergépkocsi ismertetése II. rész, Haditechnika, XLVI. évfolyam 4. szám, 2012/4, 11–15.
7. Kovácsházy Miklós: A 43M Tas nehézpáncélos 1:16 léptékű modellje, Haditechnika, XLVI. évfolyam 5. szám, 2012/5, 43–46.
8. Kovácsházy Miklós: A Zrínyi járműcsalád története I. rész, Haditechnika, XLVII. évfolyam 6. szám, 2013/6, 10–16.
9. Kovácsházy Miklós: Az új holtak ütege, Haditechnika, XLVII. évfolyam 6. szám, 2013/6, 38.
10. Kovácsházy Miklós: A Zrínyi járműcsalád története II. rész, Haditechnika, XLVIII. évfolyam 1. szám, 2014/1, 52–57.

11. Kovácsházy Miklós: A Zrínyi járműcsalád története III. rész, Haditechnika, XLVIII. évfolyam 2. szám, 2014/2, 41–44.

12. Kovácsházy Miklós: Mikor kerék, mikor lánctalp?, Hadmérnök, IX. évfolyam 2. szám, 2014. június, 103–127, http://www.hadmernok.hu/142_10_kovacshazym_2.pdf (Letöltés időpontja: 2014. június 05.)

13. Kovácsházy Miklós: A páncélozott harcjárművek kiválasztásával kapcsolatos kérdések a mozgékonyság tükrében, Hadmérnök, IX. évfolyam 2. szám, 2014. június, 91–102, http://www.hadmernok.hu/142_09_kovacshazym_1.pdf (Letöltés időpontja: 2014. május 09.)

14. Kovácsházy Miklós: Kovácsházy Ernő páncélozott harcjármű- és motortervező száz éve, Haditechnika, XLVIII. évfolyam 5. szám, 2014/5, 35–36.

15. Kovácsházy Miklós: Az RDO Komondor többcélú páncélvédett járműcsalád I. rész, Haditechnika, XLIX. évfolyam 4. szám, 2015/4, 50–53.

16. Kovácsházy Miklós: Az RDO Komondor többcélú páncélvédett járműcsalád II. rész, Haditechnika, XLIX. évfolyam 5. szám, 2015/5, 27–32.

17. Kovácsházy Miklós: Magyar páncélautó-gyártás és –fejlesztés 1916-2016, Haditechnika, L. évfolyam 1. szám, 2016/1, 26–30.

Articles published in periodicals in foreign language:

18. Kovácsházy Miklós: The Modernization of the Armored Combat Vehicle Fleet of the Hungarian Defense Forces in Terms of Mobility, AARMS, Bp., 2014, 337–346.

11.PROFESSIONAL – SCIENTIFIC CURRICULUM VITAE OF THE CANDIDATE

Education

- Technical University of Budapest (BME) faculty of Mechanical Engineering. 2005. (PTI003971 90/2005.)
- National University of Public Service (NKE), Military Science Doctoral School, Date obtaining Absolutorium: November 2012.

Language knowledge

- English intermediate level „C" 2002. (A 166902 143190)
- German basic level „C" 2011. (GJ060-02046 1394213)

Positions

- Olajterv Ltd. Budapest, junior designer 2005-2007
- Mélyépterv Komplex Ltd. Budapest, junior designer 2007-2014
- Főmterv Ltd. Budapest, senior designer 2014-2016
- Kristály Ltd. Budaörs, senior designer 2016-

He specializes in analysis of the pressurized hydraulic piping systems, drinking, fire-, industrial and waste water transport and water engineering issues of water purification technologies. In its activities, it carries out design and expert tasks.

Scientific and publication activities

- Research interests: The production and development of the Hungarian Fighting Vehicles, the selection problems of Armored Fighting Vehicles, and the development of tracked - wheeled suspension with the criteria for selection.
- 18 publications (one in English)

Future research plans:

- The development history of the Hungarian armored car projects in the 50's.

Public activities:

- Member of the Hungarian Military-science Association (Magyar Hadtudományi Társaság)

22. Aug of 2016., Budapest